Homestead Bay Development Consent Application

Engineering Feasibility Assessment

VOLUME 2 – APPENDICES

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RCL Homestead Bay Limited

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Revision Schedule

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A	20-Dec-24	Draft discussion	Grant Kluyts Nick Keenan Ben Davies Andrew Metherell Ferdie Zimmerman	Richard Bennett Matt Barber Iain Banks	Peter White	Peter White
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C	11-April-25	Final Draft for Review	Grant Kluyts Nick Keenan Iain Banks	Richard Bennett Matt Barber	Peter White	Peter White

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Technical Memo

Queenstown Lakes District Council

Project:	Queenstown water supply modelling		
Our reference:	418190-QLDC-AB02-WS-006	**Revision:**	Final - E
Prepared by:	Giulio Pozzuto	**Date:**	15 October 2021
Approved by:	Nasrine Tomasi	**Checked by:**	Diana Galindo
Subject:	Coneburn and Hanley's Farm water supply infrastructure assessment 2021 (v5)		

1 Introduction

In August 2021, the Queenstown Lakes District Council (QLDC) commissioned Mott MacDonald to assess the water supply (WS) network infrastructure within the Queenstown Southern Corridor WS (SCWS) area; the study area is shown in Figure 1.1. A new scenario was modelled to capture the ultimate demands (2068) within the SCWS area, which were confirmed by QLDC and hereafter referred to as 'the modelled scenario'

Previously, four studies were carried out between November 2019 and April 2021 within the SCWS area, each one focusing on a different network component. This is the fourth iteration of this memo and the objective of this study is to assess the following five items:

1. Confirm the minimum pipe sizes required for the rising main (RM) and falling main (FM) at Coneburn Reservoir.
2. Review the proposed reticulation within the Coneburn Special Housing Areas (SHA) subdivision and check compliance with QLDC's Level of Service (LoS).
3. Analyse Coneburn Reservoir in terms of minimum storage capacity and reservoir turnover.
4. Propose a high-level strategy for pressure management within the Coneburn Industrial development area.
5. Investigate high-level options to reduce high-pressure within Hanley's Farm, including the feasibility of supplying Hanley's Farm via Kelvin Heights.

The findings from this technical memo supersede those concluded in the previous four studies. Where information has been superseded by a subsequent study, it has been stated in this memo. A summary of the previous four assessments is presented in the last section of this document.

The Queenstown model build was completed in 2016, recalibrated in 2019, and the working model is currently undergoing an update. This assessment was based solely on the existing working model and additional information provided by QLDC between July and October 2021.

Importantly, the information presented in this assessment depends on the accuracy and reliability of the model and the data made available to Mott MacDonald at the time of the assessment.

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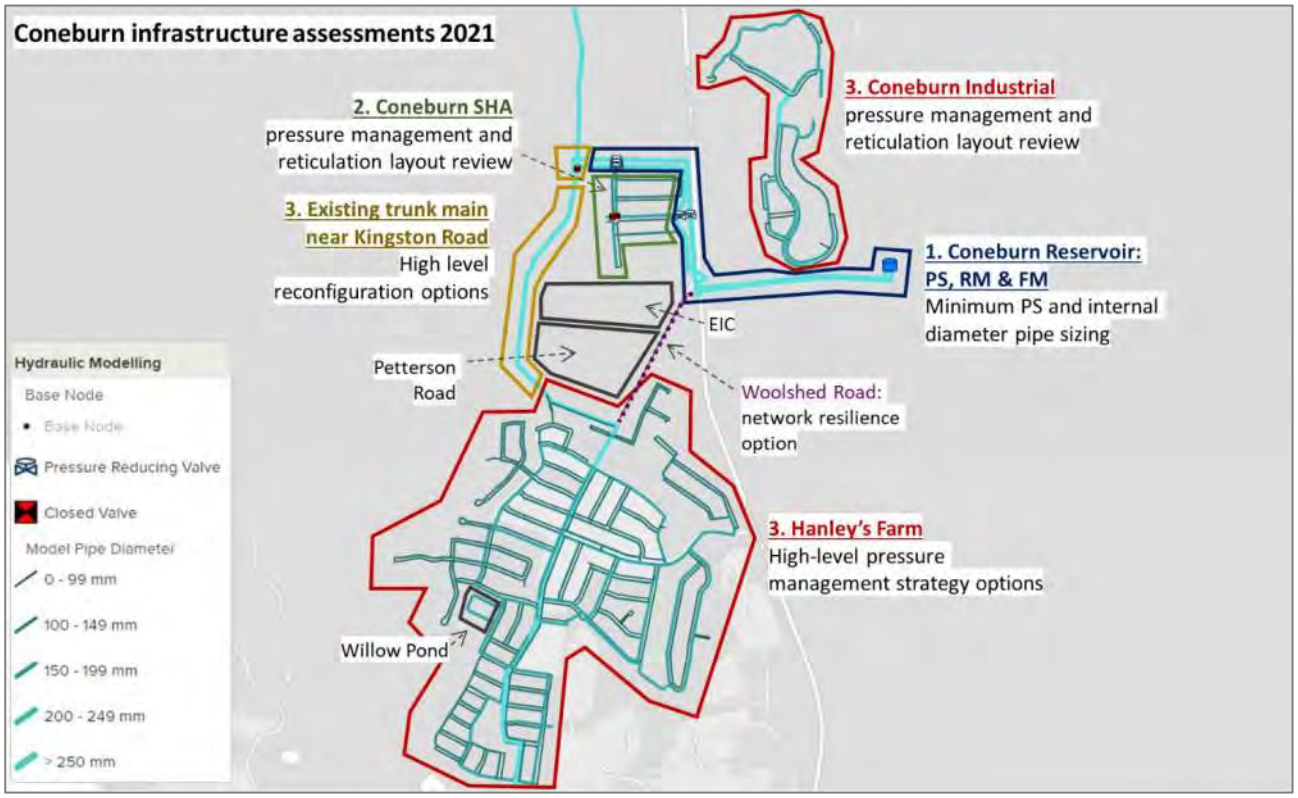
Figure 1.1: Study Area – SCWS area



2 Modelling assumptions

2.1 Demand calculations

The modelled scenario used for this assessment considers the ultimate demands within the SCWS area. These demands are based on the QLDC's latest growth rating unit (GRU) projections from August 2019, which only cover the Hanley's Farm development area (outlined in Figure 1.1). The Peak day demand (PDD) for this area was calculated by factoring the demand observed in the current peak day scenario (2019) by the population growth percentage calculated using the GRU projections.

The demand for the Educational Innovation Centre (EIC), Petterson Road, Willow Pond, Coneburn SHA and Coneburn Industrial developments are not included in the GRU projections. Therefore, they were added to the model using the demand calculated based on a specified number of projected dwelling unit equivalents (DUEs), which were provided by QLDC.

The criteria used to calculate the PDD for the additional developments was based on the criteria presented in Table 2.1, which was informed by the QLDC Land Development and Subdivision Code of Practice (LDSC) report written in 2018.

Table 2.1: Demand calculation criteria

Criteria (QLDC LDSC, 2018)	
Peak day factor	2
Industrial peak hour factor	1.25
Industrial design flow considered (litres/second/hectare)	0.7 (medium)
Average occupancy per dwelling	3

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Criteria (QLDC LDSC, 2018)

Hanley's Farm PDD consumption rate per dwelling (litres/dwelling/day)	2,000
Consumption rate per person equivalent (litres/person/day)	*667*
Queenstown PDD consumption rate per dwelling (litre/dwelling/day)	2,100
Consumption rate per person equivalent (litres/person/day)	*700*
Pumping regime	18 hours

The population, DUEs, PDD, instantaneous peak demand (IPD), average day demand (ADD) and flows during the 18-hour pumping regime are shown in Table 2.2 below.

The values shown in Table 2.2 were calculated as follows:

- The **population** is calculated by multiplying the number of DUEs by the average occupancy per dwelling
- The **DUE** approximation is based on the following equation:

$$DUEs = \frac{Peak\ day\ demand}{Consumption\ rate\ per\ dwelling\ (peak\ day)}$$

- The **PDD** is equal to the consumption rate per dwelling multiplied by the number of DUEs
- The **ADD** is equal to the PDD divided by the peak day factor (not derived from monitoring data).
- The **IPD** is calculated by multiplying the PDD by the diurnal peak hour factor.
- The **flows during the 18-hour pumping regime** are equal to the PDD multiplied by (24/18).

Table 2.2: Demand summary in the SCWS area

		EIC, Patterson Land & Willow Pond	Coneburn SHA	Coneburn Industrial	Hanley's Farm	Total
Population		1,950	1,950	2,290	5,350	**11,539**
DUEs approximation		650	650	763 [a]	1,783 [b]	**3,846**
Diurnal peak hour factors considered		2	2	2.25	2.46	**-**
Peak day demand (PDD)	**Flow (l/s)**	15.8	15.8	18.6	41.3	**91.4**
	Volume (m^3/hr)	56.9	56.9	66.8	148.6	**329.1**
	Volume (m^3/day)	1,365	1,365	1,602.7	3,566.4	**7,899.1**
PDD flow over 18-hour pumping regime	**Flow (l/s)**	21.1	21.1	24.7	55	**121.9**
	Volume (m^3/day)	1820	1820	2137	4755.2	**10,532.2**
Instantaneous peak demand	**Flow (l/s)**	31.6	31.6	41.7	101.4	**206.3**
	Volume (m3/day)	2730	2730	3606.1	8756.9	**17,823**
Average day demand (ADD)	**Flow (l/s)**	7.9	7.9	9.3	20.6	**45.7**
	Volume (m3/day)	682.5	682.5	801.4	1,783.2	**3,949.6**
ADD flow over 18-hour pumping regime	**Flow (l/s)**	10.5	10.5	12.4	27.5	**60.9**
	Volume (m3/day)	910	910	1,068.5	2,377.6	**5266.1**

[a] *The PDD for Coneburn Industrial was equated to population and DUEs for consistency and comparison purposes.*

[b] *As agreed with QLDC, Hanley's Farm's demand has been converted to DUEs based on a peak daily consumption rate of 2,000 litres/dwelling/day*

The diurnal peak hour factors used were extracted from the consumption patterns in the working model. These patterns were derived from the latest calibration model, which was based on the flow data collected during the monitoring campaign in January 2019. Flow records were not available for the study area, and instead, the residential pattern used in the calibration was obtained using deductive methods. This calibration pattern was not representative of the expected residential consumption in the area. Consequently, the observed pattern in Kawarau Falls DMA was applied to the Hanley's Farm area as it is a better fit for this study.

The results of this assessment are mainly driven by the peak factor of the patterns used. However, it is recommended to validate the model using recent available SCADA flow records for the study area.

Coneburn SHA, EIC, Petterson Road and Willow Pond all utilise a standardised residential pattern and Coneburn Industrial uses a standardised 10-hour commercial and industrial pattern.

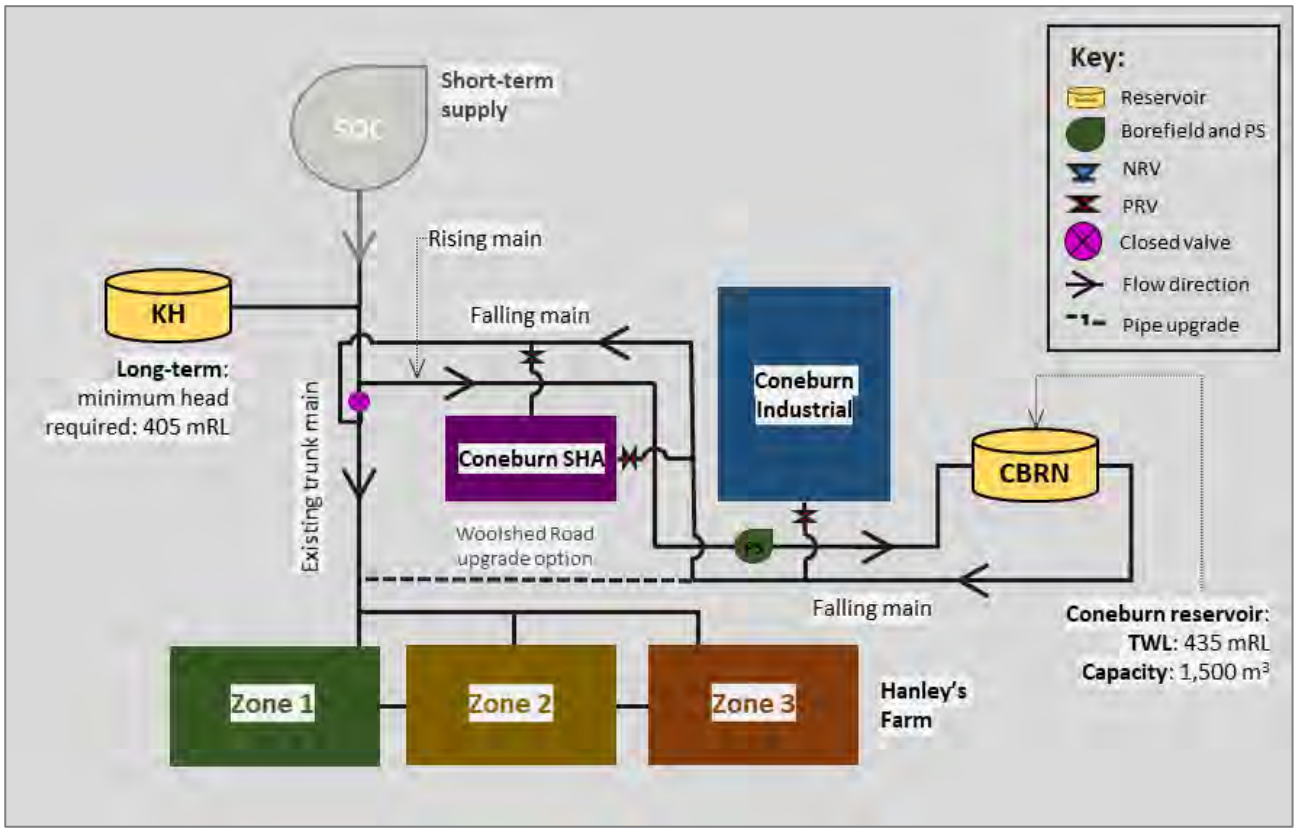
2.2 Network configuration

The outputs of this study are based on the network configuration presented in Figure 2.1. Kelvin Heights supplies Coneburn Reservoir via a dedicated RM and a Pump Station (PS); the reservoir then gravity feds the entirety of the SCWS area.

Hanley's Farm is presented in Figure 2.1 through three different elevational zones. The operation of these three zones is explored in great detail in Sections 3.4.

- **Zone 1** represents the lowest elevational area in Hanley's Farm (below 340 mRL)
- **Zone 2** represents the medium elevation (340-360 mRL)
- **Zone 3** represents the highest elevation (above 360 mRL)

Figure 2.1: SCWS Network Configuration



QLDC plans to service Kelvin Heights via the SOC borefield PS temporarily (short-term in supply in Figure 2.1). The results of this study will be applicable during the short term supply if a hydraulic head similar to that of Kelvin Heights (405 mRL) is provided via the SOC borefield PS. Any significant variations from this required head will impact the performance of the Coneburn Reservoir RM and the proposed PS.

It should be noted that in June 2020, QLDC informed Mott MacDonald of a change in the Coneburn Reservoir's bottom level from 420.6 mRL to 430 mRL. Based on this information and the assumption that the reservoir is 5.6 m in height, the top water level (TWL) is equivalent to approximately 435 mRL.

2.3 QLDC's LOS

As informed by the NZS 4404:2004 and the LDSC report (2018), the following LoS thresholds were used for operational pressure and Head losses (HL):

- Network operating pressure must fall between **30-90 m**.
- HL through network pipes must be no greater than:
  - ***5 m/km*** *in pipes smaller than* ***DN 150 mm****.*
  - ***3 m/km*** *in pipes greater than* ***DN 200 mm****.*

3 Modelling results

3.1 Coneburn Reservoir

3.1.1 Minimum pipe sizes for the RM and FM

In February 2020, the pipe sizes recommended for the Coneburn Reservoir were 424.9 mm ID for the RM and 492.7 mm ID for the FM, which were based on HDPE and PN ratings of 12.5 and 10, respectively. Recently, QLDC informed Mott MacDonald that they intend to construct the two pipelines using a PN rating of 16; effectively, reducing the internal diameters (IDs) of the said pipelines.

The pipe sizes required for the Coneburn Reservoir RM and FM were reviewed to ensure pipe HL remain below 3 m/km. The minimum pipe sizes required were determined based on the modelled scenario, which is described in Section 2. Table 3.1 compares the original and proposed minimum pipe size recommended, which were based on pipe size availability for HDPE pipes with a PN rating of 16, as requested by QLDC.

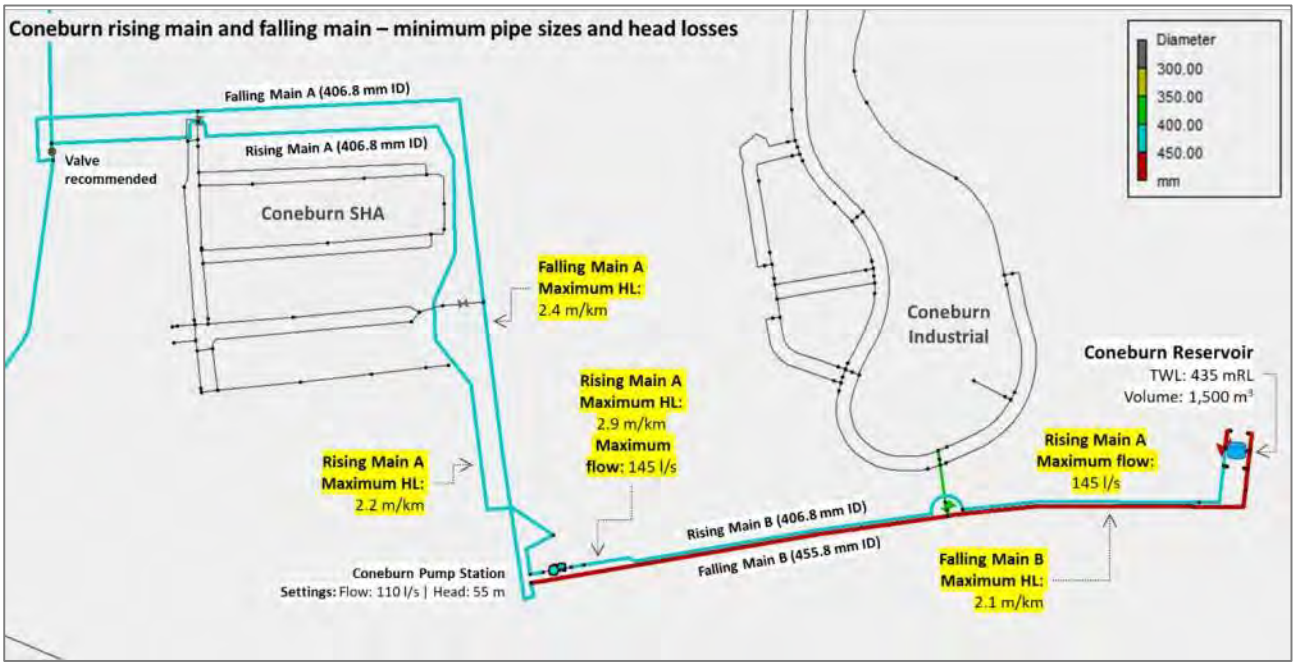
Table 3.1: Original and proposed pipe size comparison for HDPE material

	Original HDPE (February 2020)			Proposed HDPE (based on pipe availability)		
	ND (mm)	**PN**	**ID (mm)**	**ND (mm)**	**PN**	**ID (mm)**
Rising Main	500	12.5	424.9	500	16	406.8
Falling Main (A & B)	560	10	492.7	500 (A)		406.8
				560 (B)		455.8

The entirety of the RM can be sized at 406.8 mm ID (500 mm DN) and the FM can be sized at 406.8 mm ID (500 mm DN) until the Woolshed Road Junction (passing through Coneburn SHA). The remainder of the FM can be sized at 455.8 mm ID (560 mm DN) until Coneburn Reservoir.

These results are further depicted in Figure 3.1. and have been shared with and confirmed by QLDC.

Figure 3.1: Coneburn RM and FM minimum pipe sizes and head losses



Note that the pressure surge effect and analysis has not been considered and should be further investigated during the infrastructure design stage. A summary of the most recent modelling results has been tabulated for comparison with the February 2020 study in Table 3.2.

Table 3.2: RM & FM for Coneburn Reservoir modelling results (comparison)

	Original assessment (February 2020)	Revised assessment (October 2021)
Rising Main (mm ID)	424.9	406.8
RM Maximum HL (m/km)	2.3	2.9
Falling Main (mm ID)	492.7	406.8 (A) and 455.8 (B)
FM Maximum HL (m/km)	2.8	2.4

3.1.2 Coneburn Pump Station

The proposed size of the Coneburn PS was also reviewed to reflect changes in the demand and the Coneburn Reservoir's bottom level. A summary of the most recent modelling results has been tabulated for comparison with the February 2020 study in Table 3.3 below.

Table 3.3: Coneburn Reservoir PS modelling results (comparison)

	Original assessment (February 2020)	Revised assessment (October 2021)
Maximum head upstream of PS (mRL)	410	407
Maximum discharge head (mRL)	427	437
Maximum flow (l/s)	143	145

The QLDC's Three Waters System Performance (TWSP) Methodology (2019) stipulates that the intended supply schemes must be able to provide the PDD whilst utilising less than 16 hours pump run time per day (WS -SPM02), which is equivalent to a daily utilisation rate of 67%

When assuming ultimate demands in the SCWS area and 1,500 m^3 storage at Coneburn Reservoir, this requirement is not met with the proposed Coneburn PS. The non-compliant utilisation rate is driven by the need to optimise peak day storage hours and keep Coneburn Reservoir close to full capacity when possible (see Section 3.1.3). With this approach, the Coneburn PS will be active approximately 20 hours on a peak day, which is equivalent to an 83% utilisation.

However, the utilisation rate observed in the model will likely reduce once the storage capacity at Coneburn Reservoir increases. Therefore, the implementation of variable speed drive (VSD) at Coneburn PS should be considered during the detailed design phase.

3.1.3 Coneburn Reservoir storage

Coneburn Reservoir was assessed to confirm compliance with QLDC's TWSP Methodology (2019). The document stipulates that all tanks should operate above the 60% water level (WS-SPM05). Furthermore, the minimum reservoir storage available should be the greater value of one of the following three criteria (WS-SPM01):

a. 24 hours of average day storage only (incorporates firefighting).
b. 12 hours of peak day storage only (incorporates firefighting.
c. 6 hours of average day storage plus firefighting.

Under the modelled scenario, the total PDD from the SCWS area is 7,899 m^3/day (see Table 2.2). Therefore, the total reservoir storage equivalent for each of the criteria shown above are stated below:

a. 3,950 m^3
b. 3,950 m^3
c. 987 m^3

Criteria 'a' and 'b' require the same storage capacities and are the greater value, therefore, the storage assessment was based on this value. Notably, the required firefighting capability at Coneburn Reservoir is FW4 (100 l/s over 90 minutes), which is equivalent to 540 m^3. This is already incorporated in criteria 'a' and 'b' and does not need to be considered in addition.

QLDC plan to construct the Coneburn Reservoir (tank farm) in three phases and will be in response to future demand increases. The full capacity is projected to increase from 1,500 m^3 to 3,000 m^3 and eventually 4,500 m^3 over the next 50 years. The construction of the first reservoir is planned to be built before 2028.

Table 3.4 summarises Coneburn Reservoir's storage capacity and the number of peak day storage hours available for the modelled scenario (considering ultimate PDD). The required storage will be only met once all three phases are implemented. With the first stage, the maximum number of storage hours is approximately 4.6 hours, and by the time phase two is constructed, it will increase to 9.1 hours; then again to 13.7 hours once phase three is built.

Table 3.4: Storage hours available for reservoir implementation phases one, two and three

	Reservoir capacity (m^3)	12 hours of storage considering ultimate PDD (m^3/day)	Number of hours of storage to supply ultimate PDD
Phase one	1,500	3,950 m^3	4.6
Phase two	3,000		9.1
Phase three	4,500		13.7

It is recommended that QLDC use these findings to inform the future phasing of Coneburn Reservoir's upsizing. Due to the uncertainty of the population growth within the SCWS area, demands within the area should be closely monitored and the construction timing of phases two and three assessed accordingly.

3.1.4 Coneburn Reservoir turnover

The turnover of Coneburn Reservoir, which is mainly driven by the size of Coneburn PS, has a significant influence on HL along the Coneburn RM; and consequently, the minimum pipe diameter required. The RM has been designed to maintain water levels as high as possible and maximise the availability of peak day storage hours, which are required for resilience and in case of an emergency.

Assumptively, the reservoir is 5.6 m in height and has a TWL equivalent to 435 mRL. The model was set up to enable Coneburn PS to operate based on the following operational rules:

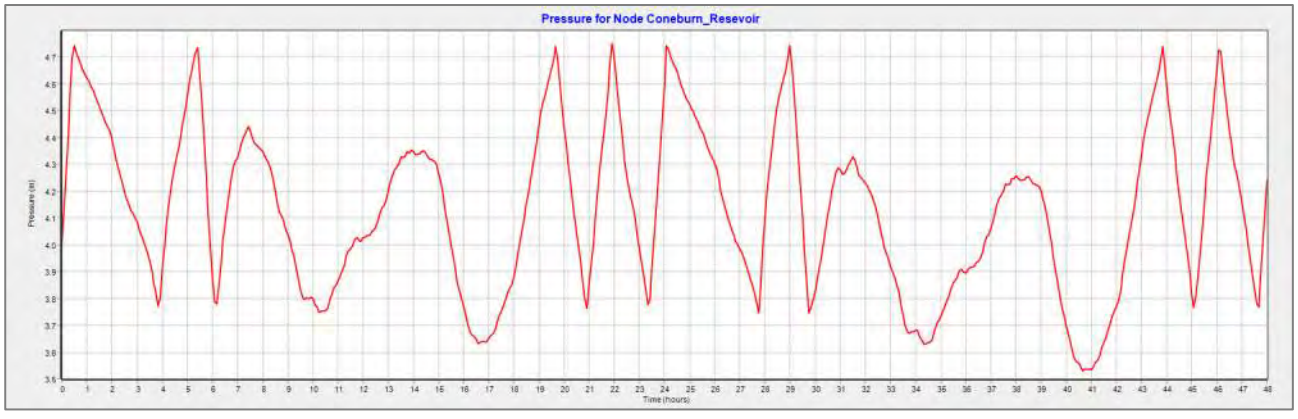
- Start filling when the tank is equal to or below 65% full (3.7 m)
- Stop filling when the tank is equal to or above 85% full (4.8 m)

Over 48-hours with ultimate PDD, the model predicts the tank to fluctuate between 63% (3.5 m) and 85% (4.8 m), as shown in Table 3.5 and Figure 3.2. The model predicts that Coneburn Reservoir will meet the reservoir turnover operational criteria (WS-SPM05: operating above 60%). Notably, the water level does drop below the intended operational levels (65%), but this is only for short periods during peak demands.

Table 3.5: Coneburn Reservoir (1,500 m^3) turnover over 48-hours

	Original assessment (February 2020)	Revised assessment (October 2021)
Minimum water level (m)	2.7 (48%)	3.5 (63%)
Maximum water level (m)	4.8 (86%)	4.7 (85%)

Figure 3.2: Coneburn Reservoir (1,500 m^3) turnover over 48-hours



3.2 Coneburn SHA internal reticulation update and review

The internal reticulation within the Coneburn SHA was updated in the model based on the most recent drawings provided by QLDC in October 2021. The proposed reticulation layout and diameters were reviewed to determine their compliance with QLDC's LoS (2018) in terms of pressure and HL.

The revised drawing (06/10/2021) entitled 'SPECIAL HOUSING AREA WATER SUPPLY RETICULATED NETWORK MASTERPLAN' depicted the nominal bore (NB) sizing for all pipes within the development area. As agreed with QLDC, the revised layout and sizing were integrated into the working model, superseding the

previous data used for Coneburn SHA. Site elevations were derived from LiDAR data made available online and vary between 320-335 mRL.

It should also be noted that aside from the hydrants that were already integrated into the model in July 2021, any proposed hydrants within the extended south-eastern and western areas of the internal reticulation were not depicted in the revised drawing (06/10/2021). Therefore, they have not been represented in the model.

Although firefighting was not assessed as part of the review, as it was partially assessed during the assessment completed in April 2021 (see Section 3.5.3), seven critical nodes (shown in Figure 3.3) were tested to predict whether FW2 (25 l/s for 30-minutes) would be available in that area of the network.

Figure 3.3 shows the updated layout, pipe sizing, connectivity, and hydrants within the Coneburn SHA development area; the review is based on this configuration.

Figure 3.3: Coneburn SHA: reticulation layout and pipe sizing update

Proposedly, the pressure within this area will be controlled via two PRVs, creating two subzones, one at the northern and another at the eastern boundary of the network; both connections points are via the future FM from Coneburn Reservoir (406.8 mm ID). A setting of 45 m was assumed at both PRVs to keep pressure between 37-56 m and maintain the required QLDC's LoS (2018); however, this is subject to operational change once constructed. This setting can be adjusted, but it should be tested to ensure pressure within Coneburn SHA stays between 30-90 m.

In terms of the model demand, it was distributed proportionately to the number of lots. Approximately, the eastern half accounts for 51% and the western half accounts for 49% of the total demand in Coneburn SHA (see Table 2.2).

Within the western portion of Coneburn SHA, an additional connection point via the existing trunk main has been proposed (shown in Figure 3.3) in the latest drawings. It was agreed with QLDC that this additional connection will likely be used for resilience and emergency supply, and therefore it closed in the model. If the QLDC decides to supply the western area via the additional trunk main connection during normal operations, a PRV will be required to control high pressure. This should be considered during the detailed design phase.

The system performance within Coneburn SHA was reviewed in terms of pressure and HL. Based on the modelling results from integrating the revised reticulation layout, pipe sizing and connectivity in Coneburn SHA, most of the proposed pipe sizes are appropriate and enable the network to be compliant with QLDC's LoS (2018) in terms of pressure and HL. However, two pipes should be reviewed and potentially upsized based on HL and firefighting capability; both are detailed below:

- Along 'Road 04' within the eastern half, the proposed 150 mm NB pipe predicts HL to exceed 10 m/km (shown in Figure 3.4). However, if the pipe was upsized to 212.4 mm ID from the FM connection point (2) until the proposed trunk main connection point within the western half (highlighted in yellow in Figure 3.4), then the maximum HL would drop to approximately 2.8 m/km.
  - Other options could be explored, such as improving pipe conveyance through the creation of additional pipe loops and connection points. It is recommended that the feasibility of alternative options is explored and confirmed through a comprehensive system performance assessment.
- As previously mentioned, seven critical nodes were tested, to assess whether FW2 would be possible. Conservatively, the test was undertaken without the proposed upsizing along 'Road 04'.
  - Six of the seven nodes passed the test (green boxes in Figure 3.4) and only one node along 'Road 08' (red box in Figure 3.4) did not pass the test. However, if the proposed 50 mm NB pipe was upsized to 63.7 mm ID (highlighted in yellow in Figure 3.4), then FW2 would be possible at that node.
  - Other options could be explored in terms of additional loops and connection points, but the feasibility of alternative options should be explored once the location of all future hydrants is known throughout the entirety of Coneburn SHA; including their maximum firefighting capability.
  - It should be noted that the PRV settings at connection points '1' and '2' have a significant influence over the firefighting capabilities within Coneburn SHA.

The proposed internal reticulation in Coneburn SHA was not optimised as part of this assessment. The proposed reticulation and pipe sizes were reviewed, and recommendations were made regarding possible upgrade options. However, they should be confirmed through a comprehensive system performance assessment.

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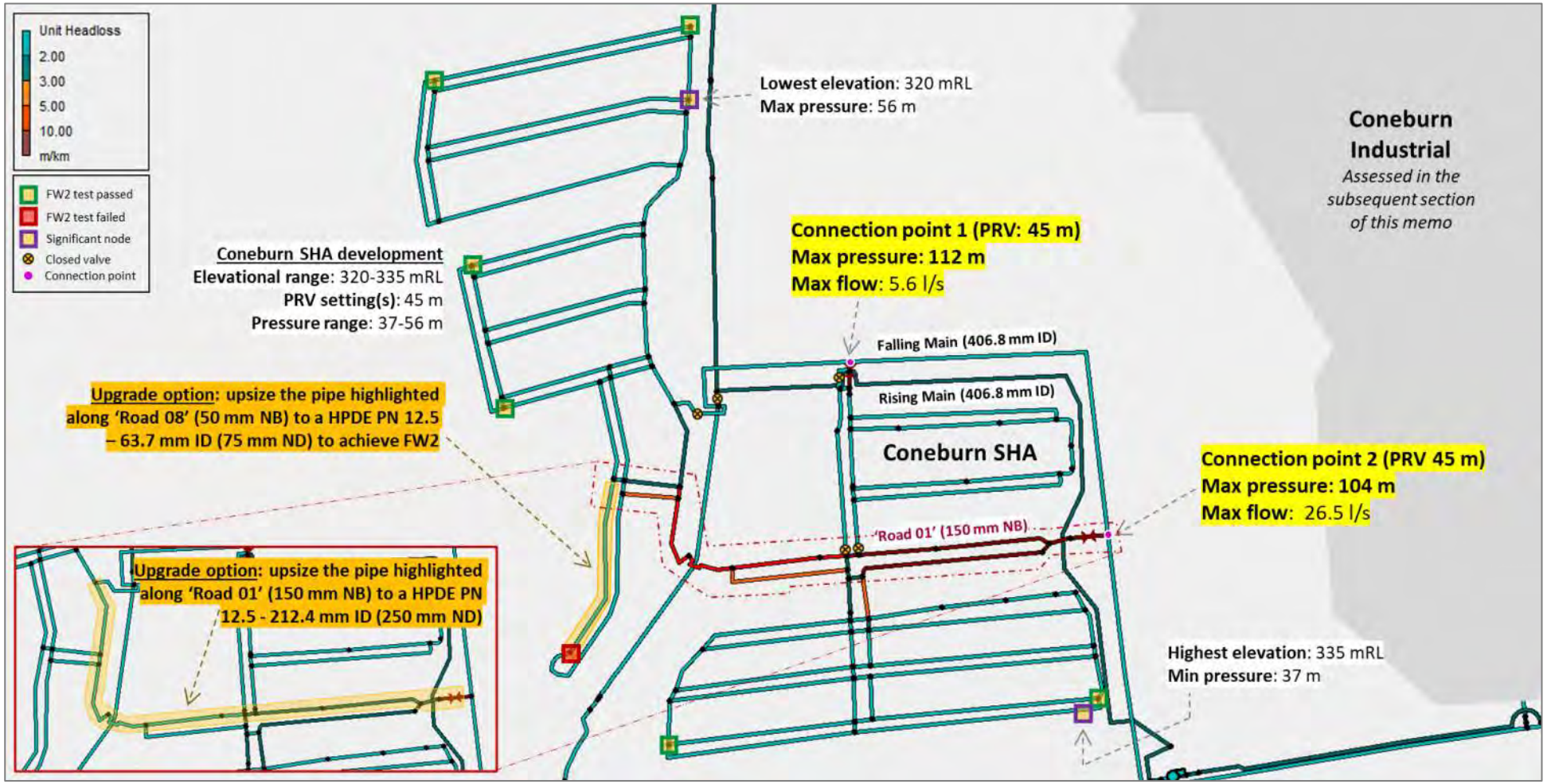
Figure 3.4: Coneburn internal reticulation review and maximum head losses



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3.3 Pressure management in Coneburn Industrial

Pressure in the western boundary of the industrial zone within Coneburn Industrial does not meet the LoS in terms of pressure (above 90 m). As shown in Figure 3.5, the network pressure varied from 50-106 m.

Figure 3.5: Maximum pressure within Coneburn Industrial (pre-assessment)

Two pressure management options were investigated, and the results are presented below.

Option one assessed the feasibility of isolating the most north-western arm of the network (outlined in pink in Figure 3.5) to enable the pressure reduction just in this zone. The implementation of the small zone will require multiple new PRVs and upsizing and re-configuring multiple pipes within the northern boundary. Furthermore, the pressure would remain relatively high (between 75-90 m), albeit compliant with QLDC's target range (outline in blue in Figure 3.5). Therefore, a second option was considered to minimise network layout re-configuration and to reduce pressure across a greater portion of the industrial zone.

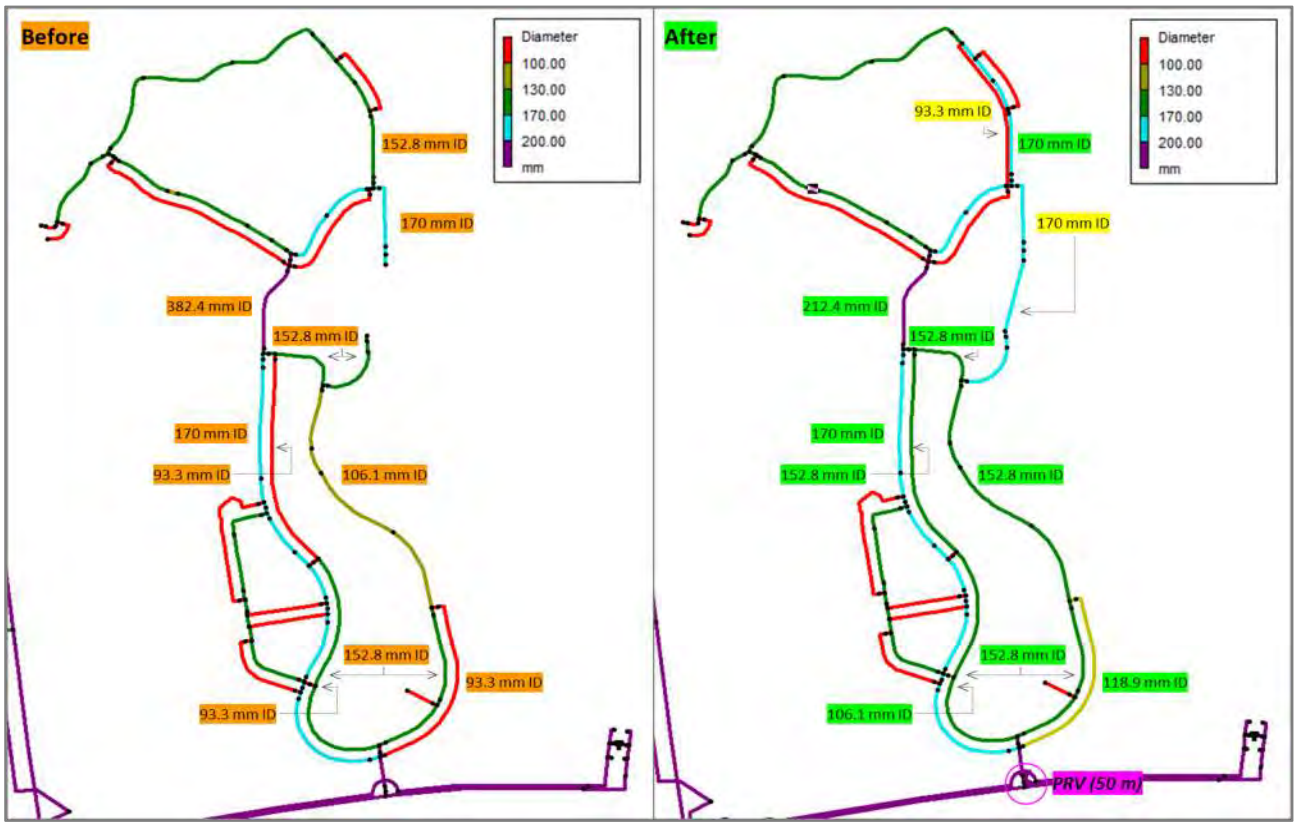
Option two assessed the feasibility of managing the entire area as one pressure zone using a single PRV. The valve will be located at the connection point between the Coneburn Reservoir FM and the local network of Coneburn Industrial (encircled in pink in Figure 3.6). Using a valve setting of 50 m, it is possible to reduce the pressure across the entire industrial zone, ranging from 33-85 m.

Firefighting capability was assessed to ensure that FW4 (100 l/s) would still be compliant across the region and to confirm the feasibility of option two. As a result, pipe sizes have to be increased throughout the

internal reticulation and two pipes needed to be added. The changes in pipe diameters are based on maintaining HL below 3 m/km and enabling the required firefighting flows.

Regarding the two additional pipes, these were added within the north-eastern portion of the network (the diameters are highlighted in yellow in Figure 3.6), one of the two will create an additional ring main along the eastern boundary (170 mm ID) and the other is a duplicated pipe within the same area (93.3 mm ID).

Figure 3.6: Coneburn Industrial: pipe size changes (HPDE PN 12.5) – Option two



* *Orange represents the diameters pre-assessment and green represents the updated pipe sizes; yellow diameters are additional pipes.*

Option two appears to be the most viable option and analysis of operational pressure, HL and firefighting were undertaken based on the network layout depicted in Figure 3.6 ('after'). The results are summarised below and should be viewed in conjunction with Figure 3.7.

Operational pressure

Minimum pressure within Coneburn Industrial ranges from 33 m along the north-eastern boundary (lighter green in Figure 3.7) to 83 m along the north-western arm (orange). The minimum pressure within the remainder of the area is predicted to range from 45-75 m.

Maximum pressure shows very similar results, with the north-western arm showing comparatively higher pressure (75-90 m), the north-eastern portion showing the lowest pressure within the zone (30-45 m) and the remainder of the zone between 45-75 m.

Head losses (HL)

Maximum HL is less than 2 m/km across most of the network (light blue), with only the three pipes showing HL between 2-3 m/km (based on the updated pipe sizes).

Firefighting capability and hydrant coverage

The twenty-six hydrants (red nodes) are all capable of supplying FW4, equivalent to 100 l/s for 90 minutes. Additionally, hydrants coverage is shown to be compliant (maximum 135 m between hydrants). It is important to note that the firefighting capabilities within Coneburn Industrial depend on the reservoir levels and Coneburn Reservoir should operate above 60% to avoid low pressure during fire flow events.

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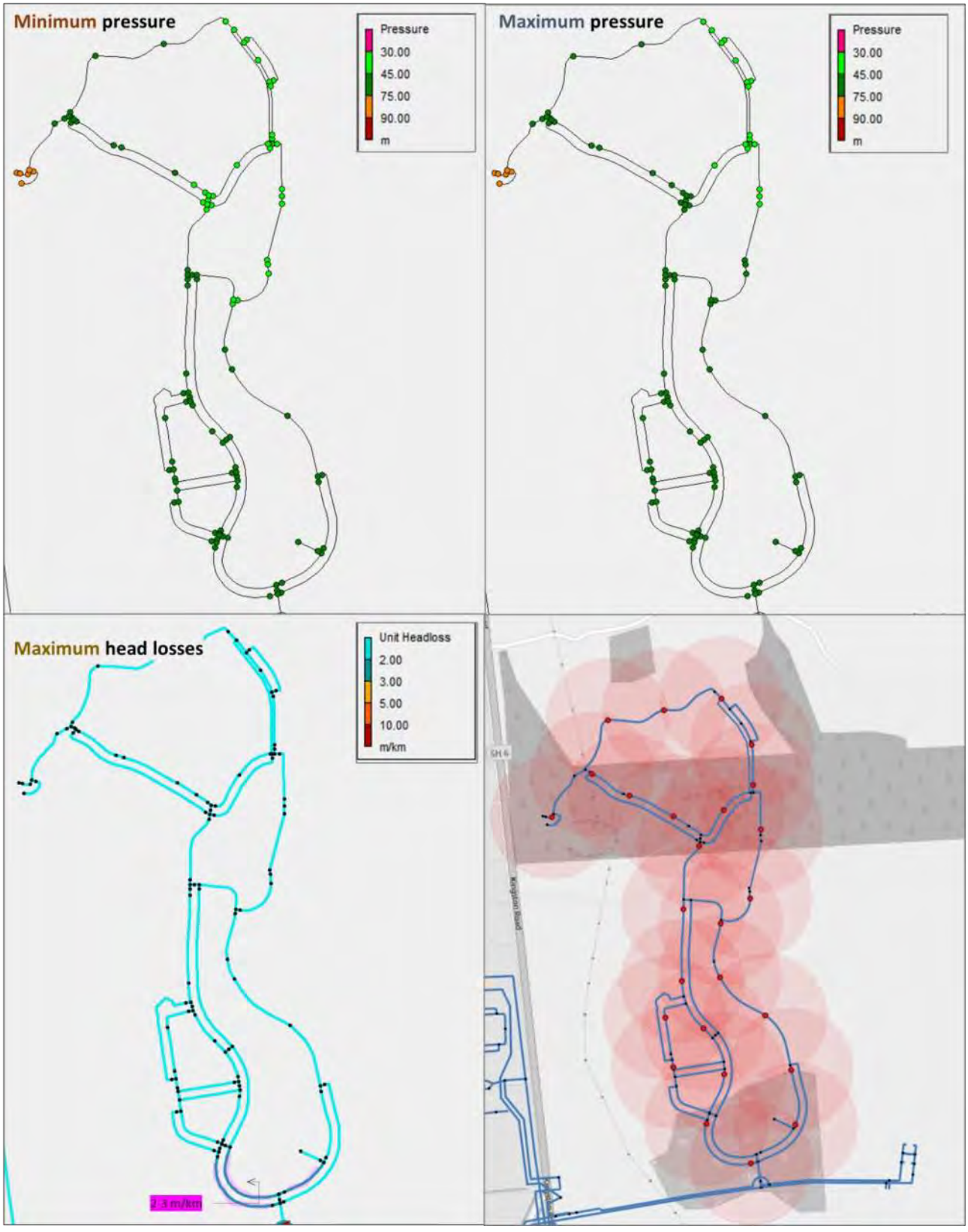
Figure 3.7: Coneburn Industrial system performance analysis (post-assessment)



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3.4 Pressure management options in Hanley's Farm

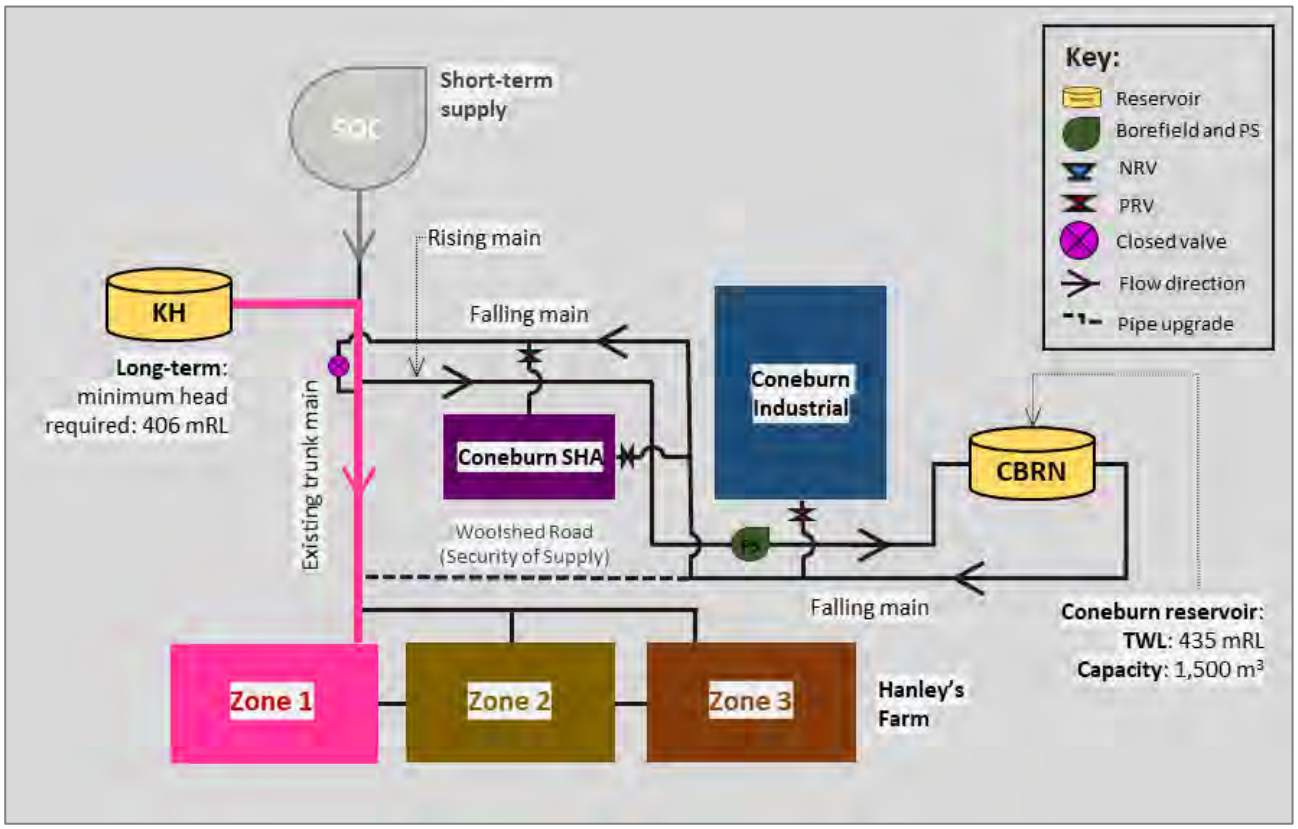
The hydraulic head provided by Coneburn Reservoir (TWL of 435 mRL) is sufficient to supply customers in elevated areas of Hanley's Farm (above 360 m and outlined in red in Figure 3.8). However, pressure above 90 m becomes an issue for customers under 340 m (dark pink nodes).

Figure 3.8: Maximum pressure within Hanley's Farm (pre-assessment)

3.4.1 Direct supply from Kelvin Heights

A direct supply from Kelvin Heights to Hanley's Farm was assessed to reduce pressure within the zone. Coneburn Reservoir continues to service both Coneburn Industrial and Coneburn SHA during this alternative supply option (see Figure 3.9).

Figure 3.9: SCWS area operational schematic: re-configuration option



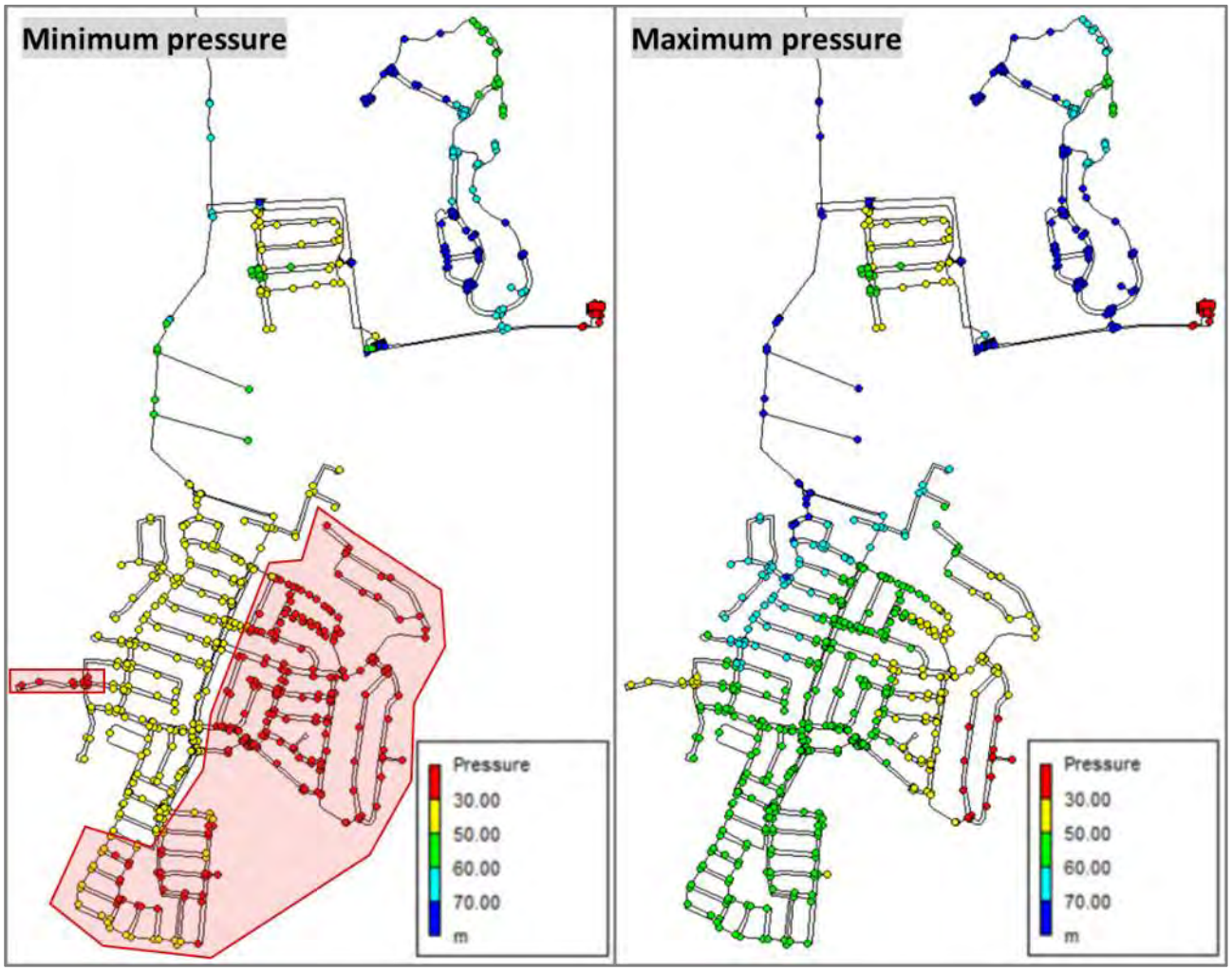
As shown in Figure 3.9 and Figure 3.10, Kelvin Heights can only supply a limited area within Hanley's Farm (Zone 1 and potentially Zone 2). The maximum pressure issues within the zone improve significantly and drop below 70 m; however, approximately half of the customers cannot be supplied due to low or null pressure issues, particularly in higher elevated areas (outline in red in Figure 3.10).

The modelling results are highly influenced by the available head being supplied via Kelvin Heights, demands and HL along the existing trunk main. For this study, Kelvin Heights was modelled with a maximum head of 406 m, which was extracted from the monitoring data observed in 2018 during the field test.

A direct gravity feed from Kelvin Heights is a sensible solution to reduce partially high-pressure issues within Hanley's Farm, whilst also reducing the carbon cost associated with pumping water up to Coneburn Reservoir. However, this current network configuration will be insufficient to service the ultimate population projected (approximately 3,846 DUEs) and will require further booster pumps to be re-implemented in high-elevated parts of Hanley's Farm.

Finally, the alternative option supply will not provide sufficient network resilience in terms of the security of supply, which is required and imperative in this part of the network, due to the isolation of the SCWS area from the rest of the Queenstown WS network.

Figure 3.10: SCWS area: fragmentation option based on HGL



In conclusion, this option is not recommended as the default operational scheme to supply Hanley's Farm. Nevertheless, it should be viewed as a temporary or an emergency supply solution. It is recommended that further investigation be undertaken to ensure network resilience within this part of the Queenstown WS network and other options should be explored. This could include the implementation of a new main along Woolshed Road, the re-implementation of booster pumps for high-elevated areas, or a combination of multiple supply options.

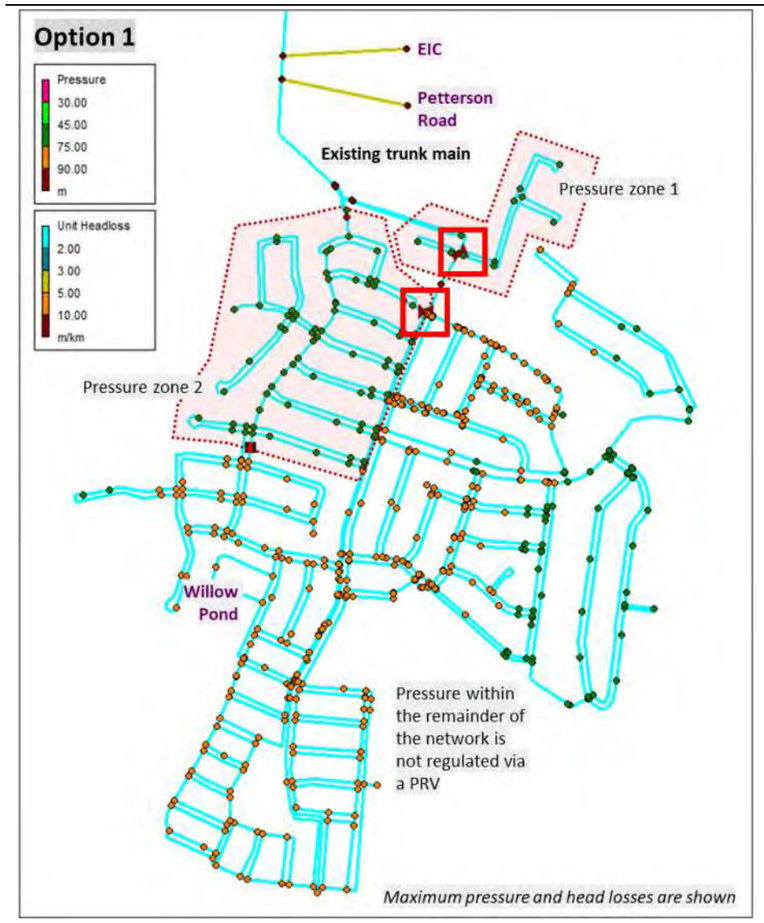
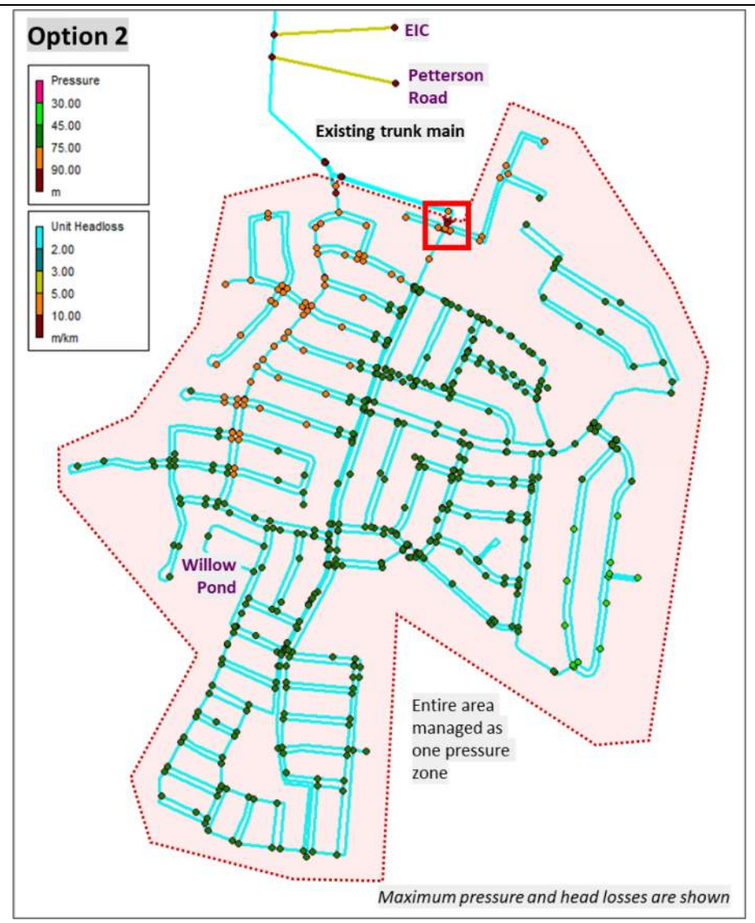
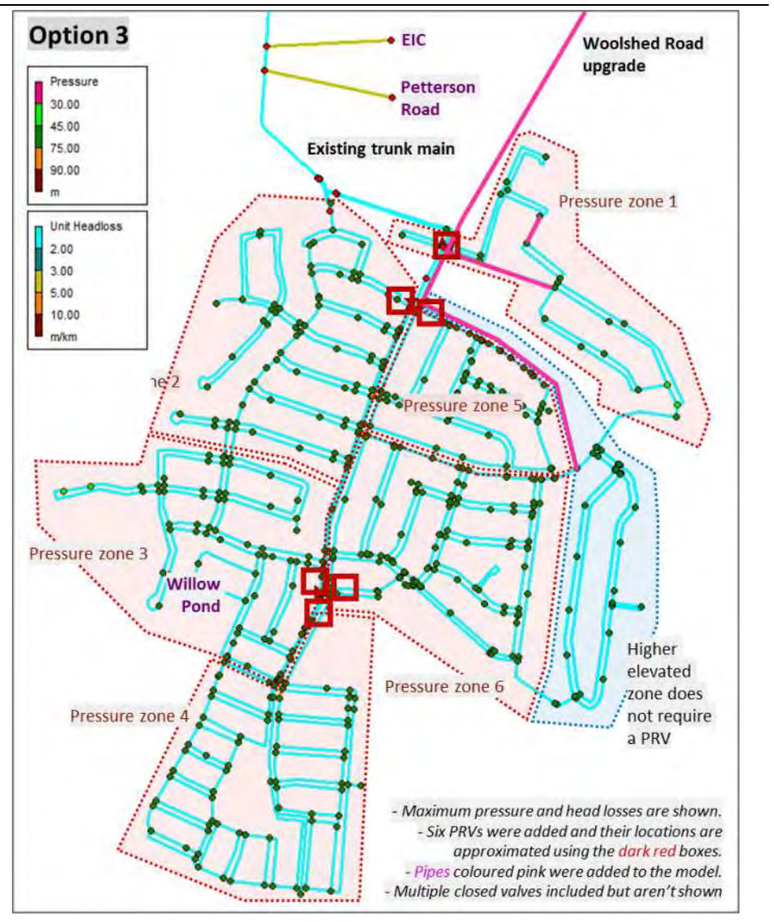
A cost-benefit analysis is recommended to adequately support this decision-making process.

3.4.2 Network fragmentation options

Network fragmentation options were explored within Hanley's Farm were assessed from a high-level perspective by breaking down the network into smaller pressure zones using PRVs. The options summarised in Table 3.6 were discussed with QLDC and are simply exploratory at this time. They should be reviewed by QLDC when making future network planning decisions, however, brief comments have been made below:

- **Option one**: is the most feasible and requires the least network interference or adjustment.
- **Option two**: is not recommended as it would be more feasible and potentially cost-effective to reduce Coneburn Reservoir's TWL.
- **Option three**: is not recommended as it is overly complex for the size of the network and number of customers.

Table 3.6: Pressure management options in Hanley's Farm

Option One – Two PRVs (smaller pressure zones)	Option Two – One PRVs on trunk main (one larger pressure zone)	Option three (multiple pressure zones based on elevation)
		
Description (pressure fluctuates between 38-73 m) Two small pressure zones focusing on reducing pressure in areas with pressure above 90 m only.	**Description (pressure fluctuates between 32-86 m)** Pressure reduction throughout Hanley's Farm by decreasing inlet head from Coneburn Reservoir.	**Description (pressure fluctuates between 43-73 m)** Delineation of six pressure subzones to reduce pressure across the entirety of Hanley's Farm.
Key infrastructure required • Two PRVs to service the two smaller pressure zones (assumed setting: 60 m). • Changes to the network configuration may be needed are needed to avoid high HL. • A few valves would need to be closed and pipe crossings are required to isolate zones. • EIC and Petterson developments will require pressure management if supplied via the trunk main.	**Key infrastructure required** • One PRV at the existing trunk main (406.8 mm ID) with an 80 m setting. • EIC and Petterson developments will require pressure management if supplied via the trunk main.	**Key infrastructure required** • Six PRVs to service 6 smaller pressure zones (55-70 m settings but subject to change). • Additional trunk main along Woolshed Road is required (as a dedicated main toward the high elevated zone). • A significant number of valves would need to be closed to delineate the six zones. • EIC and Petterson developments will require pressure management if supplied via the trunk main.
Strengths • Maximum pressure can be significantly reduced within the specified pressure zones.	**Strengths** • Maximum pressure can be reduced below 90 m. • Fewer pipe upgrades would be required in comparison with option three.	**Strengths** • Greater control of pressure and understanding of the supply. Detailed network control and potential leakage reduction. • Network resilience maintained with emergency supply options.
Weaknesses • Outside the two pressure zones, high pressure would remain (above 75 m) within the remainder of the network. • The pressure would fluctuate between 31-89 m, which is marginally compliant.	**Weaknesses** • Pressure remains above 75 m throughout most of the network (86 m within the north-western portion). • PRV is situated on the existing trunk main. • The same result can be achieved by lowering the Coneburn Reservoir's TWL. However, QLDC confirmed there are geotechnical constrictions that limit the feasibility of this option.	**Weaknesses** • High cost associated with the implementation of the subzones. • Pipe upgrades will be required in specific areas of the network (pipes highlight in pink).

3.5 Re-summarisation of previous assessments

As requested by the QLDC, important notes from the previous assessments (see Table 3.7) are re-summarised below and should be reviewed by all stakeholders.

Table 3.7: Previous Coneburn and Hanley's Farm assessments (2019-2021)

	Assessment number & title	Revision	Delivery date
1.	Coneburn Reservoir Water Modelling: Water Infrastructure Sizing – Reticulation Network	Draft - A	27/11/2019
2.	Coneburn Valley Water Modelling: Water Infrastructure Sizing (including High-Level Cost Estimate and Concept Plan)	Draft - A	27/02/2020
3.	Coneburn SHA and Hanley's Farm interim modelling on Kingston Road: Water supply infrastructure optioneering and assessment	Draft - A	22/09/2020
4.	QLDC water supply modelling in Hanley's Farm: Water supply infrastructure assessment – network update 2021	Draft - A	09/04/2021

Each assessment is succinctly summarised below, and further details are provided in the subsequent four sections.

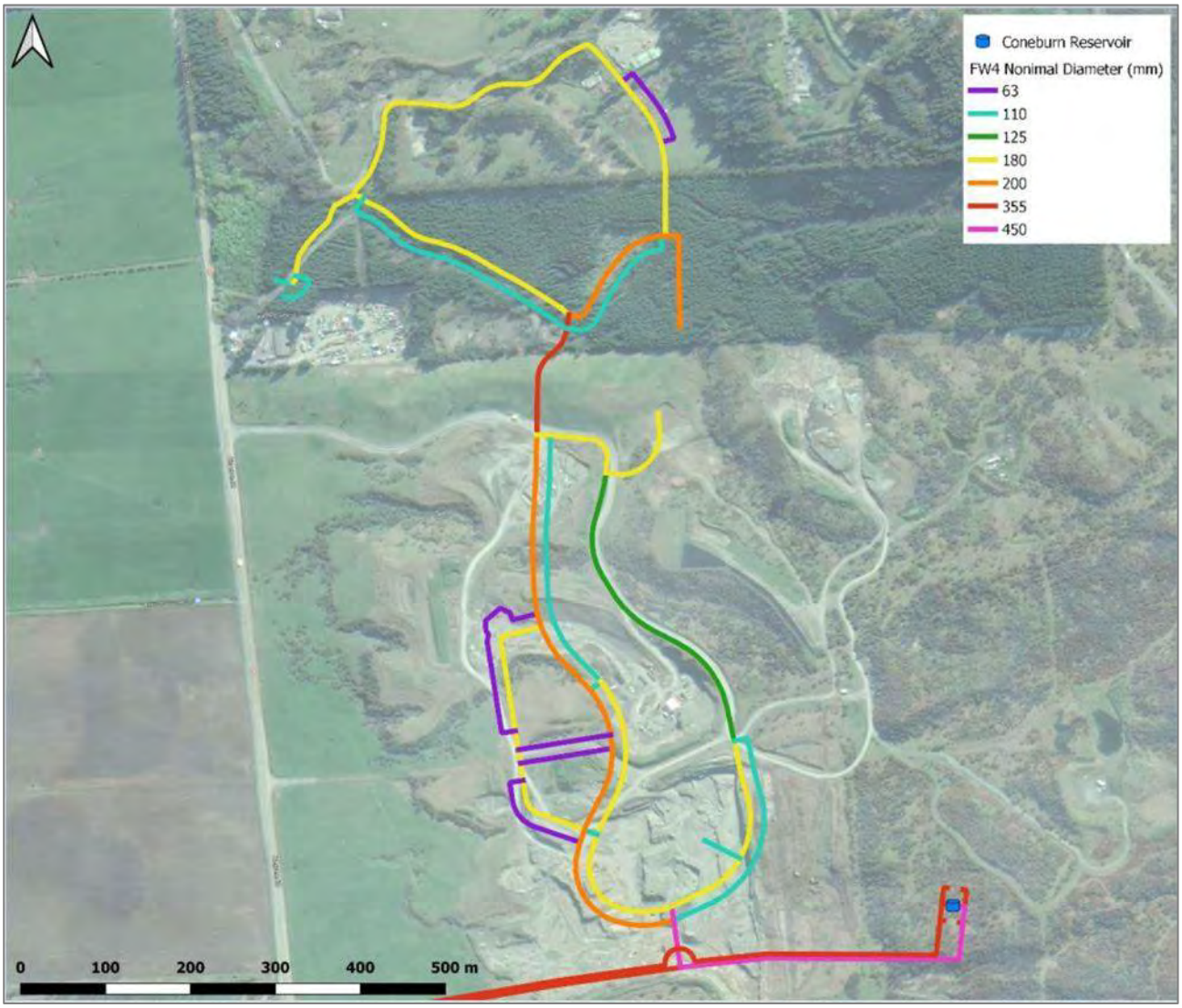
- **Assessment one (2019)**: the demand within Coneburn SHA and Hanley's Farm has changed since 2019 and therefore influencing the predicted HL and firefighting capabilities. The recommended pipe sizes from this assessment were used in all modelling work between February 2019 and July 2021 and are now superseded by this assessment (August 2021).
- **Assessment two (2020a)**: The minimum pipe sizes required for Coneburn RM and FM and high-level capital construction costings (+/- 25% accuracy) were provided. The recommended pipe sizes from this assessment were used in all modelling work between February 2020 and July 2021 and are now superseded by this assessment (August 2021).
- **Assessment three (2020b)**: Two alignments for the RM and FM were modelled and compared to assess which would be more viable. Ultimately, "Option 1 – the northern alignment" was taken forward and is in the final design phase. Additionally, the pipe sizes required within Coneburn SHA were recommended, but are now superseded by this assessment (August 2021).
- **Assessment four (2021)**: The Hanley's Farm reticulation and demand distribution were updated based on a reduced number of DUEs (63% less when compared with this assessment). The proposed reticulation was deemed appropriate at the time, based on HL and firefighting capabilities (once the Coneburn Reservoir was operational).

  However, issues with variable and high pressure were highlighted and the following recommendation was made "*investigate optioneering that focuses on reducing the overly high and variable pressure within part or all the HF network (non-compliant across the majority of the network)*". Three pressure management schemes have been explored as part of this assessment. QLDC will review the three options and will determine the most viable pressure management scheme.

3.5.1 Assessment one – November 2019

The first assessment (2019) assessed the minimum sizes required to achieve FW2 or FW4 within the Coneburn Industrial zone and the impact of the development upon the existing Hanley's Farm network. Since the assessment, the pipe sizes that were recommended to supply FW4 (100 l/s) were used in all subsequent modelling until this assessment (see Figure 3.11).

Figure 3.11: Minimum pipe sizes required in Coneburn Industrial to achieve FW4



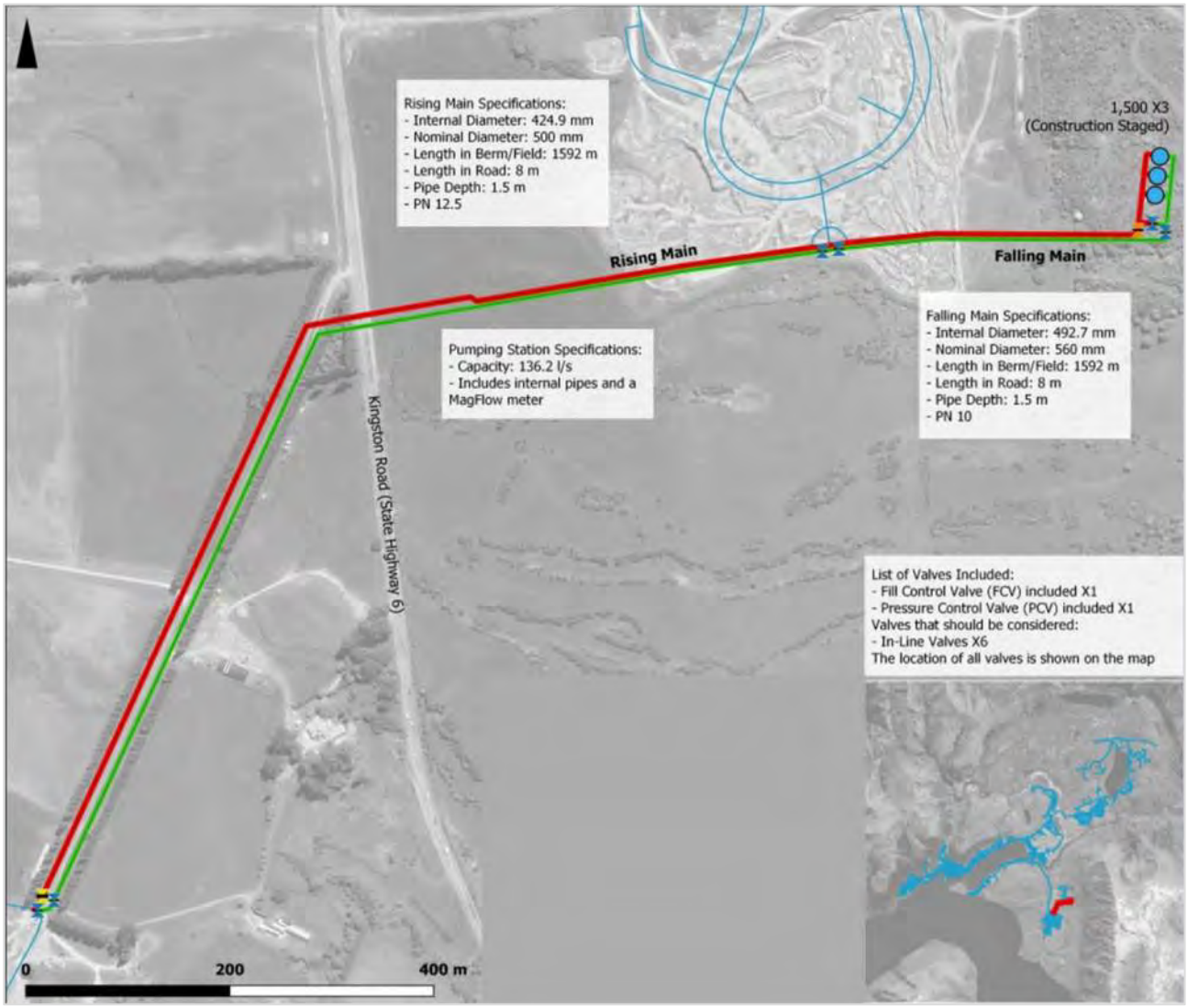
Importantly, the demand within the remainder of the zone (Coneburn SHA and Hanley's Farm) has changed since 2019 and therefore affecting the network performance. In the first assessment (2018), only the demand from Coneburn Industrial was considered. In the fourth and most recent study (April 2021) where the overall zone demand was 63% less, only FW3 was available along the eastern portion of the industrial zone and (see Figure 3.15).

In addition to the pressure management investigation, the minimum pipe sizes required within Coneburn Industrial have now been superseded by this assessment (August 2021) and can be seen in Section 3.3.

3.5.2 Assessment two – February 2020

The second assessment (2020a) involved the calculation of the minimum pipe sizes required (specifications) for Coneburn RM and FM (424.9 mm and 492.7 mm, respectively) and provided high-level capital construction costings for these mains. See Figure 3.12 below. This was the first time where the demand from the remainder of the Hanley's Farm DMA was considered during the pipe sizing exercise.

Figure 3.12: RM and FM specifications from the original pipe sizing assessment (2020a)

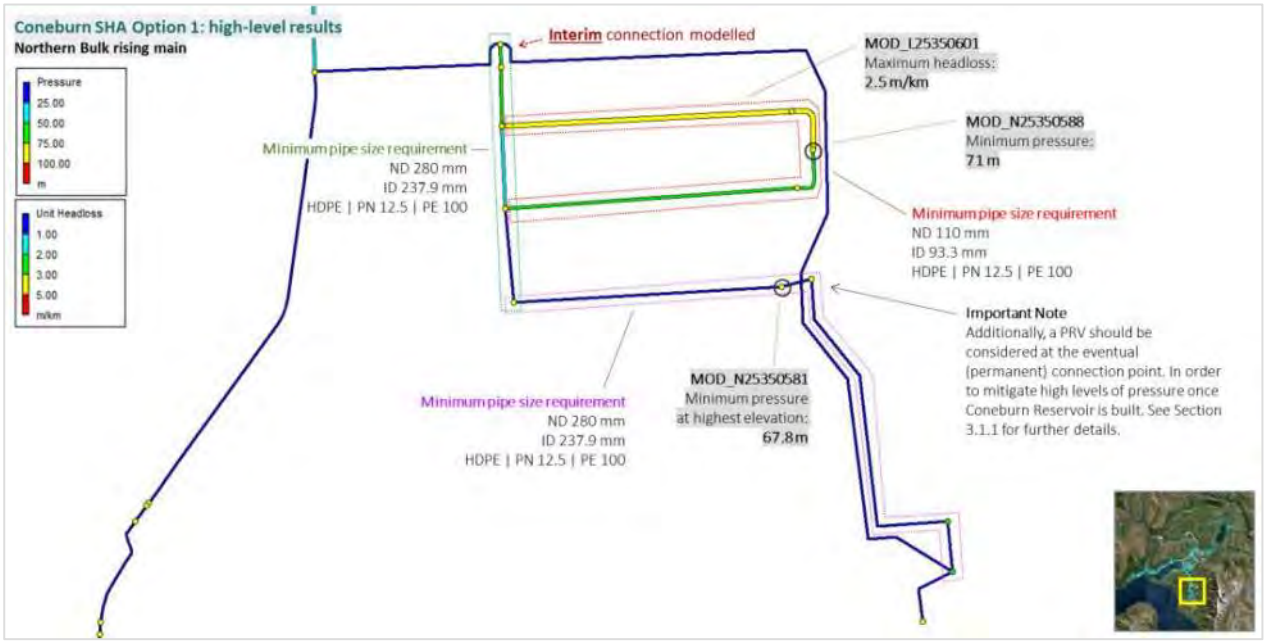


Importantly, the recommended pipe sizes from this assessment were used in all modelling work between February 2020 and July 2021 and are now been superseded by this assessment (August 2021).

3.5.3 Assessment three – October 2020

Based on the pipe sizes recommended in the previous assessment (2020a), two proposed alignments were modelled and compared to assess which would be more viable. Ultimately, “Option 1 – the northern alignment” was taken forward and is in the final design phase. The pipe sizes required within the subdivision were also recommended; however, the entire reticulation was not modelled as part of the assessment and has been re-assessed as part of this assessment (see Figure 3.13).

Figure 3.13: Coneburn SHA: optioneering modelling and original pipe size recommendations



Therefore, the minimum pipe sizes from the original assessment (Figure 3.13) have been superseded and updated based on the drawings provided by QLDC on the 30/07/2021 entitled '*Coneburn Residential Development Stage 1: roading and utilities drawings'*. The revised system performance results are presented in Assessment four – April 2021

3.5.4 Assessment four – April 2021

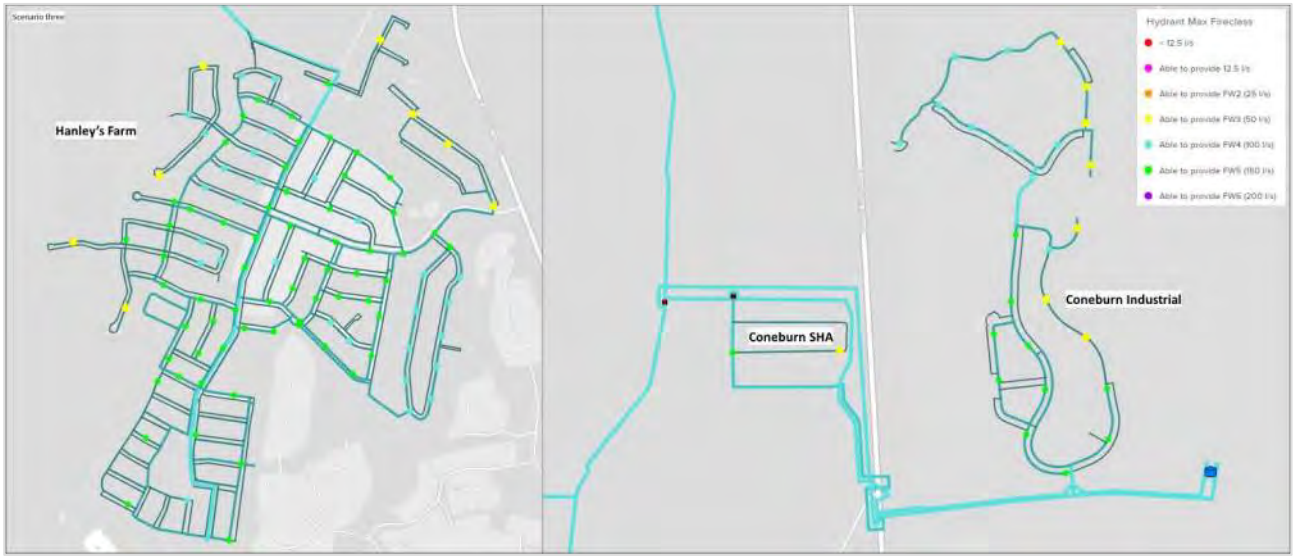
The most recent assessment (2021) was undertaken to update the Hanley's Farm reticulation and demand distribution; based on the demands provided by QLDC, which totalled 2,613 DUEs collectively and excludes Coneburn Industrial demand (see Figure 3.14). Notably, this is approximately 804 DUEs less than the rating units considered in this assessment (excluding Coneburn Industrial), which is based on the QLDC's latest growth rating unit projections. In comparison with all other assessments undertaken in Hanley's Farm, this assessment included the system performance within Hanley's Farm area with greater clarity and accuracy.

Succinctly, the proposed Hanley's Farm reticulation was deemed appropriate, based on HL and firefighting capabilities once Coneburn Reservoir was operational; however, issues with variable and high pressure were highlighted once again. Mott MacDonald's recommendation was "*QLDC should investigate optioneering that focuses on reducing the overly high and variable pressure within part or all the HF network (non-compliant across the majority of the network)*".

Figure 3.14: Study area: Hanley's Farm, Coneburn, Deer Park Heights South and Small Jack's Point

The firefighting capabilities across the entirety of Hanley's Farm and Coneburn SHA were deemed compliant with QLDC's LoS (2018). However, the eastern portion of Coneburn Industrial could not supply more than FW3 (see Figure 3.15). If FW4 is required, it is recommended that the pipe sizing exercise be repeated based on the most recent demand and network configuration.

Figure 3.15: Maximum firefighting capabilities from April 2021 assessment



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4 Conclusions and recommendations

This section concludes the study with the modelling outcome for each assessment item and provides recommendations where appropriate:

The newly proposed pipe sizes for the RM and FM at Coneburn Reservoir were assessed to determine whether they were appropriate. Based on maximum HL only, the entirety of the RM can be sized at 406.8 mm ID (500 mm DN) and the FM can be sized at 406.8 mm ID (500 mm DN) until the Woolshed Road Junction (passing through Coneburn SHA), with the remainder being sized at 455.8 mm ID (560 mm DN) until Coneburn Reservoir

Twelve hours of peak day storage is not available at Coneburn Reservoir during phase one; however, once the overall capacity increases to 4,500 m^3, peak day storage will increase to 13.7 hours. The phased upsizing of Coneburn Reservoir should be reviewed by QLDC once there is greater certainty regarding future population growth in the SCWS area. Phases two and three should be implemented sooner if the rate of population growth is faster and higher than first predicted.

Based on the modelled scenario demands (ultimate within the SCWS area) and the assumed long-term operation of the Coneburn Reservoir, the reservoir is compliant with reservoir turnover.

Within Coneburn SHA, most of the proposed reticulation is compliant with QLDC's LoS. However, two pipes could be upsized along 'Road 01' and 'Road 08', to ensure HL remain below 3 m/km and FW2 is possible at the critical node. Other options could be explored through a comprehensive system performance assessment and firefighting should be assessed with greater accuracy once the location of all hydrants is known.

Within Coneburn Industrial, two options were assessed to reduce high pressure. It was found that a single PRV at the local reticulation connection point is the most viable option. Additionally, new pipes and upsizing were proposed to improve network performance and ensure FW4 firefighting capabilities in the area.

Within Hanley's Farm, multiple pressure management options were explored to manage high pressure. These included a direct supply from Kelvin Heights and fragmenting the network into various pressure zones using PRVs (three fragmentation options were explored).

With a direct supply from Kelvin Heights, only Zone 1 and potentially parts of Zone 2 could be adequately serviced, the remainder of the SCWS area (Zone 2 and Zone 3) cannot be supplied by Kelvin Heights directly. In terms of zone fragmentation, option one could be feasible in mitigating high-pressure, however, options two and three are not recommended.

QLDC has indicated that any pressure management scheme is likely to be deferred and retrofitted to the network after Coneburn Reservoir is constructed. However, QLDC should review the pressure management options explored thus far and further optioneering is needed to explore feasible options. Furthermore, a cost-benefit analysis is recommended to adequately support this decision-making process.

Modelling results from this assessment have not been made available via Moata. Any of the network changes listed above can be added to the working model once confirmed by a QLDC representative.

Appendix B Kōmanawa Solutions Ltd Report

Stantec NZ Ltd

Report No: Z24004GSI-1 1 April 2025.

RCL Homestead Bay Ltd: Groundwater Exploration & Effects of Taking Groundwater for Water Supply

Kōmanawa:

1. ***(verb) spring, well up (of water)***
2. ***(verb) to spring, well up (of thoughts, ideas)***

Kōmanawa Solutions Limited (KSL) is a water resource consultancy and research company specialising in water resource investigation and modelling, environmental limit setting and water resource impact assessment. Our goal is to provide excellent science to facilitate the robust management of natural resources in our changing climate. Clients include New Zealand enterprises in the private sector, central and local government agencies, and community groups.

Our vision

KSL delivers high quality science and research. We aspire to be at the forefront of creativity and innovation to address our increasingly complex water resource challenges; mō tatou, ā, mō kā uri ā muri ake nei (for us and our children after us).

Our mission

Our mission is to develop solutions to the increasingly challenging water resource management issues we now face by providing a clear vision of the pathway from problem to solution. We work closely with our partners, communities, and stakeholders, deploying state-of-the-art scientific methods and building trust through knowledge and honest science communication.

Limitations

Kōmanawa Solution Ltd (KSL) has prepared this Report in accordance with the usual care and thoroughness of the consulting profession for the use of Stantec NZ and RCL Group.

This Report has been prepared in accordance with the scope of work and for the purpose outlined at the start of this report and is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this Report.

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Version control

Date	Report no	Issue notes
12/08/2024	Z23031RCL.Rev0	Initial draft by Jens Rekker without appendices.
30/09/2024	Z23031RCL.Rev1	Draft For Client by Jens Rekker.
6/12/2024	Z23031RCL.Rev2	Revised draft document following comments and edits from Richard Bennett, Stantec NZ.
1/04/2025	Z23031RCL.Rev3	Revised document following comments and edits from Richard Bennett and Grant Kuyts, Stantec.

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Shane Dale and Neil Simmons, Washington Exploration Ltd

Shane Fulton and Lucian Holgate, Benchmark Construction Ltd

Peter White, Richard Bennett, and Patrick Lindsay, Stantec New Zealand Ltd

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Executive Summary

Undeveloped land between SH6 and Homestead Bay, includes farmland that has not undergone land use change in the last 20 years. One such area of land is owned by RCL Homestead Bay Ltd within the land title Lot 8, DP 443832, and its geology comprises glacial outwash and alluvial fan terraces east of Homestead Bay and southwest of State Highway 6. Water supply in the Jacks Point area is currently obtained from three sources; lake water piped *via* the QLDC water supply network, lake water pumped directly from Homestead Bay, or local groundwater from wells F42/0150 and potentially F42/0103. The QLDC feed to the Jacks Point – Homestead Bay has limited supply capacity, and therefore alternatives required consideration for Homestead Bay

The potential water resources for the Jacks Point – Homestead Bay – Remarkables area include each of the above. Groundwater holds something of a premium for water supply development due to the usual stability in water quality (with respect to turbidity, microscopic pathogens, or solutes) but potential sources of groundwater require more investigation to define the contributing groundwater catchment.

Background Hydrogeology

Most of the information and inferences as to the groundwater basin were obtained from well number F42/0150, which was subject of an extensive, local groundwater investigations in 2016 (Dommisse, 2017[1]). It was also clear from published geological and geomorphological mapping of the sedimentary basin that glacial deposits including alluvial fans containing silty, sandy gravel host an active groundwater flow system and local aquifers. The groundwater resource of this sedimentary basin in the Jacks Point area is estimated as being at least 1.38 million cubic metres per annum (in accordance with the Otago Regional Plan: Water limit of 50% of mean recharge, and Dommisse, 2017).

Potential Water Requirement and 2024 Investigations

Water demand for the supply of 2,531 dwellings or dwelling equivalents in Homestead Bay Lot 8 is projected to require approximately 61 litres per second at the peak daily flow, with buffering of hourly peaks in water demand and firefighting storage provided by the working volume in the treated water reservoir of 2,860 cubic metres. The Average Daily Flow (ADF) associated with Lot 8 DP 443832 would be 30 litres per second

In February 2024, RCL Group and Stantec NZ commissioned groundwater exploration to be conducted by Kōmanawa Solutions and Washington Exploration. A drilling plan was developed to drill two side-by-side bores near the shore of Homestead Bay / Drift Bay, Lake Wakatipu but within the RCL property boundary. In the case that unfavourable conditions were encountered in drilling exploration, a reserve or back-up site was included in bore consent applications and a drilling pad also installed.

Drilling at the primary site on exploration bore CC11/0151P with 150 mm diameter casing was logged as non-water-bearing silty sands and clays down to the top of water-bearing gravels at 75 metres below ground and the drilling extended further to a depth of 95 metres amongst water-bearing sandy gravels. To provide a bore for full-scale groundwater testing of capacity, a second bore (CC11/0151) with a 300 mm diameter was drilled and installed alongside the exploration bore. This test production bore was screened from 87.9 m to 94.9 m below ground and developed using air-lift over-pumping. While indications at the conclusion of developing pointed to the natural gravel pack being adequately graded for optimal well screen hydraulic efficiency, subsequent multi-day pumping with a submersible pump caused variability in drawdown that suggested re-packing of the formation surrounding the well screen was still taking place. As a result, flow rates and the internal water level became unstable during the multi-day pumping test.

[1] Dommisse, J. 2017. Groundwater Take from Homestead Bay, Queenstown, Assessment of Environmental Effects. Prepared by Stantec NZ Ltd for Clark Fortune McDonald & Associates, August 2017, unpublished draft report, Christchurch. 36 pages, plus 7 appendices (81 pages).

Aquifer Testing

While the carrying out of bore performance and aquifer tests in the test production bore was hampered by the aforementioned instability of the bore screen, a step rate test was undertaken, and a constant rate test was run for 52 hours. The step rate test was run at four, hour-long pump rate steps of 9.9, 19.4, 29.5, and 39.5 L/s. The test production bore water level drew down to 39 m below top of casing or a net drawdown of 40.7 m at the highest pumping step (note, the test bores were flowing artesian in the absence of pumping). Some instability was discernible in the variable measured pumping rates and measured water levels plotting unevenly. The constant rate test undertaken for 52.2 hours manifested substantial variability in pumped bore water level and consequently pumped rate (between 25 and 41.7 L/s). Short bursts of elevated turbidity were also visible in pump discharge on occasion during the test. Although potentially unrelated, the pump unit also shut down abruptly, 20 hours short of the targeted 72 hour pumping phase duration.

Aquifer Properties

Pumping test analysis point to moderate transmissivity (approximately 200 square metres per day) and leaky aquifer properties, with moderate storativity. The groundwater pressure measured within the bores immediately after their installation was 1 – 2 m above ground level. The groundwater pressure in the bores was also estimated to be approximately 12 m above lake level in Lake Wakatipu, of the bores lying about 85 m to the southwest. This combination of groundwater properties, significant depth available for pumping drawdown and high initial groundwater level contributes to a measured capacity for the test production bore of approximately 40 L/s. However, it is considered that the test production bore would require further focused hydraulic development to deal with observed episodic drops in well screen efficiency.

Water Quality & Groundwater Security

Water quality was assessed by sampling pump discharge during the constant rate test and analysis at an accredited laboratory. The groundwater is circum-neutral with respect to pH and low Total Dissolved Solids content of about 95 mg/L. Hardness is moderate at approximately 65 mg/L. Dissolved iron and manganese concentrations were very low at concentrations less than the detection limits. Only arsenic has a concentration approaching the drinking water standard, at a measured concentration of 0.0098 mg/L. Nitrate is also very low at 0.4 mgN/L, indicating 'minimally impacted nutrient status' (Daughney *et a*l, 2023[2]), . Although bacterial indicators were not analysed for, microbial security is initially assessed as good to excellent.

The prospects for water quality management were considered to be good. We note that the source aquifer has solid indications of being secure in terms of the drinking water quality management guidelines, particularly in the case of protozoa, bacteria and viruses. Water chemistry monitoring for stability analysis and potentially isotope dating is recommended. The bore construction using a 6 metre deep pre-collar and bentonite seal demonstrated that a sanitary seal could be installed into the top of the silty capping layer, which was found at 4.8 metres depth. Thus, a secure well head was achieved. The remaining water quality matter of health concern was the dissolved arsenic concentration in pumped groundwater. Water treatment to remove arsenic using ferric chloride dosing, coagulation and filtration is widely employed to remove dissolved arsenic in both valence states, As (III, V). The practical experience of treating raw water for arsenic in Northern Chile mining communities demonstrates that the inline removal of arsenic is feasible for medium size water supplies (Sancha, 2006)[3]. The experience in New Zealand is that Hamilton City has been successfully and reliably treating raw water (alum dosing , coagulation and filtration) at raw concentrations around 0.032 mg/L and achieving supplied concentrations of 0.006 mg/L, which meets the 0.01 mg/L drinking water standard (McLaren & Kim, 1995)[4].

[2] Christopher J. Daughney, C J; Uwe Morgenstern, U; Magali Moreau, M; and Richard W. McDowell, R W. 2023. Reference conditions and threshold values for nitrate nitrogen in New Zealand groundwaters, *Journal of the Royal Society of New Zealand*, https:\\DOI:10.1080/03036758.2023.2221034

[3] Sancha, A M. 2006. Review of Coagulation Technology for Removal of Arsenic: Case of Chile. Review Article in Journal of Health Population and Nutrition Vol 24, Issue 3, pages 267-272. ISSN 1606-0997.

[4] McLaren, S. J., & Kim, N. D. (1995). Evidence for a seasonal fluctuation of arsenic in New Zealand's longest river and the effect of treatment on concentrations in drinking water. Environmental Pollution, 90(1), 67–73. doi:10.1016/0269-7491(94)00092-r

Future Prospects for an Expanded Supply Capacity

Further groundwater development potential may exist within the RCL Homestead Bay Lot 8 DP 443832, for instance Bore B in Figure 6, or indeed elsewhere in the inland extents of Homestead Bay land. The installation of a second bore with capacity to augment the Average Daily Flow requirement of 44 litres per second served by the 2024 test bore, up to the Peak Daily Requirement of 60.79 litres per second is envisaged to complete the full demand projections for the planned water supply of Lot 8 in Homestead Bay. The expectation of such a standby capacity water source prospect, given the drilling success indicated in bores F41/0150 and CC11/0151 within the Homestead Bay land or lake frontage, is reasonable.

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1 Background

The Jacks Point – Homestead Bay – Remarkables area has become a focus for residential and accommodation development in the last two decades. Among the requirements for enabling current and future development of land in the Jacks Point – Homestead Bay – Remarkables area are access to Three Waters Infrastructure. Figure 1 map the Queenstown Lakes District Council's Geographic Information System (GIS) – Services layer with water supply and wastewater services segregated, respectively.

The water supply spectrum includes a range of private water supplies with diverse raw water sources –

- The Jacks Point Village provided with treated water from the QLDC system since 2017,
- Private bore supplies at Homestead Bay and Lakeside Estates, and
- Private intake on Lake Wakatipu for the majority of residential area of Jacks Point.

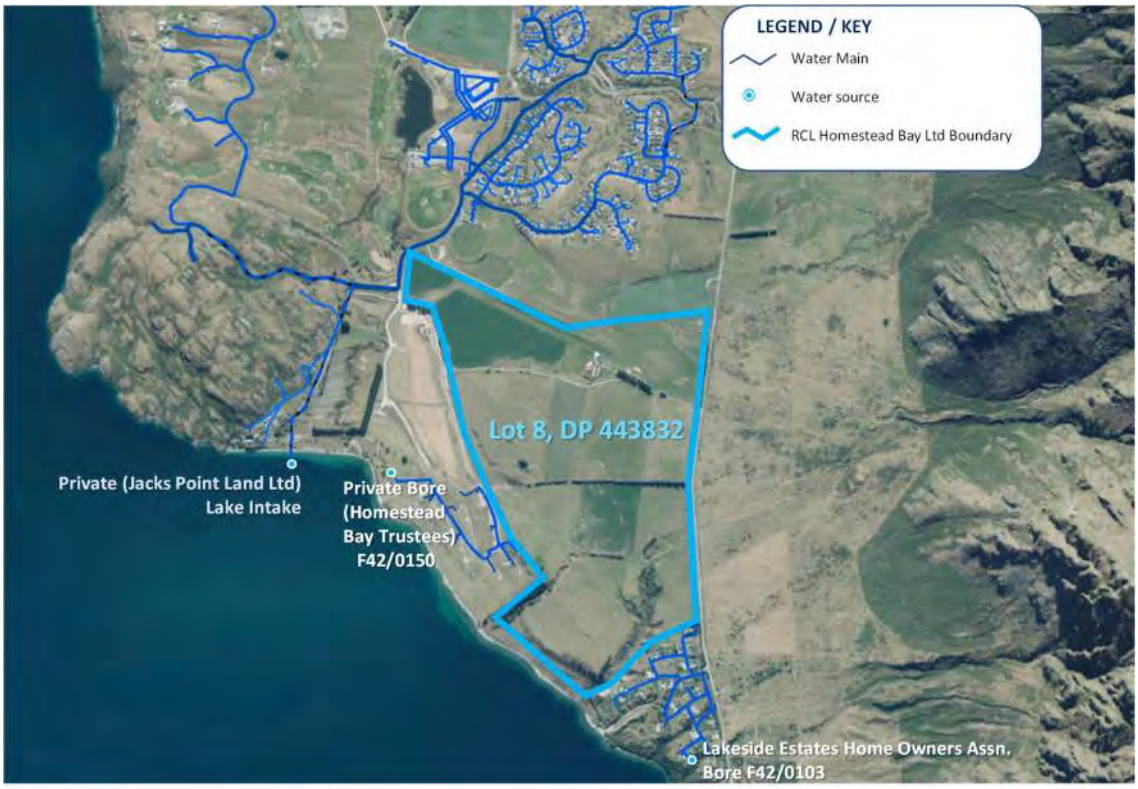


Figure 1: Location map of water supply in the Jacks Point – Homestead Bay – Remarkables area

RCL Group has been the central fixture in the development of the Hanleys Farm residential settlement to the immediate north of Jacks Point. The Group also owns under its RCL Homestead Bay Ltd subsidiary, comprising undeveloped rural land within the tile of Lot 8 Deposited Plan 443832. This 163.7 hectare lot is potentially changed to residential land use in common with the surrounding developments fringing State Highway 6 (SH6). Among the water infrastructure that would be required for development is domestic water supply. Currently, the Jacks Point Village area is provided by the Queenstown Lakes District Council water supply that is piped from the nearest lake intake and water treatment plant. Additional areas are supplied locally from Lake Wakatipu as well. In addition, houses in Lakeside Estates and Nathanael Place are provided with water from private bores F42/0103 and F42/0150, respectively. These private bores that bracket the RCL Homestead Bay property have established the presence of a groundwater resource.

In planning a new water supply for residential development of Lot 8 DP 443832, one needs to consider the potential sources of raw water. The main options are Lake Wakatipu and local groundwater, which have contrasting microbiological security characteristics. Lake water is available and abundant with excellent overall measurable water chemistry. However, the protections in water supplies based on surface raw water have been brought into question by water contamination of water supplies involving such water-borne pathogens as protozoa, bacteria and viruses. In spring 2023, a *Cryptosporidium* water contamination event was identified from cases of gastroenteritis in the township[5]. The source of *Cryptosporidium* oocysts in water was judged by Te Whatu Ora to be the Two-Mile water treatment plant intake on Lake Wakatipu near Queenstown and it was commented that a human faecal source of a transient nature was the most likely ultimate cause. This and previous episodes in Queenstown Lakes District [e.g., 1984 sewer overflow with associated gastroenteritis outbreak[6] and Cardrona Hotel norovirus mass infection (Nicolas & Weaver, 2001)[7]] underline the public health risks posed by lake or other surface water as a raw water source, or indeed the small separations between water supply and wastewater discharges or network overflows. One aspect of planning for a multiple barrier approach to public health risk management includes careful planning and risk assessment in the realm of source protection.

In view of a preference for a groundwater sourced water supply over lake water, and also in view of the potential groundwater resource indicated to occur at private water supplies either side of the Lot 8 DP 443832, RCL Group commissioned drilling investigations to establish a test production bore and undertake groundwater testing for quantity and quality aspects of a future water supply. This report is intended to summarise these drilling investigations and the implications, alongside an assessment of environmental effects.

2 Existing Environment

Homestead Bay lies at the southern terminus of a glacial sedimentary basin extending from Frankton to Lake Wakatipu on Homestead Bay. The basin is wedged between the Peninsula Hill – Jacks Point range of hills and the Remarkables Range. The sedimentary basin comprises Pleistocene glacial till overlain by younger (Holocene) alluvial fans. The basin is elongate with an axis trend approximately north – south and is cross-cut to the north by the Kawarau River downstream of Kawarau Falls (bridge). The coarser gravel and sand deposits within the basin are the main prospects for raw water supply from groundwater within the area.

The hills on all sides of the basin comprise Otago Schist of textural zone 3 (Turnbull et al., 2001)[8] in the central and southern parts of the basin, and Otago Schist of textural zone 4 in the north especially under Frankton Flats. The schist of both textural zones is massive and dense, and as a result the schist is over consolidated with negligible original porosity. Any ability to convey or conduct groundwater flow within the schist is restricted to subsequent interconnected jointing and fracturing of the rock mass. Weak flows of groundwater can issue to wells or springs issuing from the schist rock. However, compared to the often high permeability and porosity of the glacial or alluvial sediments, schist rock is effectively impermeable to groundwater.

2.1 Previous Water Supplies

Water supplies for domestic water have already been developed from the glacial or alluvial sediments at Homestead Bay and the Lakeside subdivision using bores F42/0150 and F42/0103, respectively (see Figure 1 for locations). A further bore (F41/0324) for water supply was developed near the corner of Māori Jack Road and

5 https://www.tewhatuora.govt.nz/whats-happening/news-and-updates/boil-water-notice-remains-in-place-as-investigations-identify-water-contamination-as-likely-source-of-crypto-outbreak/

6 https://www.scene.co.nz/queenstown-news/local-life/qtowns-real-water-crisis/

7 Nicholas, G; and Weaver, L. 2016. Effective public health practice: Insights from Cardrona 2012. Prepared by ESR for Ministry of Health, ESR Report FW16016, May 2016, Christchurch. pp35.

8 Turnbull, I M; Mortimer, N; & Craw, D. 2001. Textural zones in the Haast Schist—a reappraisal. New Zealand Journal of Geology and Geophysics, 44:1, 171-183, DOI:10.1080/00288306.2001.9514933

Jacks Point Rise in connection with the Jacks Point development but decommissioned when the need for the water source ceased.

2.2 Groundwater

2.2.1 Previous Studies & Information Sources

The Jacks Point – Homestead Bay – Remarkables area has not been the subject of specific hydrological or groundwater investigations. The closest Otago Regional Council investigation would be the Wakatipu Basin aquifers study (Rekker, 2014)[9], which extended to the Frankton Terrace. The superficial deposit map in Figure 2 is taken from Barrell et al (1994), which was primarily drawn from sedimentary reconstructions of largely glacial deposits across the Wakatipu Basin and environs. Figure 2 also reveals the basin at Homestead Bay to be filled with an outwardly chaotic mix of glacial debris over-printed by alluvial fans emanating from the Remarkables' interfluves.

The national publication is the Q Map Wakatipu sheet (I M Turnbull, 2000, Volume 18)[10] and Geological Map of New Zealand[11] that maps surface geology. A more relevant geological mapping project was the surficial geology of the Wakatipu Basin (Barrell et al., 1994)[12], including deposit mapping with an emphasis on Holocene and Pleistocene deposits. The surficial mapping focused on the Frankton - Homestead Bay sedimentary basin is reproduced in Figure 2.

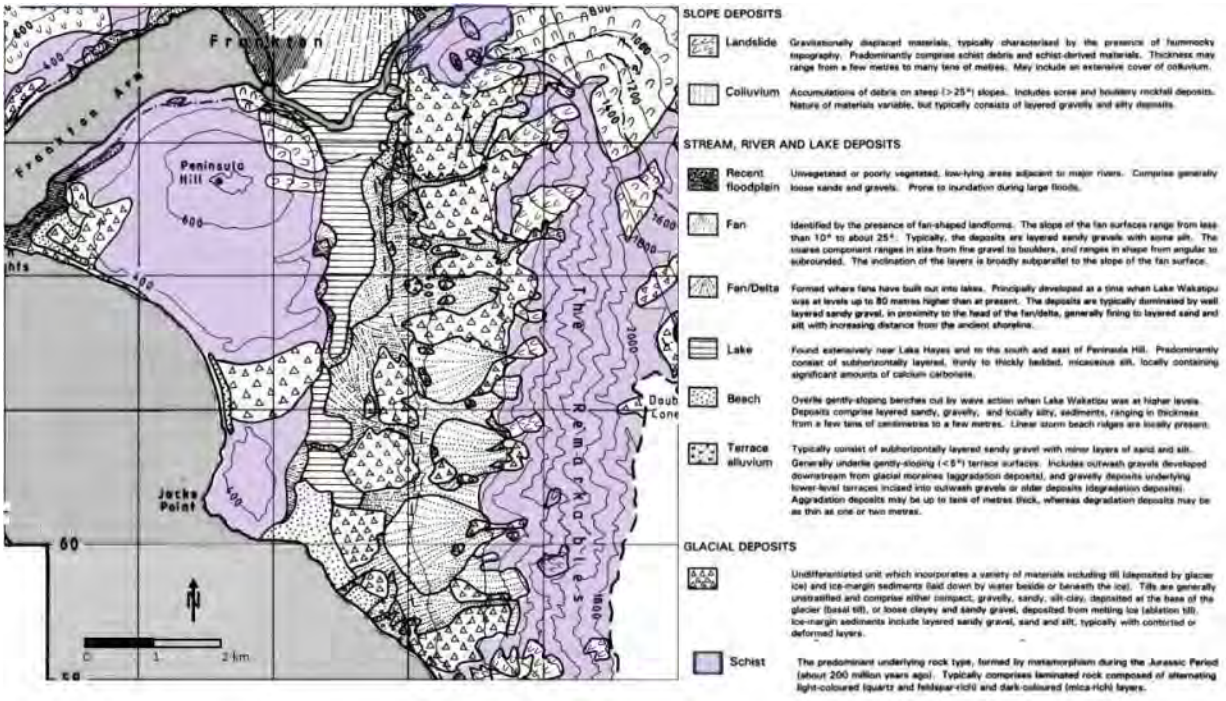


Figure 2: Superficial mapping of the Frankton – Homestead Bay basin showing glacial & post-glacial deposits

9 Rekker, J H. 2014. Investigation into the Wakatipu Basin Aquifers. Prepared by ORC Resource Science Unit for Otago Regional Council, July 2014. Dunedin. pp66. ISBN 978-0-478-37673-9

10 Turnbull, I.M. (compiler) 2000. Geology of the Wakatipu area. Institute of Geological & Nuclear Sciences 1:250 000 geological map 18. Lower Hutt, New Zealand. Institute of Geological & Nuclear Sciences Limited. 72 p. + 1 sheet.

11 Heron, D.W. (custodian) 2018. Geological Map of New Zealand 1:250 000. GNS Science geological map 1 (**2nd edition**). Lower Hutt, New Zealand. GNS Science.

12 Barrell, D J A; Riddolls, B W; Riddolls, P M; Thompson, R. 1994. Surficial geology of the Wakatipu Basin, Central Otago, New Zealand. IGNS Science Report 94/39, Lower Hutt, New Zealand. p31 plus maps.

The surficial geological deposit mapping was supplemented by natural hazard, alluvial fan mapping by GNS and ORC (Barrell et al., 2009) (see Figure 3). Besides the geological and deposit mapping, the sole groundwater report for the Homestead Bay area relates to the private water supply bore F42/0150, undertaken by Stantec NZ Ltd for Clark Fortune McDonald & Associates (Dommisse, 2017). The report details the drilling of four bores in a tight radius of each other approximately 100 m east of Homestead Bay, including a 260 mm diameter production bore, 50 mm diameter observation bore located 15 m distant from July 2017, and two Aircore (reverse circulation) drill holes drilled 2½ years previously in December 2015. All drilling described above was focused on the 30 m to 37 m depth range encountering silty coarse gravel deposits with high hydraulic conductivity (permeability and transmissivity). The production bore and connected aquifer was comprehensively quantified at a local scale through aquifer testing, water sampling / analysis and numerical analysis of testing data. The limited amount of groundwater basin analysis within the report was mostly restricted to climate modelling of soil-mediated land surface recharge.

ORC maintains a well database, including bore logs and well construction details, plus links between bores, state of the environment and groundwater take consenting. Up to 19 well records are provided within the ORC database for the Jacks Point -Homestead Bay – Remarkables area. The Dommisse (2017) records of four bores (2 exploratory, production bore, and observation bore) were added to Table 1.

Table 1: Summary of ORC Well Records for Jacks Point -Homestead Bay – Remarkables area

Bore ID	Easting NZTM	Northing NZTM	Depth (m BGL)	Screen Top (m BGL)	Completion Status	Depth To Water (m BGL)
F41/0108	1265625	5002821	31		_	
F41/0119	1264787	5003857	21.6	18.6	Complete	1.65
F41/0127	1265625	5003422	45			
F41/0143	1265425	5003522	62	59	Complete	
F41/0153	1265724	5004023	57.44	56.1	Complete	
F41/0156	1265724	5004023	35		_	
F41/0157	1265224	5004222	30		_	
F41/0163	1266528	5000820	36	12.7	Complete	7.97
F41/0216	1265625	5002921	23.97	21.82	Complete	16.2
F41/0304	1265609	5003020	35.7	34.6	Complete	1.72
F41/0324	1264635	4999899	46.64	40.16	Complete	
F41/0327	1266914	5003080	50		Complete	
F41/0334	1266025	5003222	22		Filled-in	
F41/0382	1263993	4998351	9.6		Complete	2.4
F41/0482	1265578	5003802	34.83		Complete	7.56
F42/0100	1265917	4997067	55	52	Complete	36
F42/0103	**1265975**	**4996882**	**55**		**Complete**	
BH-1*	1264620	4998175	37	_	Filled-in	0.3
BH-2*	1264554	4998269	36	_	Filled-in	-2.6¥
F42/0150	**1264612**	**4998187**	**35.8**	**29.77**	**Complete**	**0.89**
F42/0150A	1264607	4998193	35.7	29.7	Complete	0.74

Note: BGL = Below Ground Level; * Not obtained from ORC well records, detailed within Dommisse (2017); ¥ A negative Depth To Water means the groundwater level measured above the bore top or ground level, i.e., flowing artesian. **Bold** indicates source of a communal water supply.

Extractive groundwater use is not considered to be significant, as most water requirements for communal water supply or irrigation are obtained from piped water supply networks derived from surface water, while the two communal water supplies obtained from bores [Homestead Bay Trustees, Nathaneal Place and Lakeside Estates] are small in terms of the number of dwelling connections. ORC does not undertake any State of the Environment (SOE) groundwater monitoring in the area, such as recording groundwater level or taking regular groundwater samples for laboratory analysis. The Jacks Point – Homestead Bay – Remarkables sedimentary basin does not form a declared aquifer within the Regional Plan: Water for Otago, therefore the groundwater resources are subject to only general Policies and Rules within the Regional Plan: Water. Special groundwater management of the area is not proposed within the Otago Land & Water Regional Plan set down for notification in June 2024.

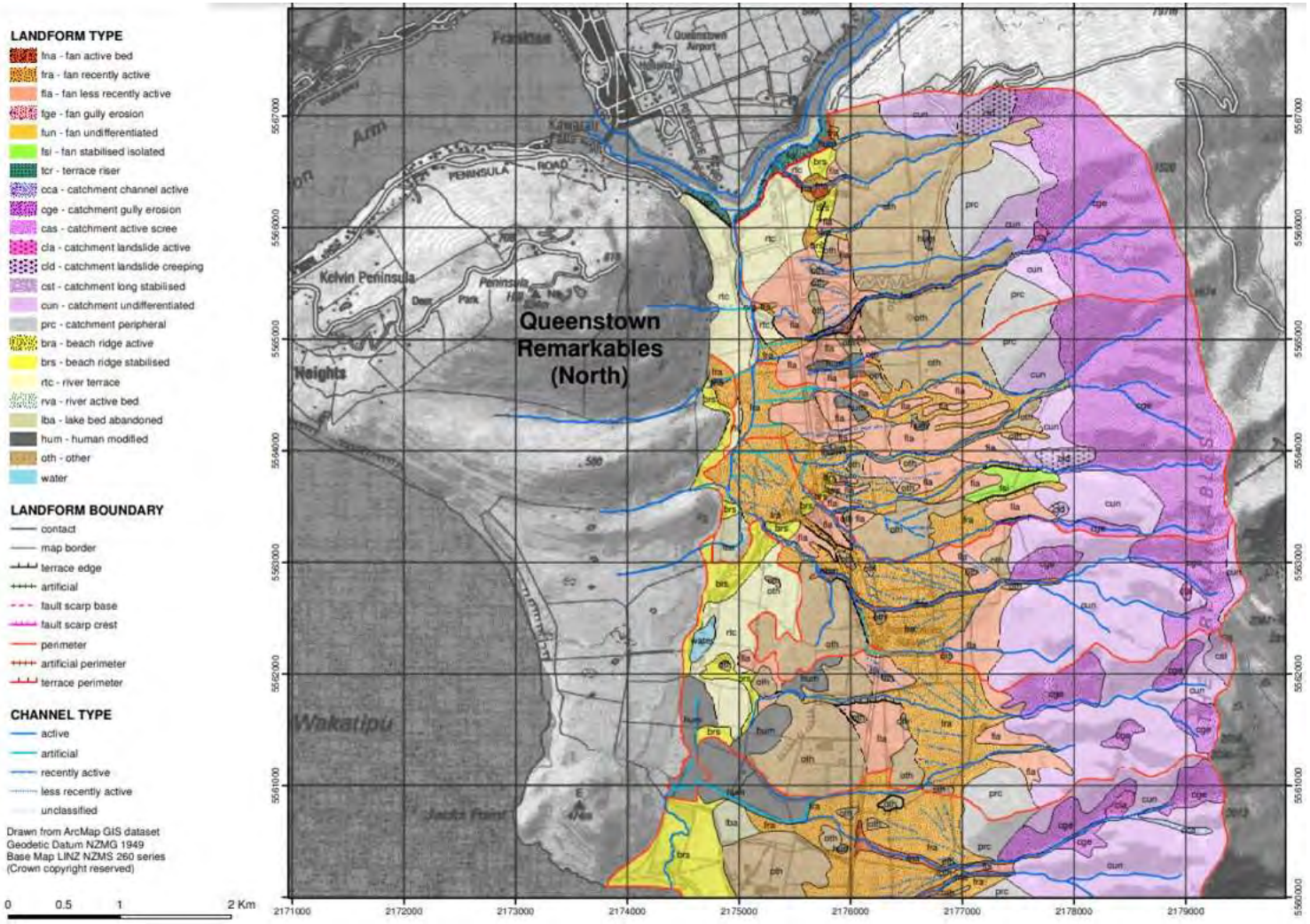


Figure 3: Queenstown (Remarkables) alluvial fan mapping (Barrell et al, 2009)

2.3 Surface Water

2.3.1 Existing Information

Homestead Bay lies within the Upper Clutha Lakes rohe of the Clutha / Mata Au Freshwater Management Unit (FMU). The sedimentary basin north of Homestead Bay is drained by Stoney Creek into the Kawarau River and four unnamed lake-draining creeks that discharge into Lake Wakatipu at Homestead Bay and Drift Bay. All creeks are largely fed by rain and snow melt with the Remarkables Range having a strong pluviographic gradient (see Figure 4 from ORC Grow Otago mapping). No hydrological flow gauging has been established by ORC to allow the generation of hydrological statistics, so rainfall – runoff modelling using HIRDS or the NZ Water Flow Model – Hydrology are the sole means of estimating surface water hydrology statistics.

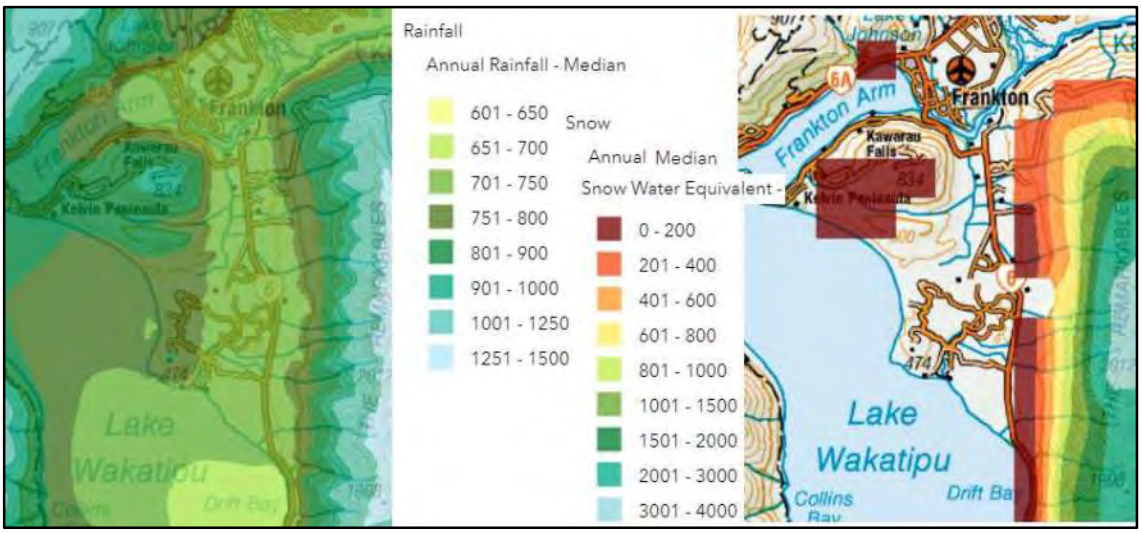


Figure 4: Colour flood of median annual rainfall (left) and snow accumulation (right) in millimetres per annum

The Lake Wakatipu catchment has been part of the original Upper Clutha hydrological monitoring programme since 1963 as measured at the flow measurement site in the Frankton Arm of Lake Wakatipu, immediately upstream of the Kawarau Falls control gates.

Table 2: Station details, measuring period and summary statistics for Lake Wakatipu at Willow Place

	NZ Segment #	Area (km^2)	Start	End	No. of years	Mean (L/s)	Median (L/s)	$MALF_{7d}$ (L/s)
Lake Wakatipu at Willow Place, Kelvin Heights	14223274	3,041	2/02/63	ongoing	54	181,257	157,353	75,100

Note: No. of years = Number of whole years of flow record. $MALF_{7d}$ is the seven day Mean Annual Low Flow statistic.

The hydrology of Lake Wakatipu is largely natural and contributed by Main Divide (Southern Alps) river tributaries such as the Rees, Dart, Caples, Greenstone, Von, Afton, Lochy, Staircase, Wye, Twelve Mile, and Buckler. The specific median runoff of the Lake Wakatipu catchment is approximately 52 litres per second per square kilometre of catchment (L/s/km^2). Lake Wakatipu, alongside Lake Wānaka and Lake Hāwea, contributes much of the water resources available at Clyde, Roxburgh, and the Lower Clutha / Mata Au.

The Upper Clutha Lakes rōhe tends not to be at full allocation due to the lack of surface water allocation limits set in the Regional Plan: Water, but also importantly due to the substantial overhang of catchment Mean Annual Flow (7-day) above the current consumptive allocation in individual resource consents. For example, $MALF_{7d}$ at Willow Place is 75,100 L/s, while the total Wakatipu catchment surface water allocated in consents is only 756 L/s (effectively 1% of $MALF_{7d}$).

More specific hydrological or water resource statistics are available for creeks draining the Remarkables Range in the NZ Water Flow Model – Hydrology maintained by the National Institute of Water & Atmosphere (NIWA) within the Shiny NZ Rivers Maps database (https://shiny.niwa.co.nz/nzrivermaps/). Table 3 lists the derived hydrological statistics and Figure 5 maps the locations of the river-segments, in accordance with New Zealand river segment numbering referred to in Table 3.

Table 3: Rainfall – Runoff modelled Hydrological Statistics for Homestead Bay Sedimentary Basin

Creek / Burn Catchment	NZ River Segment #	Area (km^2)	Mean Flow (m^3/s)	Median Flow (m^3/s)	$MALF_{7d}$ (m^3/s)
Stoney Creek Main Stem at Kawarau River	14223640	25.128	0.45643	0.33452	0.099759
Stoney Creek East No. 1	14223920	2.534	0.0537	0.03922	0.0221
Stoney Creek East No. 2	14224643	3.037	0.04493	0.02903	0.010685
Stoney Creek East (Remarkables) No. 1	14224944	4.577	0.10197	0.07323	0.03167
Stoney Creek East (Remarkables) No. 2	14225326	4.189	0.04099	0.02081	0.006289
Hanley Farms Residential Area Creek	14225673	0.506	0.00508	0.00249	0.000755
Stoney Ck West, Peninsula Hill No. 1	14224549	3.178	0.03536	0.01642	0.004646
Stoney Ck West, Peninsula Hill No. 2	14225154	0.744	0.00763	0.00358	0.001111
Stoney Creek West, Reservoir Hill & Saddle Creek	14225672	1.235	0.01259	0.00647	0.002075
Woolshed Creek at Lake confluence	14227448	10.756	0.21113	0.15399	0.054147
Homestead Bay minor creek	14227600	1.300	0.01269	0.00633	0.001905
Unnamed Trib Drift Bay No. 1	14227917	3.803	0.08735	0.06266	0.035764
Unnamed Trib Drift Bay No. 2	14227972	1.579	0.04089	0.02989	0.01674

Note: Green shaded catchments drain north to the Kawarau River in the Stoney Creek main stem; Blue shaded catchments drain individually to Homestead Bay and Drift Bay on Lake Wakatipu; "$MALF_{7d}$" = seven-day aggregated Mean Annual Low Flow statistic; Flow in units of 1 cubic metres per second (m^3/s) is the same as 1,000 litres per second (L/s); creeks at lake edge may lack perennial flow due to infiltration.

Figure 5: Location of creek / burn river-segments within Remarkables – Peninsula Hill basin (NZ Rivers Maps)

Otago hydrologists consider that the New Zealand Rivers Maps estimates of hydrological statistics are often inaccurate due to the more localised effects of precipitation, topography and underlying geology. In the case of the Homestead Bay catchments such as Woolshed Creek, the creek channels only carry flow during high intensity or extended period rainfall such as floods. The reason for the normally dry creek beds is the permeability and porosity of the deposits described in Geology, primarily gravel alluvial fans emanating from the Remarkables range front.

2.3.2 Lake Wakatipu and Surface Water Tributaries

2.3.2.1 Lake Wakatipu

Lake Wakatipu and tributaries have excellent physical availability and the ability to secure legal access to its waters. The lake itself has the following water resource dimensions, listed in Table 4.

Table 4: Lake Wakatipu Water Resource Dimensions

Dimension	Value	Unit
Max. length	75.2	km
Max. width	5	km
Surface area	289	km^2
Average depth	130	metres
Max. depth	420	metres
Water volume	37.57	cubic kilometres
Residence time	12	years
Surface elevation	310	metres
Catchment area	2,674	km^2
Median Water Level	309.6	m AMSL
Upper Water Level	310.8	m AMSL
Water Level Range	1.2	m
Live storage	3.47	cubic kilometres
Mean Flow Rate at Outlet	181.3	m^3/s
Outlet Flow $MALF_{7d}$	75.1	m^3/s
Estimated allocated abstraction	0.75	m^3/s

Annual median water levels, averaged over the 1963-2023 water years were 309.88 ± 0.12 m in Lake Wakatipu. Corresponding Lake Wakatipu annual interquartile and 5 - 95 percentile ranges were 0.40 and 0.99. So, lake level is quite stable, responding to headwater rainfall or snowmelt. There is a weak seasonal pattern in lake level towards lower levels in the winter (Hawes, 2023)[13].

2.3.2.2 Lake Tributaries

Quantification of hydrological statistics for the Lake Wakatipu tributaries is problematic due to the lack of recorded flows at hydrological flow sites on these tributaries. A long-term hydrological flow site is present on the Dart River at the Hillocks, and short records are available for Staircase Creek and Twelve Mile Creek. To provide some indications of water resource availability, Table 5 lists the control site, NZ river segment, catchment area and indicative (i.e., approximate) modelled $MALF_{7d}$. From the list, the largest and smaller tributary water resources can be determined. Wye Creek is listed with an indicative $MALF_{7d}$ of only 66 L/s, despite being the closest tributary of scale close to Homestead Bay.

[13] Hawes, I. 2023. Lake levels and water abstraction limits for Lake Wanaka and Lake Whakatipu. Unpublished report prepared for Otago Regional Council by Aquatic Research Solutions Ltd, May 2023, Tauranga. 34 pages.

Table 5: Adjacent Lake Wakatipu Tributaries with a record of flow measurement and indicative MALF

Description of Site	NZ Segment #	Area (km^2)	Indicative* $MALF_{7d}$ (L/s)	Specific $MALF_{7d}$ (L/s)
Wye Creek at upstream of SH6 crossing	14230724	3.1	66	21.3
Staircase Creek at upstream of SH6 crossing	14238652	46	403	8.8
Twelve Mile Creek at Lake Wakatipu	14226451	5.05	100 (135¥)	19.8

Note: * Values from NZ Rivers Maps and (Singh et al., 2021)[14]; ¥A tailored estimate of $MALF_{7d}$ provided in (Olsen, 2014)[15] using correlation with Shotover at Peats Huts hydrological flow site and 1 year of concurrent flow measurement on Twelve Mile Creek. Modelled hydrological statistics are provided for the Jacks Point – Homestead Bay – Remarkables sedimentary basin in Table 3 and mapped in Figure 5. The Woolshed and Drift Bay tributaries belong to the Lake Wakatipu watershed, while Stoney Creek is a Kawarau tributary.

2.3.3 Water Allocation & Actual Use

Lake Wakatipu catchment upstream of the Kawarau Falls outlet also has a modest sum of surface allocated within water take resource consents relative to the available water resource, which is estimated as 750 litres per second (0.75 m^3/s). The Resource Management Act considered that taking water for hydroelectric schemes, even run-of-river schemes used in the Wakatipu catchment, required water allocation. Estimates of actual use of natural water was estimated on the basis of water metering of consented water takes greater than 5 L/s between July 2015 to June 2020 lie at approximately 1,800 L/s (1.8 m^3/s), including non-consumptive hydroelectricity diversions of about 1,600 L/s, or approximately 200 L/s without hydroelectric water use (i.e., lake abstraction and groundwater; see Table 6).

Table 6: Summary of mean rates of water take as recorded in water meters required under the National Environmental Standard (Water Metering) Wakatipu catchment from 2015 to 2020

Water Meter Category	Metered Mean Water Take (L/s)
Lake Wakatipu • direct from lake, or • highly connected groundwater	197
Groundwater, not highly connected	2.3
Hydroelectricity on lake tributaries	1,593
Total Wakatipu Catchment	**1,793**

14 Singh, S; Sandoval, D; Rajanayaka, C; Henderson, R; and Shiona, H. 2021. Generation of Hydrological Statistics for Otago. Prepared for Otago Regional Council, NIWA Client Report No: 2021030CH, April 2021, Riccarton. 50 pages.

15 Olsen, D. 2014. Management Flows for Aquatic Ecosystems in Twelve Mile Creek. Prepared for Otago Regional Council by ORC Resource Science Unit, December 2014, Dunedin. 32 pages ISBN 978-0-478-37696-8.

2.3.4 Authorisations under Acts of Parliament and Regional Planning

Many of the small water takes are authorised by Resource Management Act domestic and stock water authorisation, certificates of compliance or permitted activity rules under the Otago Regional Plan: Water. The bulk of permitted activity rule water takes include general, domestic, and stock water use per land holding at 25 cubic metres per day (0.29 L/s) anywhere in the catchment.

Somewhat unique to the Otago glacial lakes and main stem Kawarau and Clutha rivers, a significant permitted activity is provided for taking from surface water and connected groundwater under Otago Regional Plan: Water Rule 12.1.2.2. This rule allows for up to 11.57 L/s or 1,000 m^3/d to be taken directly from Lake Wakatipu or the Kawarau River[16] in the Kawarau catchment. There should be some doubt whether Rule 12.1.2.2 would be carried over into the proposed Land & Water Regional Plan to be notified in June 2024, since the rule is potentially inconsistent with the National Policy Statement on Freshwater Management 2020 and Te Mana o te Wai.

2.3.5 Basis for Allocating Surface Water

Surface water allocation is most commonly capped as a fixed proportion of $MALF_{7d}$. The Otago Regional Plan: Water states the "*catchments that are not listed in Schedule 2A* (for tailored allocation) *have a 'default' primary allocation limit, which is 50% of the 7-day mean annual low flow (MALF)*. Modern New Zealand surface water allocation limits or caps tend to place the primary allocation limit equivalent to 30% of $MALF_{7d}$ and the primary minimum flow restriction at 90% of MALF. On the flip side, combined total river or stream abstraction up to 5% to 10% of the water course's $MALF_{7d}$ is considered to have minor to small impact on ecological values. In this context, the Lake Wakatipu catchment through flowing $MALF_{7d}$ of 75,100 L/s can be compared with the primary consented allocation of 750 L/s, or 10% of $MALF_{7d}$. Furthermore, the majority of the water allocated in water take consents is for hydroelectricity on lake tributaries, which are effectively non-consumptive and have minimal effect on lake through flow. Thus, water take consent applications for Lake Wakatipu amounting to small or medium rates / volumes of take would be likely to be granted on the basis of allocation. Site-specific environmental assessment of large lake water takes tend to be *pro forma*.

2.3.6 Basis for Allocating Groundwater

2.3.6.1 Current Basis for Groundwater Management

The allocation and regional water resource management of groundwater in the project area is currently governed by the Otago Regional Plan: Water. The groundwater resource management of the Homestead Bay sedimentary basin is not specified as requiring special management within declared aquifers or groundwater protection zones (C Maps), water take restriction areas (D Maps), or Nitrogen Sensitive Zones (H Maps, but PC6A has effectively been postponed by PC6AA until April 2026). Otago Regional Council (ORC) environmental monitoring or science groups have no particular focus on the groundwater resources south of Frankton Arm or Kawarau River, along the western flanks of the Remarkables. Therefore, only general rules and methods within the Regional Plan: Water apply to groundwater management for a future water supply.

Water takes for drinking water supply has a somewhat privileged status, including being exempt from minimum water levels or minimum flow restrictions. Increasingly as a result of the Havelock North inquiry into the 2016 campylobacteriosis outbreak that had contaminated groundwater as its source, groundwater source protection has been advanced by Ministry for the Environment or Ministry of Health (Taumata Arowai) and included in resource management and public health regulatory instruments. The groundwater protection zones bring with

[16] Providing with Rule 12.1.2.2 conditions –
(b) No more than one such take occurs per landholding; and
(c) No backflow of any contaminated water occurs to the water body; and
(d) Fish are prevented from entering the intake structure.
Also, under the NES Water Metering, the taking of water at more than 5 L/s must include a water meter.

them the potential for reverse sensitivity objections due to the limits and restrictions on potentially contaminating land use activities in surrounding catchment land.

There is currently only one groundwater take consent in the Homestead Bay sedimentary basin, for the Lakeside Estate drinking water supply near SH6. The consent authorises the taking of 5 L/s and 250 m^3/d for 365 days per annum. Water meter data from July 2015 to December 2016, the mean, median, and maximum daily rates of take were 0.77, 0.50 and 3.65 L/s, respectively. As a result, only 0.09 million cubic metres of groundwater per annum are allocated from the basin's groundwater where the likely allocatable groundwater resource is 1.38 million m^3/year (Dommisse, 2017). The basin is significantly under-allocated.

2.3.6.2 Future Basis for Groundwater Management

Proposed Land & Water Regional Plan for Otago

The Otago Regional Plan: Water is acknowledged to be dated and less than "fit-for-purpose"[17]. The Minister for the Environment required ORC to notify a Land & Water Plan by 31 December 2023, which was recently extended to 30 June 2024. Water management in Otago is in something of a fluid position due to the expiry of deemed water permits on 1 October 2021 that were overtaken by a plan change to provide a transition to the Land & Water Regional Plan (Plan Change 7 of the Regional Plan: Water). Foreshadowing of the Otago proposed Land & Water Regional Plan by ORC in early 2024 had shown that a change from 50% to 35% of Mean Annual Recharge as the basis of a groundwater allocation limit would be favoured within new water allocation policy. Thus the allocatable groundwater would shrink from 1.38 to 0.96 million cubic metres per annum should this change be carried over into the Land & Water Regional Plan that is replacing the Regional Plan: Water.

Additional uncertainty is engendered by the change in the central government following the 14 October 2023 general election. The outgoing government passed the third reading of the Natural & Built Environment Bill, and the Act came into force on 23 August 2023. The main parties of the incoming government had indicated an intention to repeal the Natural & Built Environment Act and the associated Spatial Planning Act 2023 by the end of 2023, and to begin a fresh process of legislative reform of the Resource Management Act 1991. The Natural & Built Environment Act and the associated Spatial Planning Act 2023 were repealed on 24 December 2023 by the coalition government and the government had announced the intention to begin a fresh process of legislative reform of the Resource Management Act in 2024. However, it is reasonable to assume that existing rights to water would be maintained in the medium term and the water allocation regime would not undergo radical reform preventing the issuance of fresh authorisations to take water under transitional arrangements. It is also reasonable to assume the National Environmental Standard for Freshwater Management (2020), including the Te Mana o te Wai (TMTW) framework, would be substantially removed in the reform process.

[17] https://environment.govt.nz/acts-and-regulations/acts/resource-management-act-1991/reviews-and-investigations-of-local-authorities/reviews-and-investigations-of-local-authorities/

3 Drilling, Aquifer Testing and Capacity Assessment

3.1 Drill Site Planning and Preparations

A basic site selection study was undertaken to nominate sites for drilling investigation on the flowing basis:

- Preference for a site within the RCL Homestead Bay Ltd land holdings,
- Preference for a level site with reasonable accessibility,
- Preference for a peripheral location that would not sterilise other potential land use,
- A plus for a lower elevation site that would be less likely to result in deep drilling to secure the water table, and
- Proximity to Lake Wakatipu as a potential source of aquifer replenishment.

Ultimately, a primary drill site ("Bore A" in Figure 6) was selected behind the shore of Lake Wakatipu adjacent the Lakeside Estate. A back-up drilling location was specified to the northwest of the primary site ("Bore B" in Figure 6).

Figure 6: Location map submitted with bore consent application. Bore A site is primary (preferred) drilling site

An application was made to Otago Regional Council for consent for a bore in accordance with regional rules.

The drilling project was tendered to Washington Exploration and another contractor of equivalent capability to undertake the drilling, bore construction and aquifer testing. Washington Exploration was selected and engaged. Drilling operation began on 12 June 2024. The contractor provided a Western Star (formerly Foremost) Dual Rotation DR24 drilling rig, dual axle support truck & trailer, truck-mounted compressor, truck-mounted electrical generator, and Landcruiser support vehicle to the drilling and testing project.

3.2 Drilling and Bore Construction

3.2.1 Exploratory Drilling

Drilling of the 6-inch diameter exploratory bore (well record CC11/0151P) began on 12 June and extended until 18 June 2024. In contrast to the bore F42/0150 lying 1.3 kilometres to the northwest, water-bearing sand and gravels were not encountered in the drilling of the exploratory hole until 75 metres below ground. The initial estimated maximum depth was 60 metres, which was extended to 95 metres by approval with the client owner during exploration drilling. A screen of 2 metre length was installed between 94.15 to 92.15 metres below ground to allow water samples to be taken.

The exploratory drilling proved the presence of permeable water-bearing layers, primarily between 80 metres and 95 metres depth, although the lower aquifer limit is open-ended. The source aquifer is considered to be confined or semi-confined. The indications from air-lifting groundwater to clean up the monitoring bore were sufficiently encouraging to trigger the decision to install the adjacent 12-inch diameter test production bore. It is worth noting that exploratory drilling did not locate the base of the sandy gravel aquifer. Neither fine sediment nor schist basement was encountered below depths of 80 to 95 m. The geo-hydrological base of the groundwater system was thus not encountered with drilling halting at 95 m depth.

The exploratory bore was authorised by permitted activity rules within Otago's Regional Plan: Water, authorising drilling outside of C-Maps that do not become bores within the definition of that Plan. It was accorded the ORC bore number CC11/0151P, "P" for piezometer.

3.2.2 Test Production Bore

The rationale for test production bore drilling was to trial the installation of a full-size production bore for detailed testing of the capacity of the attached ground water resource. The co-located 6-inch diameter piezometer could also be used as an observation bore. Bore design was initially formulated to place a long screen between 95 metres and 86 metres depth and this was implemented in bore construction. Drilling began on 19 June and concluded on 27 June 2024. Pumping testing began on 4 July with a four hour step drawdown (step rate) test, followed by multi-day constant rate testing beginning on Monday 8 July 2024.

The test production bore drilling and installation revealed slight differences in the depths and materials noted during drilling. This was probably due to the differences in drilling cuttings being returned to the surface, plus inevitable differences in sedimentary composition that are normal within terrestrial glacial sedimentary sequences. Substantial challenges were encountered with 'heaving sand', essentially loose, liquified sands that were capable of intruding into the drill hole and block casing or bog the drill bit. These challenges were overcome but slowed the drilling and bore construction workflows.

The test production bore was authorised by land use consent RM24.110.01. It was accorded the ORC bore number CC11/0151. Bore completion, location and other information was provided to Otago Regional Council compliance unit as required by consent conditions and other provisions. The depth estimated in the application for land use consent RM24.110.01 was specified as 50 metres. The significant exceedance of the estimated total depth was the subject of discussion between ORC compliance unit and Kōmanawa Solutions on behalf of the applicant. The discussion resolved with explanations and final bore completion records from Kōmanawa Solutions and Washington Exploration, respectively.

In addition, two consecutive Pollution Hotline reports were made during drilling of the exploratory bore and test production bore. Responses to the washing of cuttings silt were made prior to the first complaint by halting drilling operations and hand removal of cuttings. Following the receipt of the complaint by Washington Exploration additional preventative measures, including the installation of a down-slope silt fence and the digging of mud pits to absorb surges in cuttings and air-lifted groundwater. A drone (UAV) camera survey was also undertaken to map the extent of the initial drill cuttings wash-out after manual clean-up. According to the drilling contractor, no cuttings affected discharges were made to Lake Wakatipu.

3.3 Hydrogeological Information Obtained

3.3.1 Geological information from Bore Logs

The generalised arrangement of geological domains aggregated from drill cuttings is listed in Table 7. The overall domains include –

- Overburden / unconfined water-bearing layer (0 – 4.8 m below ground)
- Silty aquitard (4.8 – 75 or 80 m below ground)
- Sandy gravel aquifer (80 m –).

Table 7: Washington Exploration recording of geological domains

Top Depth (m)	***Bottom Depth (m)***	***Soil Type*** *(Major, Secondary, Minor)*	***Colour***	***Grain Size***	***Water Content, Type***
0	*1.9*	*Gravel*	*Brown, Yellow*	*Medium*	*Dry, overburden*
1.9	*3.2*	*Sand*	*Grey*	*Fine*	*Dry, Unconfined aquifer?*
3.2	*4.8*	*Silt Sand Gravel*	*Brown*	*Fine*	*Damp, Unconfined aquifer?*
4.8	*27.8*	*Silt Sand*	*Grey, Brown*		*Damp, aquitard*
27.8	*46*	*Silt*	*Grey, Blue*		*Dry, aquitard*
46	*51*	*Silt*	*Grey, Brown*		*Damp, aquitard*
51	*67.7*	*Silt*	*Grey, Brown, Blue*		*Dry, aquitard*
67.7	*75*	*Silt Mudstone*	*Blue*		*Dry, aquitard*
75	*78*	*Clay Silt Gravel*	*Yellow*	*Medium*	*Water bearing, aquifer*
78	*80*	*Clay Silt*	*Blue*	*Dry*	*Internal aquitard?*
80	*84*	*Silt Clay Gravel*	*Yellow*	*Fine to coarse*	*Water bearing, aquifer*
84	*86.5*	*Gravel Sand*	*Brown*	*Coarse*	*Water bearing, aquifer*
86.5	*94.3*	*Sand Gravel*	*Brown*	*Fine to coarse*	*Water bearing, aquifer*

3.3.2 Saturation or Groundwater Levels

No distinct water strike was made within the overburden to 5 metres below ground. However, it seems reasonable to suggest that a thin unconfined water-bearing layer carries shallow groundwater over the top of the silty aquitard at 4.8 metres. Groundwater levels became measurable once the bore hole penetrated the aquifer beneath 80 metres depth and the compressed air flush was shut off. The bore casing began over-topping with artesian flow with the top of casing at 0.5 metres above the drill pad.

Approximate measurements of the static water level were made following full bore construction and the conclusion of development. The static water level (SWL) was taken on 11 July 2024 as 0.17 above the top of casing. As the top of casing was set at exactly 0.5 metres above the drill pad, the total above ground static head was estimated at 0.67 metres above drill pad level but could have been up to 2.5 m above the original land surface (the drill pad was built up over the original soil). The piezometer and test production bore were almost identical in this respect. The static water level is approximately 12 metres above the water level of Lake Wakatipu.

3.4 Step Rate Testing

3.4.1 Step Test Data and Initial Interpretations

A four-hour, four-step pumping test was undertaken on the test production bore. The change in water levels was monitored in the production bore (CC11/0151) and observation bore (CC11/0151P) manually with water level dippers, and electronically using level loggers. Table 8 lists the four steps and recovery in terms of the step duration, average rate of pumping, water levels at the end of each step and final drawdown. The summary in Table 8 also includes a calculation of specific capacity (SPC) based on the final drawdown and mean rate of each step showing the marginal decline in the ratio with increasing pumping rate. This decline is normal and due to the reduction in well screen efficiency at higher pumping rates.

Table 8: Summary of Step Rate Test data according to Step

					Final Drawdown		
Step No.	**Interval (min)**	**Duration (min)**	**Mean Rate (L/s)**	**Final DTW (m)**	**PB-1 (m)**	**Obs-1 (m)**	**SPC (L/s/m)**
Step-1	1 - 60	60	9.95	3.8	5.48	2.33	1.8
Step-2	61 - 120	60	19.43	9.7	11.4	3.76	1.7
Step-3	121 - 180	60	29.50	16.6	18.3	5.01	1.6
Step-4	181 - 240	60	39.48	39.0	40.7	6.68	1.0
Recovery	241 - 330	90	0	-0.2			

Note: DTW is Depth To Water in terms of the ground level reference level. Final Drawdown includes decline from estimated static water level above top of casing. SPC is the Specific Capacity as the ratio of pump rate divided by final drawdown in litres per second per metre of drawdown. PB-1 refers to the pumped bore CC11/0151, while Obs-1 refers to the observation bore CC11/0151P.

The graphical re-statement of Table 8 is displayed in Figure 7, in terms of measured drawdown in the test production bore and observation bore. Reference to Figure 7 allows the observation of disproportionate increase in pumping drawdown in the transition from the average 29.5 L/s to 39.5 L/s in Step 4. The apparent acceleration in drawdown is not visible in aquifer drawdown as observed from Step 3 to Step 4 at the observation bore. As a result, it is reasonable to conclude that well screen head losses increase more sharply between the pumping rates of 29.5 and 39.5 litres per second, implying a corresponding drop off in well screen efficiency. The difference is manifested in the calculated specific capacities between these steps in Table 8.

As any production bore submersible pump setting would be beneath the depth of 80 metres, the maximum depth to water of 39 metres is far from foreseeable pump depth settings. Accordingly rates of pumping higher than 39.5 L/s are feasible, especially for short periods. However, the implications of the abovementioned decline in well efficiency and specific capacity could be extrapolated to suggest that the maximum short-term pumping rate would be approximately 44 litres per second.

Figure 7: Measured drawdown in test production bore and observation bore during step rate test

The variability of pumping rate and drawdown during each step in the step rate test is considerable. The drawdown response variability is evident in Figure 7, including the jagged drawdown plot line for water levels measured inside the test production bore. The intra-step standard deviation in the measured pumping rate was calculated to lie between 0.8 and 1.2 L/s, which makes clear that the drawdown variation follows variation in pumping rate. It is unknown whether the pumping rate variation is a function of pump fluctuation or transient jumps in well loss. Both possibilities are alive as follows –

- During the constant rate test the pump unit failed, which may have been foreshadowed by progressive deterioration of pump impellers or motor, resulting in uneven pump operation, or
- During the constant rate test, particularly during the latter part of the test the operating water levels fluctuated widely without corresponding measured shifts in pumping rate.

3.4.2 Step Rate Test Interpretation – Pumped Bore

Interpretation of step rate tests primarily uses water levels measured inside the production bore as these measurements reflect a combination of aquifer drawdown and well screen hydraulics. In this manner, interpretation of the factors pertinent to the bore's yield can be separated and quantified. Table 9 and Figure 8 report the essential results of interpreting the step rate test.

Table 9: Summary of Step Rate Test derived Hydraulic Properties

Test Derived Parameter	Derived Value	Remarks
Transmissivity (m^2/d)	156	Determines aquifer related drawdown
A Coefficient	0.00258	Contains linear head losses
B Coefficient	0.001174	Contains non-linear head loss
C Coefficient	2.36×10^{-6}	Contains turbulent head losses

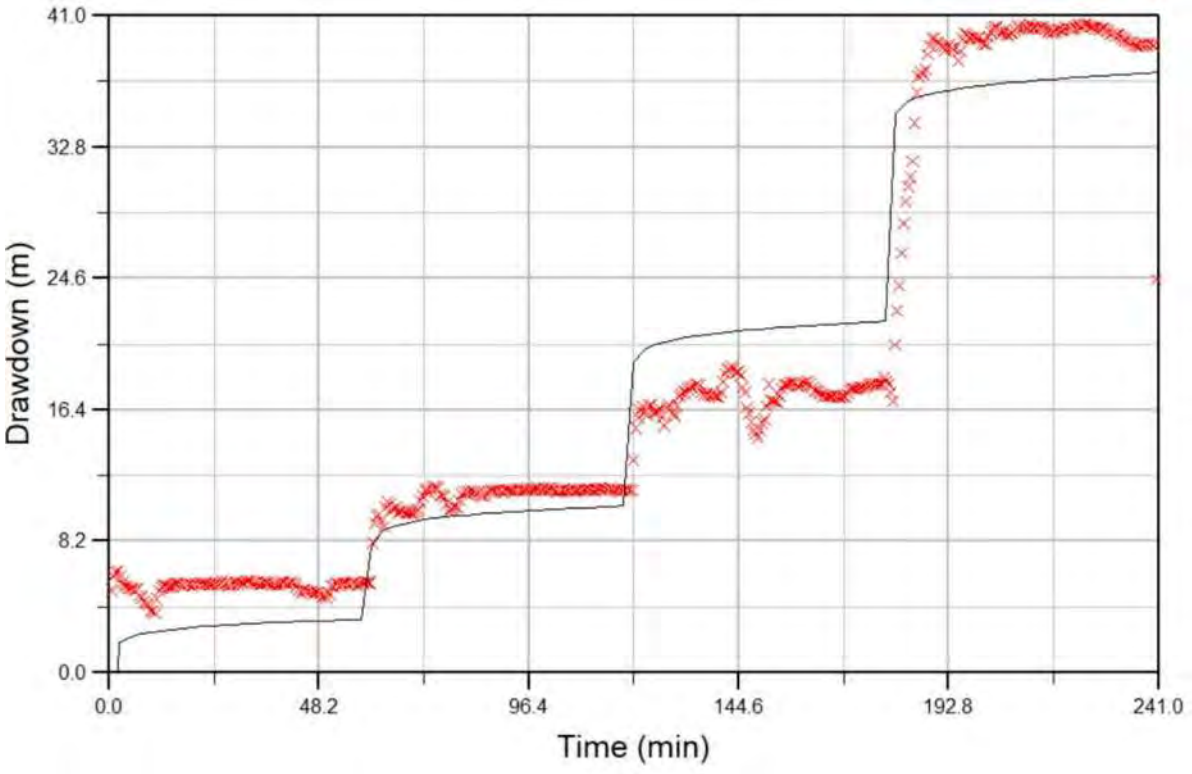


Figure 8: Aquifer^{Win32} Eden – Hazel step rate test fit in black against measured test drawdown

Figure 8 reveals a poor match between measured SRT data points and the matched Eden – Hazel solution (Eden & Hazel, 1973). The poor match would have a corresponding impact on the accuracy of the hydraulic properties reported in Table 9, particularly the well screen performance coefficients.

3.4.3 Step Rate Test Interpretation – Observation Bore

Observation bore CC11/0151P (also labelled as Obs-1) was located 10 m to the southeast of the pumped bore CC11/0151. Water level in the observation bore responded immediately to pumping in the test production bore and the water level response was distinct for the four pumping rate steps.

A non-standard drawdown curve match needed to be applied in the interpretation of the observation bore data. Leaky aquifer conditions would not allow the matching to the confined Theis solution (Theis, 1935). Therefore, the leaky solution and well function developed by Hantush (Hantush, 1960) was utilised for matching to the measured drawdown data points. Figure 9 displays the linear axes plot of the drawdown data points in black against the Hantush solution for the observation bore situation during the four hour step rate test and recovery.

The errors in the curve match of Figure 9 are relatively large; mean error of 0.18 metres, variance of 0.21 metres and standard error of 0.45 metres overall. However, the match was the best of each plausible solution attempted within the analysis software AQTESOLV. Curve matching to the recovery (residual drawdown) to the Hantush & Jacob solution (Hantush & Jacob, 1955) achieved better match results; mean error of 0.0018 metres, variance of 0.023 metres and standard error of 0.15 metres overall. Recovery only data matching to the adjusted curve is shown in Figure 10, while the results are listed in Table 11.

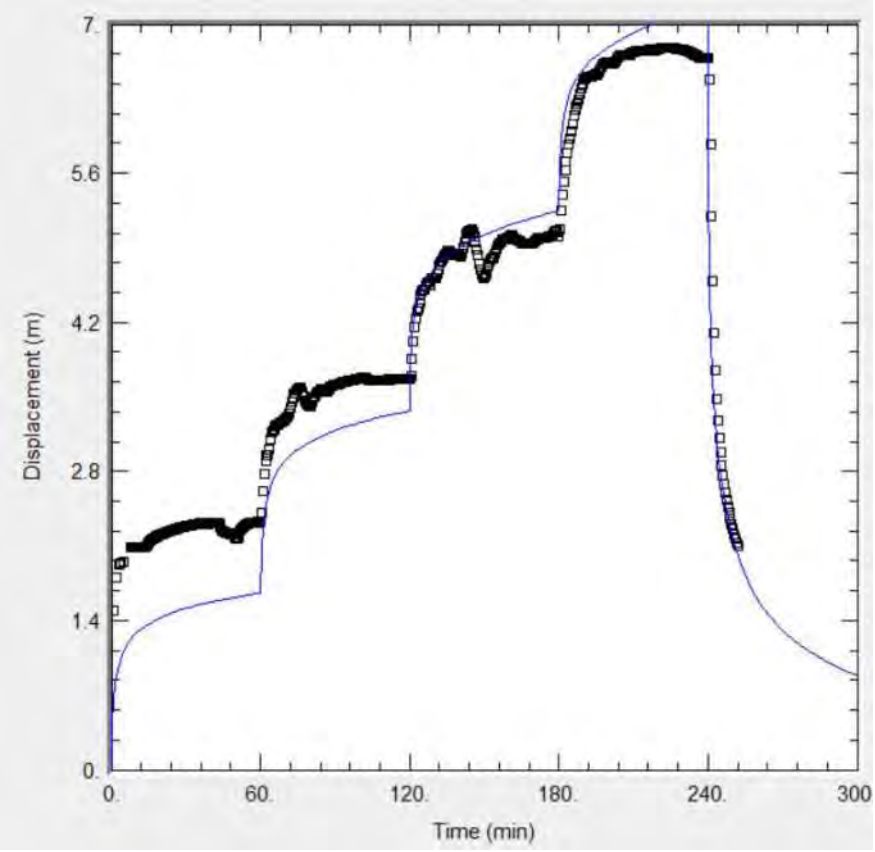


Figure 9: AQTESOLV curve match of observation bore data points against Hantush (1960) solution

Table 10: Results of Observation Bore curve match in AQTESOLV during step rate test

Test Derived Parameter	Derived Value	Remarks
Transmissivity (m^2/d)	222	
Storativity	2.98×10^{-4}	Specific storativity
β	0.025	Leaky aquifer Hantush (1960) coefficient: $\beta = \frac{r}{4}\sqrt{\frac{K'/b'}{Kb}} \times \frac{S'}{S}$

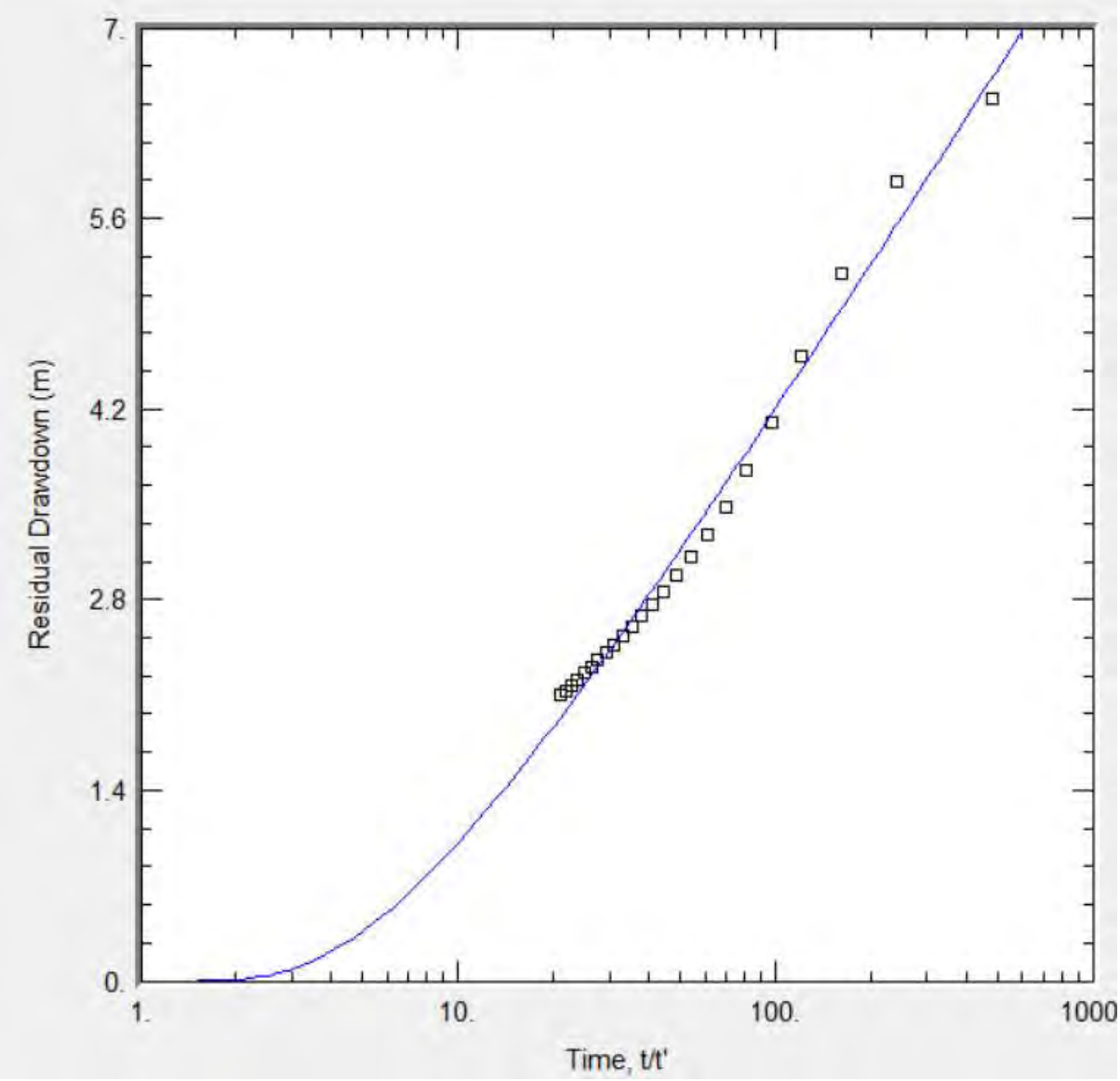


Figure 10: AQTESOLV curve match of observation bore recovery data points against the Hantush-Jacob (1960) solution

Table 11: AQTESOLV curve match of observation bore data points against Hantush-Jacob (1960) solution

Test Derived Parameter	Derived Value	Remarks
Transmissivity (m^2/d)	173	
Storativity	1.25×10^{-9}	Specific storativity
r/B	1.26×10^{-4}	Leaky aquifer coefficient where r is the observation bore radius and B is defined by the Hantush-Jacob (1960) equation: $B = \sqrt{\frac{Tb'}{K'}}$

3.5 Constant Rate Testing

Washington Exploration undertook a constant rate test starting on 9:30 am Monday 8 July and was intended to run for 72 hours (3 days). Ultimately, the submersible pump unit failed at the 52.2 hour point, halting the test pumping prematurely. The constant rate test was also plagued by internal shifts within the natural pack surrounding the well screen causing volatile changes in the test pumping rate and pumped bore water level. These high frequency variations in turn induced water level variation within the observation bore.

The pumping rate was measured to range between 25 L/s and 41.8 L/s while pumped bore water level tended to dip or spike in response to the pumping rate variation. In the latter half of the recorded test a base shift in pumped bore water level occurred whereby operating level declined from approximately 38 metres to 71 metres in the evening of Tuesday 9 July. Once again, this is considered to have been due to transient shifts in the natural pack surrounding the well screen causing reduction in the performance / efficiency of the screen. On the morning of Wednesday 10 July, it was decided to reduce the pumping rate to 30 L/s giving rise to a small recovery in water level, which was interrupted by the sudden failure of the pump unit

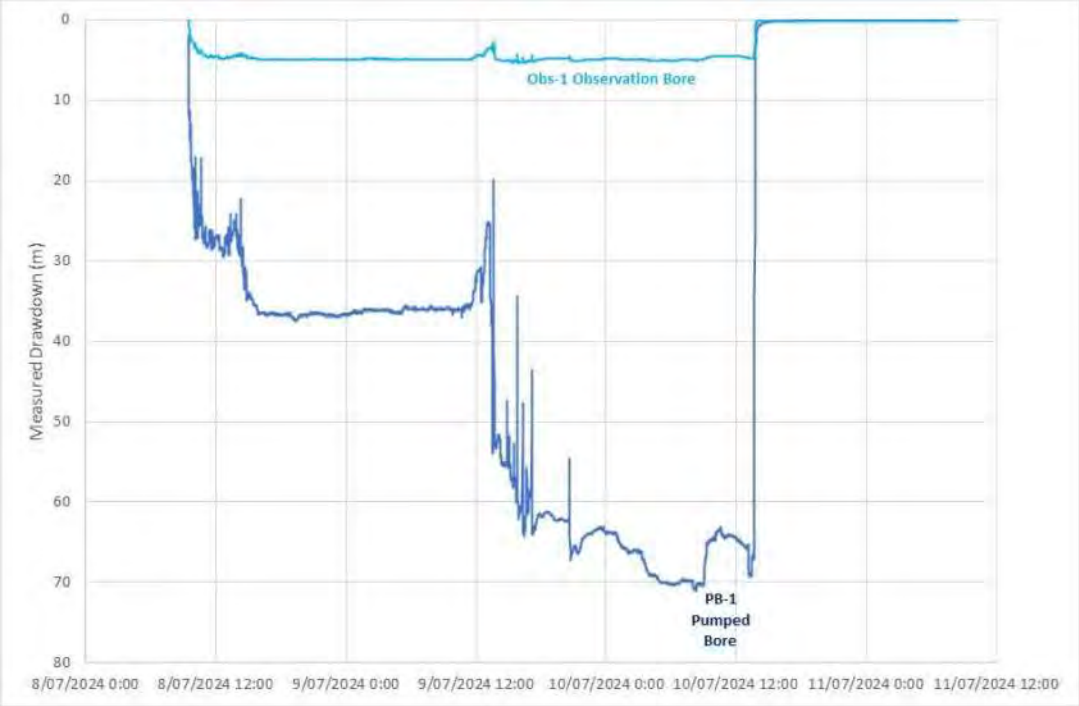


Figure 11: Measured drawdown in the pumped bore (CC11/0151) and observation bore (CC11/0151P) during the 52.2 hour constant rate test

3.6 Influences on Testing and any Correction

3.6.1 Influences external to the Pumping Test Site

Pumping tests may be influenced by one or a combination of environmental factors. These factors generally affect the measured groundwater pressures or groundwater levels measured in pumping or observation bores. The principal environmental factors may be summarised as follow:

- Barometric pressure change, particularly where the aquifer has less than perfect barometric efficiency,
- Tides or significant water body water level changes, which in this case would relate to Lake Wakatipu water levels,
- Rainfall and resulting recharge joining the water table, and/or
- Antecedent water pressure / level trends.

These potential influences are usually examined through correlations between the impulse of the factor and the apparent effect on groundwater pressure levels. The problem for this aquifer test interpretation arises from the occurrence of flowing artesian conditions at both bore heads. Despite electronic level data being available for both bores, the groundwater pressures are unconstrained by bore casing, and instead both bores overflowed whenever the pump was not pumping in the test production bore. The overflow created a flatlined groundwater pressure time series.

Instead, examination of the key factors in the lead-up to and during the pumping tests may inform consideration of influences. The measured lake water level (Willow Place, Kelvin Heights) and rainfall (Queenstown Airport in the vicinity of Homestead Bay is plotted and referenced to the pumping tests in Figure 12.

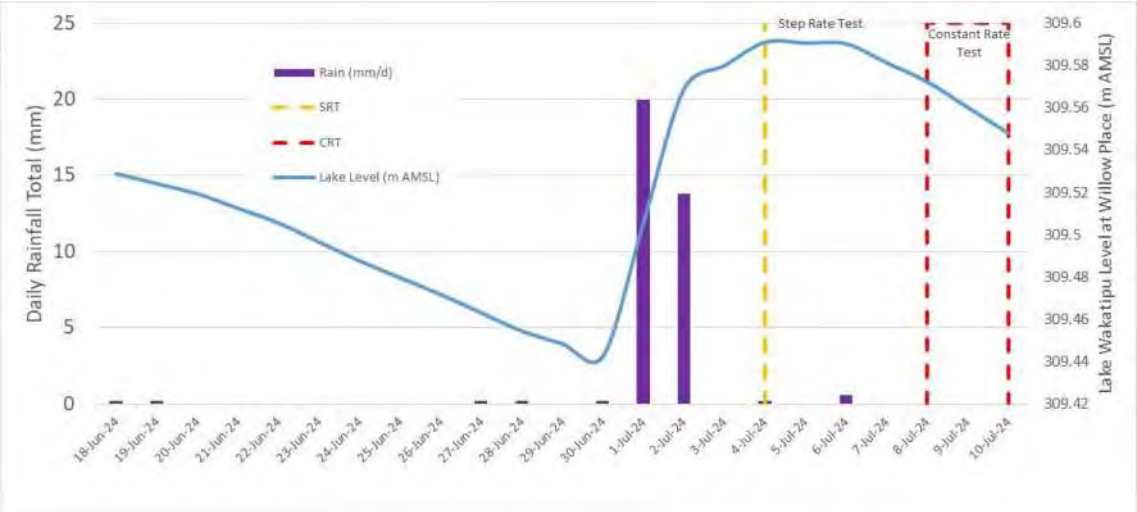


Figure 12: 3-week period in lead-up and during aquifer tests with corresponding rainfall and lake level fluctuations

While heavy rain totalling 34 millimetres occurred on 1 and 2 July, the period following was characterised by light or nil rainfall. Lake water level rose following the heavy rainfall on 1 and 2 July. The lake level rise tapered off and converted into a steady decline following 6 July, between the step drawdown and constant rate tests. During the two-day constant rate test, the lake level decline was approximately 20 millimetres.

The barometric pressure time series in Figure 13 displays a rise towards the Step Rate Test (SRT), stagnation during the SRT, and a sag up to the start of the constant rate test (CRT). During the CRT, the barometric pressure rose 10 millimetres over 52.2 hours. It is important to note that rises in barometric pressure translates into

declines in water level. Therefore, the SRT would potentially be unaffected by barometric change, while the CRT could have been affected by a no more than 10 millimetre rise in groundwater pressure.

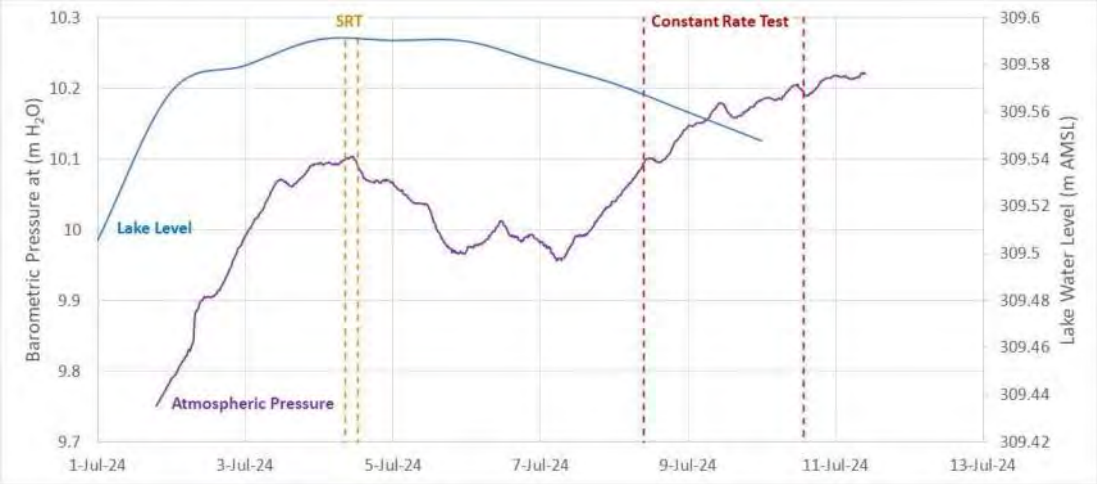


Figure 13: Two-week period showing barometric pressure trend and lake level bracketing the pumping tests

What influence might the three factors of rainfall, lake level and barometric pressure variation have on groundwater levels measured in the pumping and observation bore during either pumping test? In terms of the step rate test where observed drawdown in the pumping bore was comparatively high and the duration over which transient influences would be exerted were low, the effect of the above factors are probable to be minimal if not negligible. Therefore, the influence of such factors were neglected.

During the constant rate test, most attention in test interpretation was focused on the observation bore (CC11/0151P) and potentially over a long duration (multiday). Therefore, the influence of external factors could be anticipated to be larger. The constant rate test was also significantly affected by fluctuations in the entry resistance of the pumped bore well screen, as suggested in Figure 14.

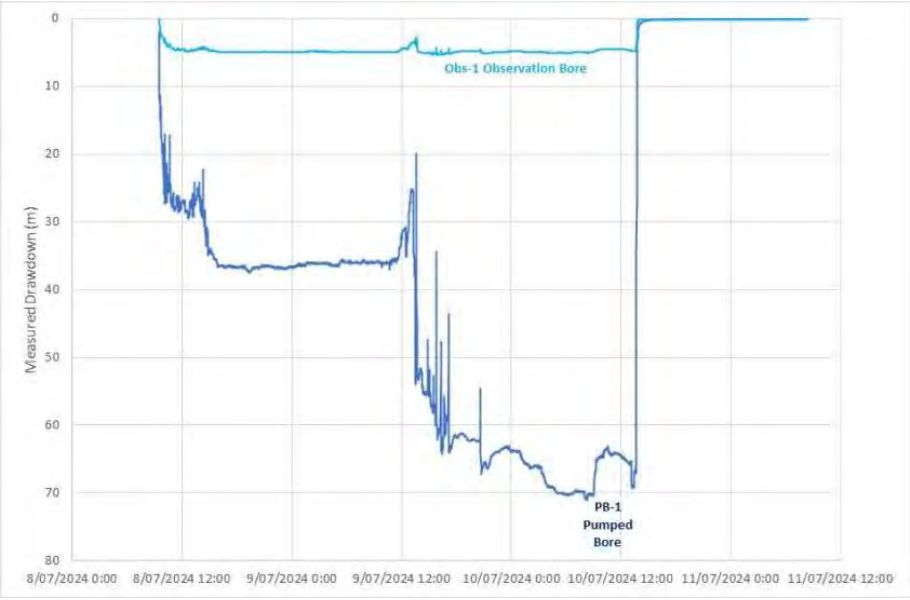


Figure 14: Hydrographs of pumped bore and observation bore recorded during the 52 hour constant rate test

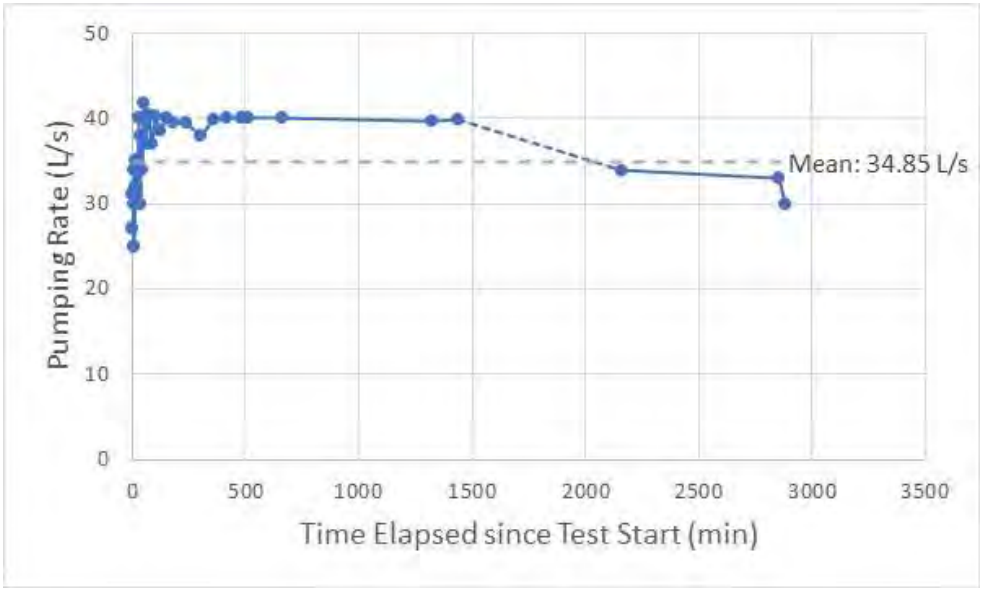


Figure 15: Recorded pattern of pumping rate variation during the constant rate test

It was thought that during the first day of pumping that test pumping rate was a control over pumped bore drawdown. This is confirmed by a moderate (R^2 – 0.78) correlation between the two in Figure 16, below.

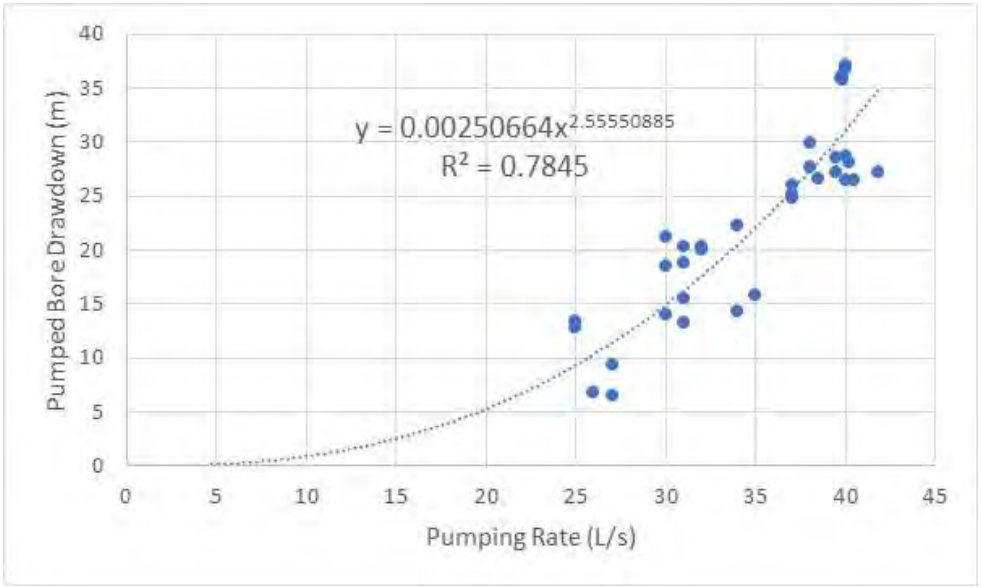


Figure 16: Relationship between pumping rate and pumped bore drawdown, including a fitted power trendline

In summary, if lake level decline of 20 millimetres affected the constant rate test, then this external influence might be expected to be counteracted by a rise in groundwater levels of up to 10 millimetres due to barometric variation. Rainfall in the days leading up to the pumping tests. Ultimately, there is significant doubt whether rainfall, lake level or barometric pressure variations at all impinge upon groundwater levels due to the flowing artesian flatlining of bore water levels at the test site. Test pumping rate variation is believed to be the dominate influence on measured drawdown in the pumped bore and observation bore during the constant rate test. Influences internal to the pumped bore are examined in the next section.

3.6.2 *Influences internal to the Pumping Bore*

During the constant rate test, pumping rates and well screen entry resistance both fluctuated resulting in varying degrees of fluctuation in the pumped bore water levels. Only the pumping rate variations would be liable to affect the observation bore water levels, since the well screen entry resistance factor would be restricted to the pumped bore. Indeed, Figure 14 illustrates the difference in level responses, especially after the first day of pumping. The observation bore water level hydrograph as measured drawdown shown in Figure 14 reveals the drawdown outside the pumped bore to be relatively invariant, although distinct periods of time when the pumping rate fluctuated induced moderate variation in recorded drawdown at the observation bore.

One means of correcting for the inconstancy in pumping rate would be to target parts of the conventional pumping test analytical technique that are least prone to interference. Therefore, the two periods of test analysis were selected for interpretation as follow:

- The **initial pumping phase from 0 to 200 minutes**, and
- The **recovery phase** after the shutdown in pumping at 3,132 minutes.

The initial phase of drawdown in the immediate period after the pump has been turned on, up to two hours, traverses a wide range of drawdown, and therefore the effect of pumping rate variations can be accounted for numerically. The recovery phase after pumping has halted has the unique feature of having zero pumping. The average of recorded pumping rates in the preceding two days would be used in the numerical solution to derive hydraulic properties. Furthermore, the observation bore residual drawdown data may be used in the curve fitting analysis. By using this approach, the confounding influence of well screen entry resistance both fluctuations and variation in test pumping rate are minimised.

3.7 Constant rate Testing Interpretations

3.7.1 *Observation Bore Early-Time Drawdown Matching*

The first 200 minutes of the constant rate test was characterised by steady rise in pumping rate and observation bore drawdown, as shown below in Figure 17 with measured data and logarithmic trendline.

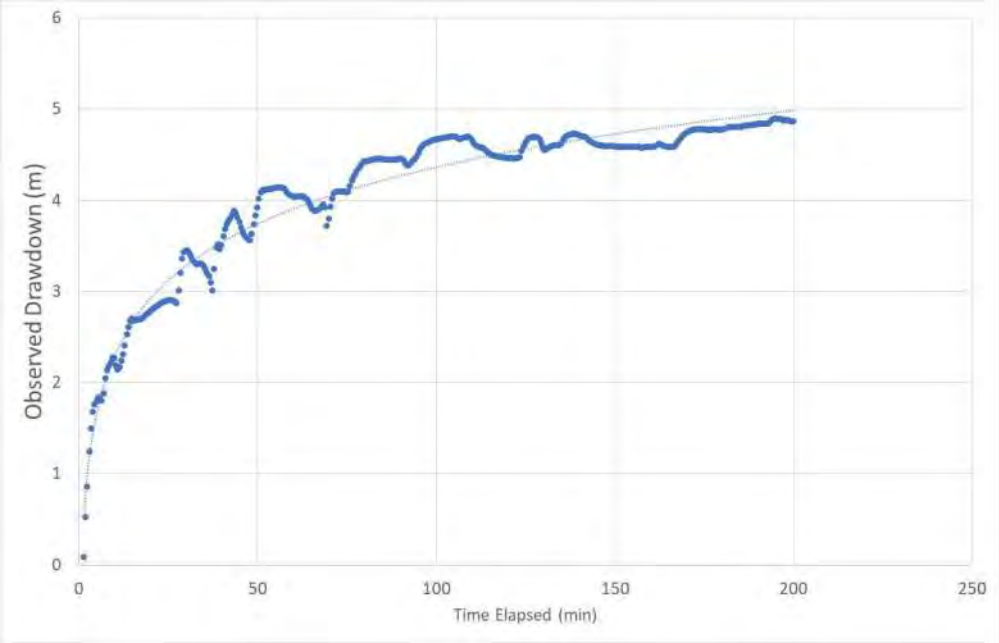


Figure 17: Drawdown trend measured in observation bore during the initial 200 minute period of the CRT

This data was subsequently used in a AQTESOLV analysis of the initial phase of the constant ate test (CRT). Figure 18 shows the optimised Hantush solution (Hantush, 1960), initial drawdown data and the mean measure pumping rate of 33.6 litres per second.

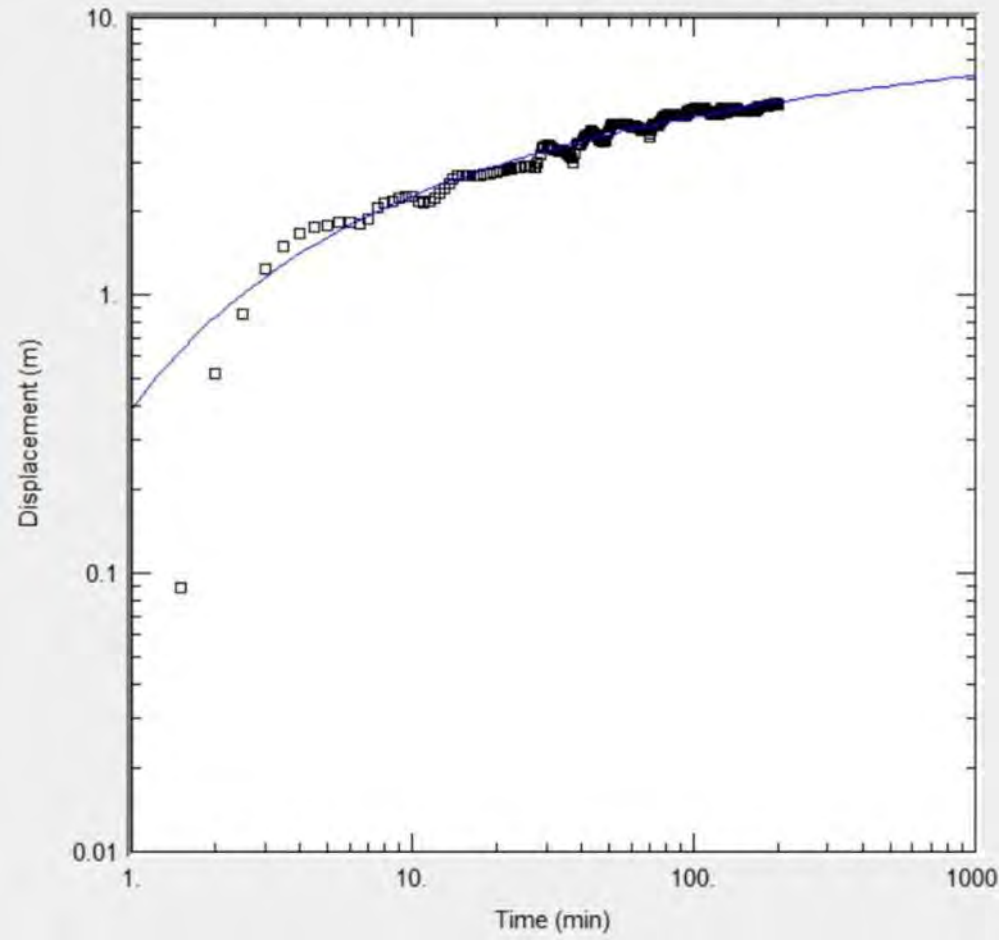


Figure 18: AQTESOLV solution to initial 200 minute drawdown data from observation bore and mean pumping rate

The hydraulic properties derived in the analysis are listed in Table 12, including results for transmissivity, storativity, and leakage coefficient, β.

Table 12: AQTESOLV match of initial 200 minute observation bore data against Hantush-Jacob (1960) solution

Test Derived Parameter	Derived Value	Remarks
Transmissivity (m^2/d)	183	
Storativity	3.80×10^{-3}	Specific storativity
β	0.051	Leaky aquifer Hantush (1960) coefficient: $\beta = \frac{r}{4}\sqrt{\frac{K'/b'}{KD} \times \frac{S'}{S}}$

3.7.2 Observation Bore Recovery Interpretation

Recovery interpretation using the Theis (Theis, 1935) and Hantush (Hantush, 1964) was employed within the AquiferWin32 optimisation software. Figure 19 displays the fitting of the recovery modified Theis – Hantush well function to measured residual drawdown in the observation bore (CC11/0151P). The mean pumping rate active through the 52 hour pumping test was 36.44 litres per second, which was used in the numerical calculation of transmissivity. Early-time data points were used in the analysis, as shown in Figure 19.

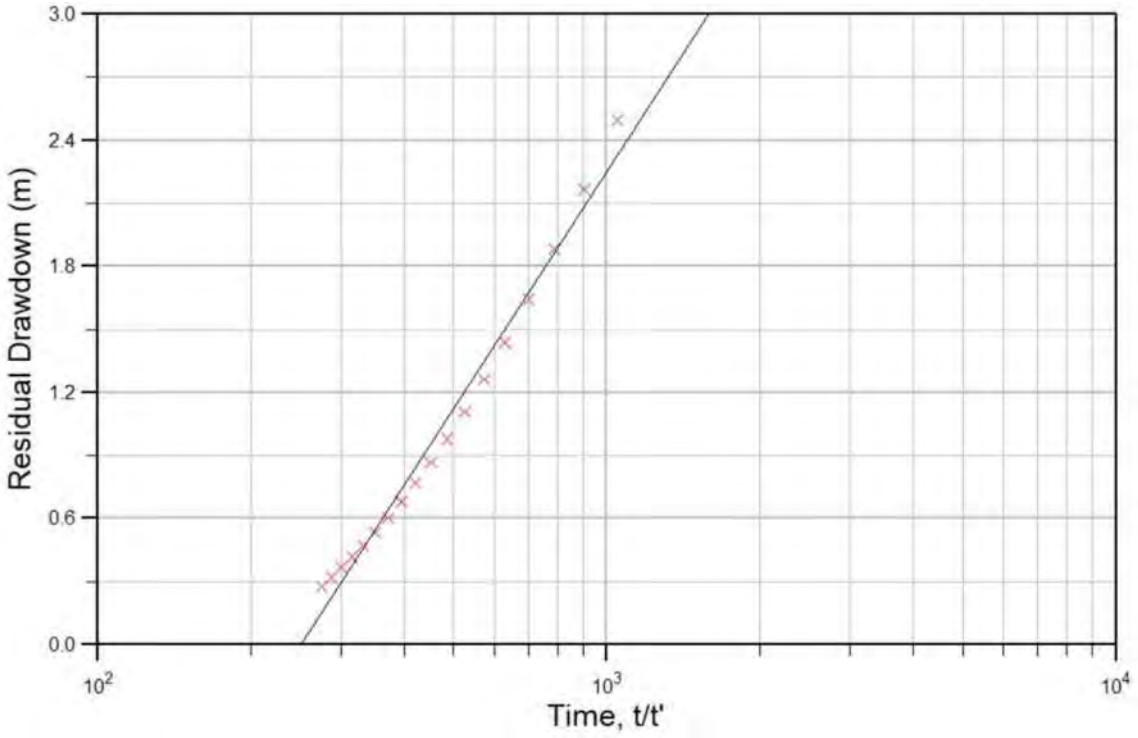


Figure 19: Residual drawdown analysis by Theis – Hantush curve matching of early-time recovery data (red)

Table 13: Recovery analysis derived Transmissivity from observation bore residual drawdown

Test Derived Parameter	Derived Value	Remarks
Transmissivity (m^2/d)	141	

3.8 Chapter Summary

Pumping test design, execution, data capture and analysis of test data is a specialised and methodologically complex area of hydrology. Several analyses to particular methodologies e.g., (Eden & Hazel, 1973), (Hantush, 1960), (Hantush & Jacob, 1955), and (Theis, 1935) are outlined above plus the specific circumstances or challenges of the Homestead Bay pumping tests in July 2024 are outlined. In order to summarise and distil the foregoing sections on pumping test analysis the assumed aquifer setting should be restated –

- Semi-confined aquifer confined by leaky silty sand to 80 m depth (perhaps 50 m aquitard thickness),
- At least 15 metres saturated thickness of silty sandy gravel,
- Base of the 'aquifer' was not encountered down to 95 metres depth, and
- Above-ground artesian groundwater pressure at rest.

Accordingly, leaky aquifer solutions were attempted, and these tended to be the most appropriate solutions in terms of the lowest curve matching residuals (errors). Table 14 lists the range of test analysis results and nominated accepted values.

Table 14: Composite of Pumping Test Analyses, Results and Accepted Values

Type of Analysis & Context	Transmissivity, T	Storativity, S	Leakage, β, r/B and derived values	Remarks
(Eden & Hazel, 1973) pumped bore data in Step Rate Test	156	_	_	Bore performance, also defined by a, b, & c coefficients
(Hantush, 1960) observed drawdown in Step Rate Test	222	2.98×10^{-4}	$\beta = 0.025$	Fitted to drawdown and recovery in AQTESOLV
(Hantush, 1960) observed recovery in Step Rate Test	173	*1.25×10^{-9}*	*$r/B = 1.26 \times 10^{-4}$*	Fitted to recovery data only. S and r/B probably unrepresentative.
(Hantush & Jacob, 1955) observed drawdown in Constant Rate Test (<200 min)	183	3.80×10^{-3}	$\beta = 0.051$	Hydraulic conductivity estimated as K = 12 m/d, with b = 15 m
(Theis, 1935) observed recovery in Constant Rate Test	141	S'/S = 250	_	Early-time data
Accepted Values (Accepted values determinations expect variability in values and are usually based on expert judgement and conservatism)	200	1×10^{-3}	**K'** = 0.016 m/d (1.8×10^{-7} m/s) *b' = 50 m* **K'/b'** = 3.2×10^{-4} **c** = 3,125 days *r = 10 m* **B** = 790 m **r/B** = 0.013 **β** = 0.05	The leakage coefficients were estimated in standard units using assumed aquitard thickness (b' = 50 m) and radius (r = 10 m).

Note: b = aquifer saturated thickness, K = aquifer hydraulic conductivity, b' = aquitard saturated thickness, S = aquifer storativity, S' = aquitard storativity, K' = aquitard hydraulic conductivity, c = vertical flow resistance, B = leakance coefficient, r/B = radius / leakance ratio, β = leakage coefficient.

The accepted values would be taken forward into groundwater effects assessments in subsequent chapters. The pumping test analyses largely confirmed the assumed moderate permeability aquifer capped by a semi-permeable aquitard. The capacity of the test production bore of 41 litres per second is possible in a bore drawing on a moderate permeability aquifer due to the large allowance within the bore water column to absorb pumping drawdown.

4 Development Proposal and Water Supply Demand Estimate

4.1 Background

RCL Group with the assistance of Stantec have prepared forecasts of potential for expanding residential development of the Homestead Bay area, including the RCL Homestead Bay land parcel (Lot 8 DP443832).

According to calculations the 2,531 Dwelling Unit Equivalents (DUEs) was mostly assigned a daily consumption rate of 1,000 L/dwelling/day, although a weighted unit rate of 1,033.3 was applied to account for a higher unit rate of 2,100 L/dwelling/day for 79 high density areas[18] in Lot 8 DP443832 (see Table 15).

Table 15: Summary of Water Demand Calculations for Land Development Proposal in Homestead Bay

Landholding Letter	Label	No. of Dwellings	Unit (L/dwelling/d)	Average Daily Flow (L/s)	Peak Daily Flow (L/s)	Peak Hourly Flow (L/s)
K & I	RCL Homestead Bay (Lot 8)	2,531	1,000	30.39	60.79	149.54

Note: Peak Daily Factor = 2; Peak Hourly Factor = 4.92

The water supply demand calculations included consideration of the minimum storage volume of reservoir(s) for allowing for peak flows. The minimum reservoir sizing was given as 2,860 cubic, this includes consideration of the requirements for sprinkler and hydrant (firefighting) demands.

Of significance for water supply development to meet the water demands of the Homestead Bay Development is that the average daily water requirement is 30.39 L/s. Also of significance is that higher supply pumping rates may need to meet peaks in demand, i.e., up to a maximum of 60.97 L/s Peak Daily Demand. These may be relatively predictable demand peaks such as the rise in demand in late spring – summer due to a combination of the increasing in vacationing (Homestead Bay is a destination) and grounds watering requirements. Daily diurnal flow variations would be served from the storage reservoir. Non-predictable peaks in demand include firefighting or marked population shifts due to external factors.

4.2 Consenting Envelope

The abstraction of raw groundwater to supply the above development's water supply would require authorisation under the Resource Management Act 1991. In making the groundwater take application, the applicant needs to make a proposal for the consenting envelope in terms of maximum instantaneous, daily, monthly and annual rates of groundwater pumping ("taking"). Table 16 set out such an envelope of water abstraction rates and volumes.

Table 16: Consenting Proposal in terms of maximum instantaneous, daily, monthly and annual rates

Duration with Units	Rate	Equivalence
Instantaneous (L/s)	45	Peak 45 L/s limitation
Daily (m^3/d)	3,800	Equivalent to a rate of 44 L/s
Monthly (m^3/mth)	103,680	Equivalent to a rate of 40 L/s
Annual (m^3/yr)	1,261,440	Equivalent to a rate of 40 L/s

[18] High and Medium Density Super-lots

5 Ground Water Quality

5.1 Water Quality Analyses

Two samples of groundwater were taken in June and July 2024. The first was an initial analysis from CC11/0151P immediately upon bore construction for major drinking water quality. The second sample was taken about three weeks later and was for a more comprehensive list of analytes. The results are shown in Table 17, below.

Table 17: Results of Analysis of Groundwater from CC11/0151P and CC11/0151 with Guideline Values

Analyte	Units Dates:	Exploratory Bore CC11/0151P 19 June 24	Test Production Bore CC11/0151 10 July 2024	Detection Limits	DWSNZ (health)	DWSNZ (aesthetic)	ANZG 99th %ile DGV (2023)
E. coli	CFU/100ml	<1	_	_	<1	_	_
Sum of Anions	meq/L		1.42	<0.07	_	_	_
Sum of Cations	meq/L		1.47	<0.07	_	_	_
Turbidity	NTU	3.25	0.84	<0.05	_	≤ 5	_
pH	pH Units	7.58	8.0	<0.1	_	7 - 8.5	_
Total Alkalinity	g/m^3 as $CaCO_3$		66	<1.0	_	_	_
Bicarbonate	g/m^3 at 25°C		79	<1.0	_	_	_
Total Hardness	g/m^3 as $CaCO_3$	62	65	<1.0	_	≤ 200	_
Electrical Conductivity	(EC) mS/m		13.5	<0.0	_	_	_
Dissolved Aluminium	g/m3		0.003	<0.003	1	≤ 0.1	0.027
Dissolved Boron	g/m^3		0.009	<0.005	2.4	_	0.34
Dissolved Calcium	g/m^3		21		_	_	_
Dissolved Iron	g/m^3	0.51	<0.02	<0.02	_	_	_
Ammoniacal Nitrogen	g/m^3	0.01	0.42	< 0.010	_	_	_
Dissolved Magnesium	g/m^3		3.0	<0.02	_	_	_
Dissolved Manganese	g/m3	0.01	<0.0005	<0.0005	0.4	≤ 0.04	1.2
Dissolved Potassium	g/m^3		0.49	<0.05	_	_	_
Dissolved Sodium	g/m^3		3.8	<0.02	_	≤200	_
Bromide	g/m^3		<0.05	<0.05	_	_	_
Total Cyanide	g/m^3		<0.002	<0.002	0.6	_	
Chloride	g/m^3	1	0.9	<0.5	_	≤250	_
Fluoride	g/m^3		0.11	<0.05	1.5	_	_
Nitrite-N	g/m^3		<0.002	<0.002	0.92	_	_
Nitrate-N	g/m^3	0.35	0.38	<0.001	11.3	_	_
Nitrate-N + Nitrite-N	g/m^3		0.38	<0.002	11.3	_	_
Reactive Silica	g/m^3 as SiO_2		13.2	<0.1	_		_
Sulphate	g/m^3		2.3	<0.5	_	≤ 250	_
Dissolved Organic Carbon (DOC)	(DOC) g/m^3		<0.5	<0.5	_	_	_
Total Organic Carbon (TOC)	(TOC) g/m^3		<0.5	<0.5	_	_	_
Absorbance at 254 nanometre	AU cm^{-1}		0.002	<0.002	_	_	_
Transmittance at 254 nm	%T, 1 cm cell		99.5	<0.5	_	_	_
Dissolved Arsenic	g/m3	**0.012**	0.0098	< 0.0010	0.01	_	0.0008
Dissolved Cadmium	g/m3		< 0.00005	< 0.00005	0.004	_	0.00006
Dissolved Chromium	g/m3		< 0.0005	< 0.0005	0.05	_	0.00001
Dissolved Copper	g/m3		< 0.0005	< 0.0005	2	≤ 1	0.001
Dissolved Lead	g/m3		<0.00010	<0.00010	0.01		0.001
Dissolved Nickel	g/m3		< 0.0005	< 0.0005	0.08	_	0.008
Dissolved Zinc	g/m3		0.0012		_	≤ 1.5	0.024

Note: Exceedance of a drinking water standard is highlighted in **bold** and red script.

The second water sample was consistent with drinking water norms of health concern, although E. coli was not sampled on 10 July, and the dissolved arsenic concentration sat immediately beneath the drinking water standard on that date. Drinking water and aesthetic norms were also adhered to in the laboratory results.

5.2 Implications for Water Quality Management

5.2.1 Characteristics of Water Quality

The groundwater at bore CC11/0151 presented as a dilute water with equivalent Total Dissolved Solids (TDS) of 125 mg/L, moderate hardness, slight alkalinity, low land use effects, and low metal/metalloid content. One sample determined that the indicator bacterial count was less than 1 CFU/100ml, thus potable. Only arsenic concentrations consistently between the two samples grazed the drinking water standard. There are few if any indications that upgradient land is affected by intensive land use, industry or habitation.

5.2.2 Hydraulic Gradient

The measured static groundwater level is estimated to be 12 m above the water level in Lake Wakatipu, therefore, it is unlikely that Lake Wakatipu chemical composition is a strong factor in groundwater composition, although long-term water supply pumping may potentially displace *in situ* groundwater.

5.2.3 Groundwater Security & Secure Well Head

The noted presence of thick overlying silty sand and clay layers above the source aquifer and upward groundwater flow gradients are both factors in groundwater security. A secure well head was achieved by the installation of 400 mm diameter pre-collar around the main bore casing and the infilling of the annular space between the pre-collar and bore casing with a bentonite seal, sealing off superficial groundwater.

5.2.4 Contrasts in Water Quality

A comparison of groundwater composition between the shallower semi-confined groundwater in production bore F41/0150 and Lake Wakatipu was made in Appendix C of the Stantec report (Dommisse, 2017). The distance between the bore and Lake Wakatipu was also 90 metres and artesian pressures were also present in the bore. Concentrations of alkalinity, chloride, nitrate and sulphate were all slightly higher in groundwater than the lake, but not so high that it was notable. Groundwater in the RCL bore CC11/0151 sampled several years later in July 2024 presented comparable concentrations, albeit slightly lower that the 2017 lake water (see Table 18).

Table 18: Comparison of 2017 groundwater, lake water and 2024 groundwater water composition

Analyte	Units	Production Bore F41/0150 20 July 2016	Lake Wakatipu @ Homestead Bay 20 July 2016	Test Production Bore CC11/0151 10 July 2024
pH	*pH Units*	7.9	7.9	8.0
Total Alkalinity	*g/m^3 as $CaCO_3$*	84	74	66
Bicarbonate	*g/m^3 at 25°C*	101	90	79
Chloride	*g/m^3*	2	1.8	0.9
Nitrate-N	*g/m^3*	1.37	1.15	0.38
Nitrate-N + Nitrite-N	*g/m^3*	1.37	1.15	0.38
Sulphate	*g/m^3*	3.0	3.2	2.3

Table 18 would suggest that there are minimal contrasts in water quality present in the water bodies at the RCL bore field on Homestead Bay. The result is that changes to the exchanges of groundwater or surface water as a consequence of the operation of the RCL Group water supply pumping is highly unlikely to result in temporal shifts in the water quality of the groundwater pumped from the production bore or Lake Wakatipu. This aspect is covered in the assessment of groundwater environmental effects below.

6 Groundwater Environmental Effects

Potential groundwater environmental effects, include the following -

- Drawdown
- Surface water depletion
- Groundwater basin depletion
- Water quality effects on persons connected to the future water supply

6.1 Drawdown

Drawdown, or lowering of surrounding groundwater pressure / groundwater level, is the principal environmental effect of water supply pumping with short-term and long-term aspects. The extent of drawdown was physically assessed during the constant rate test measurements of groundwater pressure at the observation bore, screened in the same aquifer and 10 metres distant from the site of pumping. The measured 10 metres radius drawdown stabilised to about 4.7 metres within 2¼ hours following the start of pumping. A similar level of drawdown continued for a further 2 days until the test concluded.

No more widely spread groundwater pressure / level monitoring sites were located. The two water bores were documented to be approximately 500 metres to the east of the RCL bores by the ORC wells database (see Figure 20). These bores drilled for subdivision water supply on the elevated terrace occupied by the Lakeside Estate subdivision are terminated (i.e., end of hole) only 13 - 16 metres below the estimated land surface at the RCL Group test production bore. This minimal depth of overlap meant that the screened water-bearing layer in the Lakeside Estates' bores did not coincide with the aquifer tapped by the RCL Group bores. Another water supply bore located 1.2 kilometres to the northwest of the RC Group bores terminated at a depth of only 37 metres, so it was unlikely that this bore, F41/0150, was screened across the same aquifer tapped by the RCL Group bores. Regardless, drawdown effects were calculated as if the surrounding bores were in the same aquifer as RCL bores.

Figure 20: RCL bore site (CC11/0151 and CC11/0151P) relative to surrounding well records

Projections of drawdown effect surrounding the putative water supply production bores had to utilise the a leaky aquifer equation (Hantush & Jacob, 1955) for calculated drawdown at set distances and pumping durations. Table 19 lists the relevant drawdowns

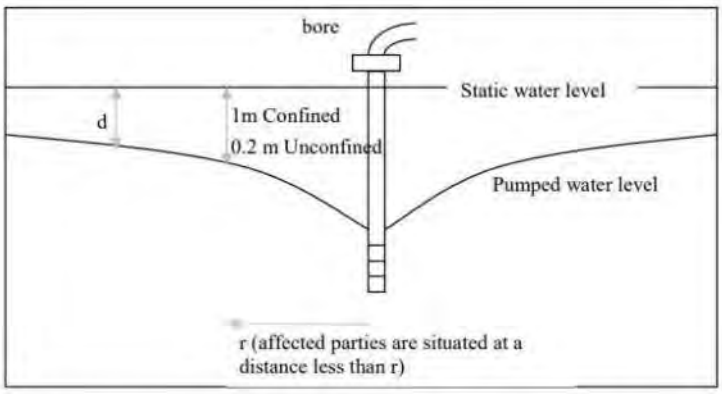
Table 19: Calculated (Hantush & Jacob, 1955) Drawdown for distances and durations

Radius (m)	0.15 m Bore Radius	500 m Lakeside Est.	1200 m F41/0150
Time (days)	Drawdown (m)	Drawdown (m)	Drawdown (m)
1	22.70	1.02	0.07
2	23.31	1.50	0.24
7	23.84	1.98	0.53
30	23.88	2.03	0.57
90	23.88	2.03	0.57
365	23.88	2.03	0.57

Parameters: T = 200 m^2/d for transmissivity
S = 1 x 10^{-3} for aquifer storativity
B = 790 m for leakance coefficient
Q = 40 L/s for pumping rate

The leaky aquifer characteristic of the source aquifer and its overlying cap results in the drawdown effect flatlining after a 2 – 3 days following the start of the pumping. Table 19 indicates that aquifer drawdown within the production bore would be less than 23.9 m, drawdown effect at Lakeside Estate bore approximately 2 metres and at the Nathaneal Place supply bore approximately 0.58 metres.

Schedule 5B of the Otago Regional Plan: Water (the operative water plan at the time of writing), specifies the threshold of drawdown effect as shown in Figure 21; 1 metre for confined aquifers and 0.2 metre for unconfined aquifers.



The radius will be determined using a significant interference of d ≥ 1 m for confined aquifers or d ≥ 0.2 m for unconfined aquifers

Figure 21: Schematic within Schedule 5B of the Otago Regional Plan: Water

A semi-confined aquifer is sufficiently alike to a confined aquifer to adopt that threshold level; therefore the threshold of drawdown significance would be 1 metre. Thus, the Lakeside Estate bores with a calculated drawdown effect of 2 metres could be considered affected in terms the calculated drawdown at 500 m

exceeding 1 m for a confined aquifer. However, the Natanael Place supply bore (i.e., F41/0150) with calculated drawdown of 0.57 metres would not be considered affected under the above scheme.

Being considered 'affected' according to Schedule 5B is not the same as the bores being minimally, significantly, or even adversely affected. The status set out in Schedule 5B and the associated policy (Policy 6.4.10B) triggers the need to assess the conservatively estimated effect using existing information on bore construction, geohydrological conditions and calculations. After such assessment, consultation or notification may be used to work with the potentially affected party or parties to resolve the drawdown effect. Written approval by potentially affected parties may be used to indicate the drawdown effect would not be considered in the strict case of the signatory's bore(s) or well(s).

6.2 Surface Water Depletion

6.2.1 Principles of Surface Water Depletion and Regional Policies

Surface water depletion by groundwater pumping is premised on connected groundwater. Connected groundwater are those parts of a groundwater system that are in hydraulic connection with adjoining surface water bodies. Such water bodies include -

- Creeks or streams,
- Rivers,
- Lakes or seas/oceans, or
- Wetlands.

Environmental water management often seeks to regulate the taking of groundwater that largely draws water from vulnerable, adjacent water bodies. An example might be a large concentration of high capacity river-proximal bores within the radius of influence of a small creek or river. Water allocation limits and surface water controls should account for the interaction between groundwater and surface water in the same catchment or sub catchment.

The Otago Regional Plan: Water included significant bolstering of groundwater – surface water management provisions, including delineation of connected groundwater. Policy 6.4.1A contains specific guidelines on the taking of groundwater being allocated to surface water, part surface water and groundwater and wholly groundwater as outlined in the policy itself:

6.4.1A A groundwater take is allocated as:

(a) Surface water, subject to a minimum flow, if the take is from any aquifer in Schedule 2C; or
(b) Surface water, subject to a minimum flow, if the take is within 100 metres[19] of any connected perennial surface water body; or
(c) Groundwater and part surface water if the take is 100 metres or more from any connected perennial surface water body, and depletes that water body most affected by at least 5 litres per second as determined by Schedule 5A; or
(d) Groundwater if (a), (b) and (c) do not apply.

The definition of wholly groundwater is further explained in the explanation to Policy 6.4.1A as follows:

All other groundwater

(i) Certain factors reduce the connection between aquifer and surface water body to a degree that surface water depletion effects are below the threshold level of 5 litres per second. These typically include:
(ii) The bed of the surface water body is impermeable; or

[19] Emphasis added due to relevance to the RCL Group test production bore.

(iii) The surface water body is ephemeral and only conveys water in periods of high runoff; or

(iv) The groundwater is separated from the underlying water table by an unsaturated zone that inhibits connection to aquifer's water table; or

(v) The groundwater system has very low permeability; or

(vi) The groundwater system has very steep gradients or perched water tables adjacent to the surface water body boundaries; or

(vii) The bore or well screen is sufficiently deep to avoid influence on surface water; or

(viii) The bore or well is sufficiently distant from the surface water body to avoid influence on the surface water body.

In these instances water is allocated as groundwater only.

The application or significance of the explanation to Policy 6.4.1A is ambiguous in the case of the RCL Group bore. Items (v) to (vii) are potentially relevant to the RCL Group bore setting and the relationship between the source aquifer and Lake Wakatipu, but the hydrogeological or hydrological indications are equivocal. Therefore, the position of the bore within 100 metres of the lake may prevail to classify the water drawn as wholly surface water.

6.2.2 Adjacent Surface Water Bodies

There are two surface water bodies or courses in proximity to the RCL bores:

- The dry gulch to the immediate east and southeast of the bores (approximately 55 metres), and
- Lake Wakatipu to the south and southwest of the bores (approximately 85 metres of the water line).

The dry gulch is essentially a flood channel only. Checks of satellite and aerial photographs between 2006 and present of the gulch indicate it was not carrying surface water in any of the many georeferenced images recorded for it. The gulch was wholly dry during the drilling and aquifer testing period in June and July 2024.

Lake Wakatipu is a perennial water body as described and quantified in the existing environment section on surface water. The lakes water level fluctuates in a tight range with the outlet at Kawarau Falls at Frankton controlling lake level. The lake's through flow is regionally significant due to elevated precipitation as snow, hail and rain along the Main Divide, including the retention of winter precipitation in permanent snow/ice fields.

The shore of Lake Wakatipu abreast of the RCL bore is mapped as gravel beach and alluvial fan materials, so the lake is theoretically in hydraulic connection with saturated terrestrial deposits and therefore the groundwater system within those deposits. It is unclear whether the groundwater system has very low permeability or the screened depth of the RCL test production bore at 87 – 95 meters in terms of clause (v) and (vii) of the policy 6.4.1A explanatory notes. However, the RCL bore lies unequivocally within 100 meters of Lake Wakatipu, which may allow 100% the water pumped at the test production bore to be classed as surface water.

6.2.3 Allocation Status – Lake Wakatipu

Under the current water plan any induced depletion of surface water at a calculated rate greater than 5 litres per second within a resource consent process requires the securing of allocation for that induced depletion from within the allocation allowable for the surface water body, in addition to groundwater allocation (see Policy 6.4.1A). As Lake Wakatipu is the sole feasible water body from which such depletion arising from pumping of groundwater for RCL Group water supply purposes, it is worthwhile checking the allocation status of the lake catchment. Table 20 lists the current and draft/proposed regional plans relating to water resources, plus the possibility to allocate further surface water from the lake.

Table 20: Estimation of Current and Future Allocation Limits for Lake Wakatipu

Otago Regional Plan relevant to Water	$MALF_{7d}$ (L/s)	Allocation Limit (L/s)	Probable Currently Allocated Surface Water in Consents (L/s)	Further allocation available? (estimate based on best available information)
Regional Plan: Water (Current)	75,100	7,510*	750¥	Yes
Proposed Land & Water Regional Plan[20]	75,100	3,000§	750¥	Yes

Note: * 10% of $MALF_{7d}$, which could be considered insignificant

¥ From section 2.3.3

§ From ORC Draft LWRP[20], proposed new rules, Upper Clutha Lakes Rohe https://www.orc.govt.nz/media/15400/draft-land-and-water-plan-proposed-new-rules-and-regulations-lwrp-upper-lakes-rohe_231018.pdf

6.3 Groundwater Basin Depletion

6.3.1 Status of the Jacks Point-Remarkable-Homestead Bay Groundwater System

The clastic materials, including alluvial fans, glacial and lake beach deposits, in the Jacks Point – Remarkables – Homestead Bay area are saturated with groundwater. Basin depths are highly variably but have recorded depths up to 47 metres. Otago Regional Council (ORC) had accumulated and collated well records for the Jacks Point – Remarkables – Homestead Bay area. However, no specific moves had been taken by ORC to consider or manage the area's groundwater as a groundwater system or aquifer. Groundwater management tools such as State of Environment Monitoring, Regional Plan: Water C-Map, Schedule 4A, Schedule 4B, or other regulatory recognition are absent from the area's groundwater management. Accordingly, default groundwater management provisions apply to the RCL bores.

6.3.2 Estimate of Rainfall Recharge to Groundwater System

The Stantec report on the Nathaneal Place water supply bore (Dommisse, 2017) estimated that the 2,245 hectare groundwater basin had an estimated mean annual recharge rate of 2.75 million cubic metres representing around 17% of mean annual rain (equating to 722 millimetres) falling on the basin soils. It is worth while noting that the Stantec report did not include groundwater recharge originating as runoff on the Remarkables range front that infiltrates in the talus and alluvial fans connecting with the groundwater basin (Dommisse, 2017). Given the general absence of surface flow in the area's water courses (outside of floods), and the high intensity of precipitation (rain and snow) on the Remarkables Mountains flank (see section Surface Water; Existing Information, plus Figure 4), range-front recharge is estimated to be equal to the direct rainfall recharge on the basin soils.

6.3.3 Estimate of Range-Front Recharge to Groundwater System

The upstream catchments at the SH6 crossing are used to estimate range-front recharges from the Remarkables in Table 21. The New Zealand Rivers Maps online database outlined in Table 5 was re-sampled to take the catchment areas and hydrology of the creeks upstream of SH6. Only a Woolshed Creek tributary and the unnamed creek catchment feeding the dry gulch alongside the RCL bores are included in the estimate. Other Jacks Point and Drift Bay creeks are considered to adjoining compartments of the groundwater system. The aggregation of the median flow in the two headwater creeks indicates combination flow of 84 litres per second.

[20] Otago Regional Council removed the notification vote from the council meeting scheduled for 23 October 2024 in response to an amendment to the Resource Management Act introduced on 22 October 2024 that retrospectively prevented the notification of land and water plans by regional councils or unitary authorities. The proposed Land & Water Regional Plan for Otago is officially on hold, but its future notification is in question.

Table 21: Estimation of Range Front Recharge to Groundwater for Homestead Bay Groundwater System

Creek / Burn Catchment	NZ River Segment #	Upstream Catchment Area (ha)	Mean Flow (L/s)	Median Flow (L/s)	$MALF_{7d}$ (L/s)
Woolshed Creek Tributary	14227017	2,682	61	44	25
Unnamed Trib Drift Bay No. 1 (dry gulch)	14227367	2,419	55	40	22
Total Flow Equivalent (L/s)				84	
Range-Front Recharge Estimate					
Range-Front Recharge Total (m^3/year)*				2,650,000	
Annual Range-Front Recharge (million m^3/year)*				2.65	

Note: * Range-front recharge estimates as the Total Flow Equivalent of Woolshed Creek Tributary and Unnamed Trib Drift Bay No. 1 (dry gulch) converted to annualised volume in cubic metres per annum.

Table 21 extends to provide an estimate of annual range-front recharge from the NIWA median modelled creek flows of 2.65 million cubic metres per annum. It is entirely reasonable to accept this estimate and add the annual range-front recharge to Land surface recharge providing a groundwater system total, giving 5.4 million cubic metres as the combined total basin recharge volume.

6.3.4 Combined Recharge to the Groundwater System & Allocation Limits

At a regulatory level, there are two separate bases for setting a limit to the groundwater that may be allocated for consumptive use, the current Regional Plan: Water or the proposed Regional Land & Water Plan[21]. Table 22 list the current and future water plans and the default allocable groundwater annual volume.

Table 22: Estimate of Allocable Groundwater for Consumptive Use under Current and Future Plans

Otago Regional Plan relevant to Water	Mean Annual Recharge* (Mm^3/yr)	Maximum Percentage of MAR (%)	Allocable Groundwater Volume (Mm^3/yr)
Regional Plan: Water (Current)	5.4	50 %	2.7
Proposed Land & Water Regional Plan[21]	5.4	35 %	1.89

Note: * Sum of estimated mean annual rainfall recharge (Dommisse, 2017) and range-front recharge (see Table 21).

Implication for Surface Water Allocation

In addition to the above sources of groundwater system replenishment, Lake Wakatipu may be induced to provide some amounts of lake bed recharge in response to sustained water supply bore pumping. The mechanisms and intensity of lake bed recharge are currently poorly defined. However, the lake may stand to provide augmentation of the groundwater resource during water supply operations, depending on intervening material hydraulic conductivities and operative hydraulic gradients.

Should future geohydrological assessment be able to quantify the level of groundwater depletion of lake Wakatipu, the maximum feasible depletion would be 45 L/s. This utmost rate of depletion of Lake Wakatipu would be feasibly consented within the allocation cap conceptually set for the lake's water resource. At a fundamental level, absent special technical pleading in accordance with the explanatory note, policy 6.4.1A would allocate the groundwater as surface water. A more nuanced policy setting with respect to groundwater – surface water consenting is likely under the draft/proposed Land and Water Regional Plan[21] once it becomes operative. This would result in the taking of water being apportioned between the aquifer and the lake.

[21] Otago Regional Council removed the notification vote from the council meeting scheduled for 23 October 2024 in response to an amendment to the Resource Management Act introduced on 22 October 2024 that retrospectively prevented the notification of land and water plans by regional councils or unitary authorities. The proposed Land & Water Regional Plan for Otago is officially on hold, but its future notification is in question.

7 Results of Groundwater Exploration & Assessment of Effects

The drilling and testing on the shore of the southern parts of Homestead Bay were exploratory, without any guarantee of viable ground water supply at the outset of drilling investigations. The following conclusions are offered in relation to the availability of water resources to provide raw water to the balance of residential land that could be potentially developed at Homestead Bay, and the assessment of the potential effects arising –

1. Geological and soil mapping of the sedimentary basin between Queenstown Hill / Lake Wakatipu and the Remarkables Range indicated the presence of permeable to sometimes highly permeable sediments across parts of the basin floor, potentially hosting aquifer(s).

2. Drilling investigations along the shore of Homestead Bay in 2016 (Dommisse, 2017) and June-July 2024 (this report) recorded water-bearing layers with groundwater yield in the region of 40 litres per second in pumping test of the individual 300 millimetres diameter bore. Drilling and aquifer tests in Homestead Bay during 2017 provided demonstration of a 37 m deep bore with a capacity of 36 litres per second and specific capacity of 2 litres per second per metre of drawdown.

3. Drilling and testing in Homestead Bay in June – July 2024 provided information on a 95 metre deep bore with a capacity of 40 litres per second and specific capacity of 1 litre per second per metre of drawdown.

4. Despite the similarities, the more recently drilled bore at the RCL bore site (CC11/0151) is substantially deeper and tested to have a transmissivity of approximately 200 metres per day, which is about a seventh of the transmissivity measured in the 2017 Homestead Bay bore (F41/0150).

5. The leakage coefficients for leaky aquifer components from each of those aquifer tests on CC11/0151 and F41/0150 point to there being less ability for groundwater to leak through the overlying fine sediment layer (aquitard) at the new RCL bore site, i.e., the aquitard permeability is significantly lower in the newer RCL bores.

6. There were definite indications during the multi-day pumping test at 40 litres per second that the well screen required further development of the natural gravel pack around the well screen, indicated by spikes in internal drawdown and episodes of elevated turbidity. It is recommended that such development is undertaken prior to or as part of bore commissioning of any future water supply.

7. While the RCL Group 95 metre deep bore and the Lakeside Estate supply bore are arguably screened in different water-bearing layers, calculation of drawdown effect of the RCL Group bore pumping at 40 litres per second for up to 365 days equates to 2 metres of drawdown effect at the closest neighbouring bore, which is more than the drawdown considered to indicate 'effect' in terms of Regional Plan: Water, Schedule 5. . It is also arguably screened in a different water-bearing layer from the more recently drilled RCL Group bore, as such the RCL bore would not have a drawdown effect on the Lakeside Estate supply bore.

8. The calculated drawdown effect on the Nathaneal Place water supply bore (F41/0150) at 1.2 kilometres to the NW of the RCL Group proposed water supply bore would be 0.57 metres, which less than the drawdown considered to indicate 'effect'. It is also arguably screened in a different water-bearing layer from the more recently drilled RCL Group bore.

9. The proposed pumping of the RCL Group water supply bore CC11/0151 at 45 litres per second would not have a depletion effect on the unnamed creek lying 55 metres of the proposed production bore, as the creek is devoid of flowing water along the course passing the RCL Group bore site, other than haphazard flood events.

10. The proposed pumping of the RCL Group water supply bore CC11/0151 at 45 litres per second would potentially have a depletion effect on Lake Wakatipu. While the bore lies within 100 metres of Lake Wakatipu and the current regulatory position under Policy 6.4.1A allocates 100% of the take to that surface water resource, evaluation of the available groundwater or surface water allocation under current and future water plans is that the respective allocation caps for groundwater or surface present no impediment to granting a consent application for the proposed activity.

11. Sampling of the RCL Group bore CC11/0151 in July 2024 provided analytical results indicating acceptable health-concern or aesthetic water quality, although arsenic in the groundwater was immediately below the drinking water standard.

12. The water chemistry of groundwater for proposed production bore CC11/0151 was found to be otherwise favourable for use in domestic water supply, including dilute water with equivalent Total Dissolved Solids (TDS) of 125 mg/L, moderate hardness, slight alkalinity, low land use effect indications in terms of dissolved nutrients, and low metal/metalloid content except arsenic.

13. Treatment of raw water from bore CC11/0151 prior to use in domestic water supply, such as dosing, coagulation and filtration, may include processes that reduce arsenic concentrations to levels significantly lower than the drinking water standard, which should be further assessed.

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Appendix 1. Bore Logs

Appendix 1.1. CC11/0151P (6-Inch Exploration / Monitoring Bore)

BORE INSTALLATION REPORT

Client	RCL HOMESTEAD BAY LIMITED	**GPS** NZTM	**East**	1265455	
			North	4997243	
Consent No.	RM24.110.01	**Bore No.**	CC11/0151P		
Bore Location	495 Kingston Road, Queenstown				
Client Address	PO Box 13052, Christchurch 8141				
Phone	027 836 4442				
Driller	Neil Simmons	**Drill Method**	Dual Rotary		
Machine/Rig	Rig 20 - Western Star DR24	**Bore Diameter**	150mm		
Start Date	12/06/2024	**Date Completed**	18/06/2024		
Water Level	-0.17 m	**Final Bore Depth**	94.15 m		

Has the bore been capped or covered?	Yes
Does the bore have a concrete pad?	Yes
Is the bore sealed with concrete or Bentonite around the annulus?	Yes
Bacterial Water Test	Yes
Chemical Water Test	Yes
Photo of Bore	Yes
Overdrilled (m)	No

FLOW TESTING

Pump Size	4"	**Pump Depth**	30 m
Pump Period	1 hours	**Rate**	LPS

DRAWDOWN

	1	2	3	4	5
Flow Rate	2.8LPS				
Drawdown from SWL (metres)	6.25				
Duration (hours)	1				
Recovery at 1 minute (metres)	2.12				
Recovered back to 90% (minutes)	2.5				

SCREEN

Screen Installed	Yes	**Screen Type**	Stainless Steel		
Top of Screen	92.15 m	**Bottom of Screen**	94.15 m		
Screen Slot	1.5 mm	**ID**	127 mm	**OD**	138 mm

CASING

Casing Material	Diameter	Height Above Ground	Set From	Set To	Length
Steel	150 mm	0.5 m	-0.5 m	92 m	92.5 m

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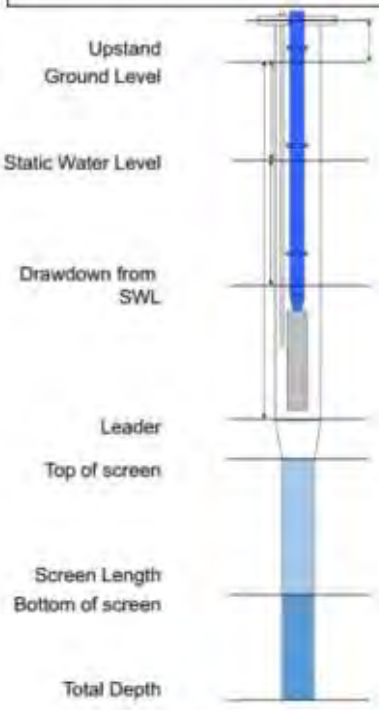
WASHINGTONS EXPLORATION LIMITED

BORE INSTALLATION REPORT **CLIENT:** RCL HOMESTEAD BAY LIMITED

STRATA

Top Depth (m)	Bottom Depth (m)	Soil Type (Major, Secondary, Minor)	Colour	Grain Size	Water Content
0	1.9	Gravel	Brown, Yellow	Medium	Dry
1.9	3.2	Sand	Grey	Fine	Dry
3.2	4.8	Silt Sand Gravel	Brown	Fine	Damp
4.8	27.8	Silt Sand	Grey, Brown	Fine	Damp
27.8	46	Silt	Grey, Blue		Dry
46	51	Silt	Grey, Brown		Damp
51	67.7	Silt	Grey, Brown, Blue		Dry
67.7	75	Silt Mudstone	Blue		Dry
75	78	Clay Silt Gravel	Yellow	Medium	Water bearing
78	80	Clay Silt	Blue		Dry
80	84	Silt Clay Gravel	Yellow	Fine to coarse	Water bearing
84	86.5	Gravel Sand	Brown	Coarse	Water bearing
86.5	94.3	Sand Gravel	Brown	Fine to coarse	Water bearing

Notes:
Bore is flowing over TOC



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NZDF

Appendix 1.2. CC11/0151 (12-Inch Test Production Bore)

BORE INSTALLATION REPORT

Client	RCL HOMESTEAD BAY LIMITED	**GPS** NZTM	**East**	1265446	
			North	4997248	
Consent No.	RM24.110.01	**Bore No.**	~~CG11/0151~~ CC11/0151		
Bore Location	495 Kingston Road, Queenstown				
Client Address	PO Box 13052, Christchurch 8141				
Phone	027 836 4442				
Driller	Neil Simmons	**Drill Method**	Dual Rotary		
Machine/Rig	Rig 20 - Western Star DR24	**Bore Diameter**	300mm		
Start Date	19/06/2024	**Date Completed**	11/07/2024		
Water Level	0.17 m	**Final Bore Depth**	94.38 m		

Has the bore been capped or covered?	Yes
Does the bore have a concrete pad?	Yes
Is the bore sealed with concrete or Bentonite around the annulus?	Yes
Bacterial Water Test	Yes
Chemical Water Test	Yes
Photo of Bore	Yes
Overdrilled (m)	No

FLOW TESTING

Pump Size		**Pump Depth**	
Pump Period	0 hours	**Rate**	

DRAWDOWN

	1	2	3	4	5
Flow Rate					
Drawdown from SWL (metres)					
Duration (hours)					
Recovery at 1 minute (metres)					
Recovered back to 90% (minutes)					

SCREEN

Screen Installed	Yes	**Screen Type**	Stainless Steel		
Top of Screen	87.88 m	**Bottom of Screen**	94.68 m		
Screen Slot	1.5 mm	**ID**	256 mm	**OD**	273 mm

CASING

Casing Material	Diameter	Height Above Ground	Set From	Set To	Length
Steel	300 mm	0.5 m	-0.5 m	86.3 m	86.8 m

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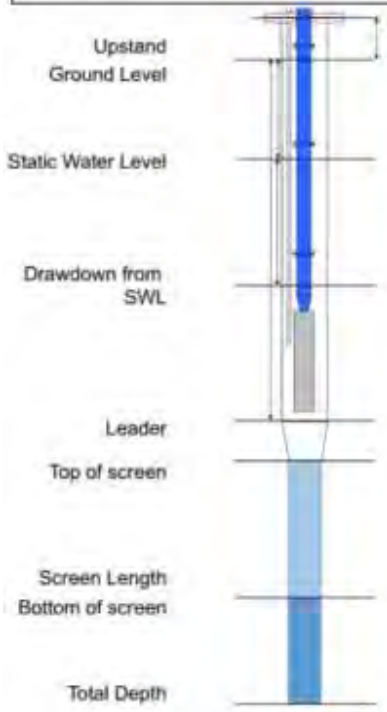
WASHINGTONS EXPLORATION LIMITED

BORE INSTALLATION REPORT **CLIENT:** RCL HOMESTEAD BAY LIMITED

STRATA

Top Depth (m)	Bottom Depth (m)	Soil Type (Major, Secondary, Minor)	Colour	Grain Size	Water Content
0	1.9	Gravel	Brown, Yellow	Medium	Dry
1.9	3.2	Sand	Grey	Fine	Dry
3.2	4.8	Silt Sand Gravel	Brown	Fine	Damp
4.8	27.8	Silt Sand	Grey, Brown	Fine	Damp
27.8	46	Silt	Grey, Blue		Dry
46	51	Silt	Grey, Brown		Damp
51	67.7	Silt	Grey, Brown, Blue		Dry
67.7	75	Silt Mudstone	Blue		Dry
75	78	Clay Silt Gravel	Yellow	Medium	Water bearing
78	80	Clay Silt	Blue		Dry
80	84	Silt Clay Gravel	Yellow	Fine to coarse	Water bearing
84	86.5	Gravel Sand	Brown	Coarse	Water bearing
86.5	94.3	Sand Gravel	Brown	Fine to coarse	Water bearing

Notes:
Bore is flowing over TOC
grout seal around 300mm drilled 425mm , grout seal 0.0m -6.00m



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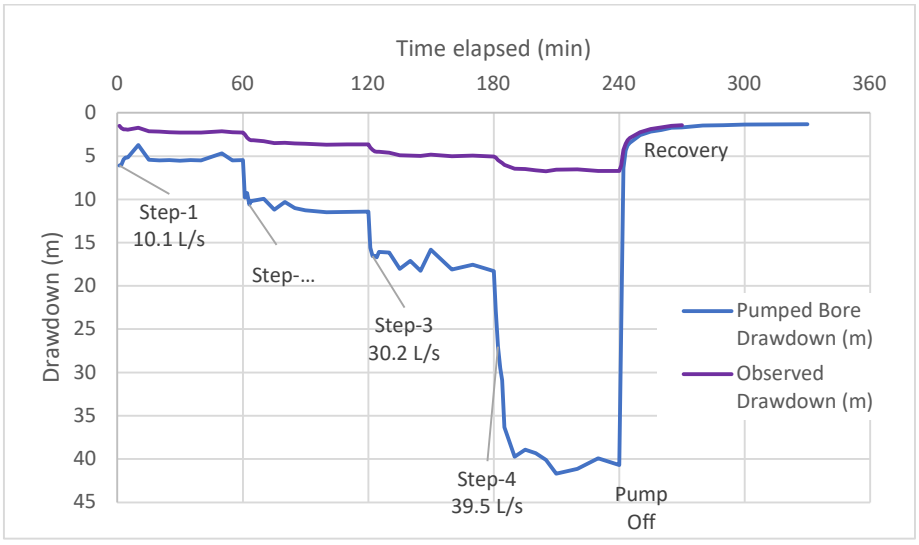
Appendix 2. Step Drawdown (Rate) Test (Manual Data)

Step#	Date & time	Time Elapsed (min)	Time within Step (min)	Pumped Bore Depth To Water (m ToC)	Pumped Bore Drawdown (m)	Pump Rate (L/s)	Observation Bore Drawdown (m)
Pre	4/07/24 7:30	-60		-1.2	0	Flowing	0
Pre		-45		-1.2	0	Flowing	0
Pre		-30		-1.2	0	Flowing	0
Pre		-15		-1.2	0	Flowing	0
Start		0		-1.2	0	Flowing	0
Step-1		1	1	4.9	6.1	11.1	1.5
		2	2	4.83	6.03		1.8
		3	3	4.21	5.41	10.1	1.92
		4	4	3.97	5.17	10.1	1.94
		5	5	3.95	5.15	10.1	1.95
		10	10	2.52	3.72	6.1	1.72
		15	15	4.23	5.43	10.5	2.12
		20	20	4.3	5.5	10.5	2.18
		25	25	4.28	5.48	10.6	2.22
		30	30	4.32	5.52	10.6	2.26
		35	35	4.28	5.48	10.5	2.28
		40	40	4.29	5.49	10.5	2.29
		50	50	3.5	4.7	8.4	2.13
		55	55	4.3	5.5	10.1	2.25
		60	60	4.28	5.48	10.1	2.29
Step-2		61	1	8.58	9.78	20	2.53
		62	2	8.1	9.3	15.6	2.88
		63	3	9.4	10.6	19.4	3.12
		64	4	9	10.2	19.6	3.17
		65	5	8.97	10.17	19.9	3.18
		70	10	8.73	9.93	19.4	3.28
		75	15	9.98	11.18	20	3.53
		80	20	9.1	10.3	19.1	3.44
		85	25	9.84	11.04	19.9	3.56
		90	30	10.06	11.26	19.9	3.6
		100	40	10.28	11.48	20.2	3.68
		110	50	10.23	11.43	19.8	3.65
		120	60	10.2	11.4	19.8	3.66
Step-3		121	1	14.38	15.58	30	4.05
		122	2	15.36	16.56	29.7	4.3
		123	3	15.3	16.5	29.5	4.45
		124	4	15.48	16.68	29.9	4.5
		125	5	14.874	16.074	29.9	4.5
		130	10	14.94	16.14	29.2	4.61
		135	15	16.84	18.04	30.3	4.91
		140	20	15.9	17.1	29.1	4.96
		145	25	17.05	18.25	30.2	4.97

Step#	Date & time	Time Elapsed (min)	Time within Step (min)	Pumped Bore Depth To Water (m ToC)	Pumped Bore Drawdown (m)	Pump Rate (L/s)	Observation Bore Drawdown (m)
		150	30	14.62	15.82	27	4.84
		160	40	16.92	18.12	29.5	5.02
		170	50	16.34	17.54	29.1	4.94
		180	60	17.1	18.3	30.2	5.05
Step-4		181	1	21.62	22.82	40	5.14
		182	2	25.8	27	38	5.46
		183	3	28.28	29.48	39	5.65
		184	4	29.7	30.9	38.5	5.82
		185	5	35.1	36.3	40.9	6.02
		190	10	38.5	39.7	40	6.47
		195	15	37.73	38.93	39.1	6.52
		200	20	38.1	39.3	39.4	6.65
		205	25	38.9	40.1	39.8	6.75
		210	30	40.46	41.66	40.44	6.58
		220	40	39.9	41.1	39.9	6.56
		230	50	38.7	39.9	38.7	6.71
		240	60	39.5	40.7	39.5	6.72
Recovery		241	1	23.8	25	0	6.1
		242	2	5.2	6.4	0	4.3
		243	3	3.15	4.35	0	3.6
		244	4	2.55	3.75	0	3.18
		245	5	2.24	3.44	0	2.92
		250	10	1.38	2.58	0	2.22
		255	15	0.97	2.17	0	1.88
		260	20	0.79	1.99	0	1.69
		265	25	0.56	1.76	0	1.52
		270	30	0.48	1.68	0	1.43

Graphically as App2-Figure 1:



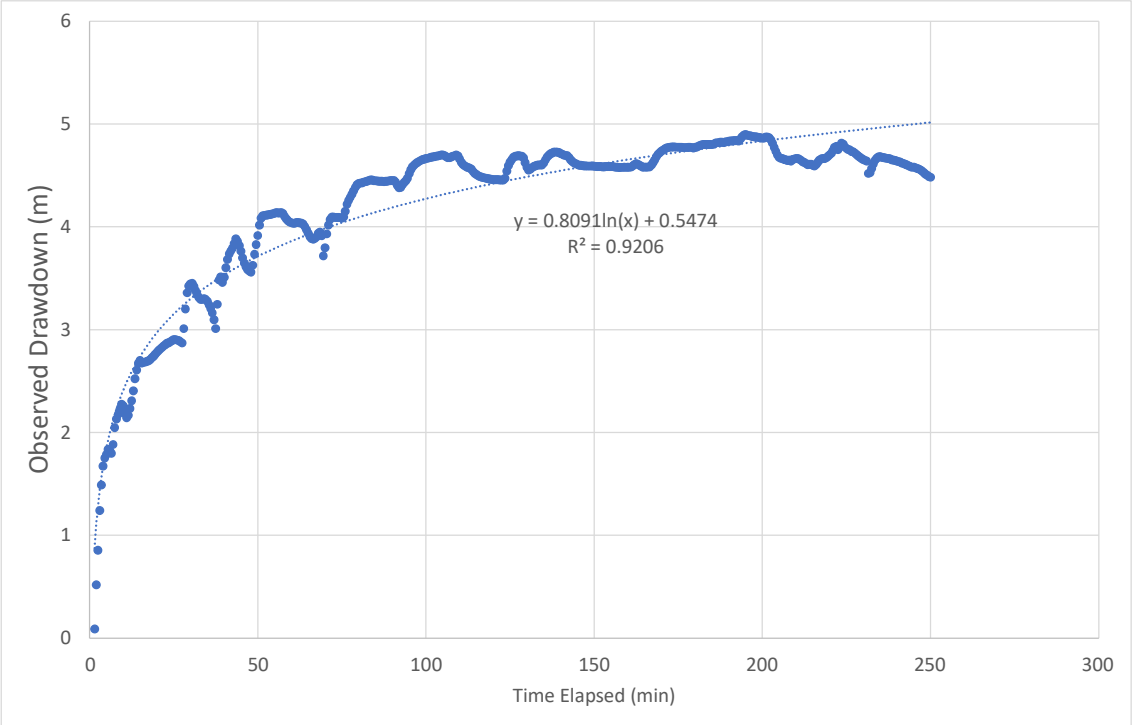
Appendix 3. Constant Rate Test (Initial 200 minutes of 5-min Electronic Data)

Data collected in 0.5 minute intervals, averaged to 5-minute intervals below -

		Pumped bore	Obs Bore	Pumped bore	Obs Bore	Pumped bore
Date/Time	Time (min)	Gw Level (m)	Gw Level (m)	Drawdown (m)	Drawdown (m)	Mean Flow (L/s)
8/07/2024 9:34	5	2.75	9.98	1.18	9.98	27.2
8/07/2024 9:39	10	7.75	13.74	2.05	13.74	30
8/07/2024 9:44	15	12.75	15.69	2.39	15.69	32.5
8/07/2024 9:49	20	17.75	18.85	2.71	18.85	31.6
8/07/2024 9:54	25	22.75	19.91	2.85	19.91	31
8/07/2024 9:59	30	27.75	22.57	3.09	22.57	40
8/07/2024 10:04	35	32.75	22.51	3.34	22.51	30
8/07/2024 10:09	40	37.75	22.83	3.29	22.83	38
8/07/2024 10:14	45	42.75	25.37	3.77	25.37	34
8/07/2024 10:19	50	47.75	23.19	3.68	23.19	41.8
8/07/2024 10:24	55	52.75	26.12	4.11	26.12	37
8/07/2024 10:29	60	57.75	25.01	4.10	25.01	37
8/07/2024 10:34	65	62.75	24.03	4.02	24.03	_
8/07/2024 10:39	70	67.75	22.97	3.88	22.97	_
8/07/2024 10:44	75	72.75	25.02	4.07	25.02	40.5
8/07/2024 10:49	80	77.75	26.91	4.29	26.91	_
8/07/2024 10:54	85	82.75	27.19	4.44	27.19	_
8/07/2024 10:59	90	87.75	26.77	4.45	26.77	37
8/07/2024 11:04	95	92.75	26.61	4.43	26.61	_
8/07/2024 11:09	100	97.75	28.17	4.62	28.17	_
8/07/2024 11:14	105	102.75	28.22	4.68	28.22	40.2
8/07/2024 11:19	110	107.75	27.93	4.68	27.93	_
8/07/2024 11:24	115	112.75	26.71	4.57	26.71	_
8/07/2024 11:29	120	117.75	26.23	4.48	26.23	38.5
8/07/2024 11:34	125	122.75	27.11	4.50	27.11	_
8/07/2024 11:39	130	127.75	27.75	4.66	27.75	_
8/07/2024 11:44	135	132.75	27.41	4.59	27.41	_
8/07/2024 11:49	140	137.75	28.38	4.71	28.38	_
8/07/2024 11:54	145	142.75	27.45	4.66	27.45	_
8/07/2024 11:59	150	147.75	27.02	4.59	27.02	40
8/07/2024 12:04	155	152.75	26.95	4.59	26.95	_
8/07/2024 12:09	160	157.75	26.97	4.58	26.97	_
8/07/2024 12:14	165	162.75	27.14	4.59	27.14	_
8/07/2024 12:19	170	167.75	27.89	4.65	27.89	_
8/07/2024 12:24	175	172.75	28.54	4.77	28.54	_
8/07/2024 12:29	180	177.75	28.37	4.77	28.37	39.5
8/07/2024 12:34	185	182.75	28.51	4.79	28.51	_
8/07/2024 12:39	190	187.75	29.05	4.82	29.05	_
8/07/2024 12:44	195	192.75	29.42	4.85	29.42	_
8/07/2024 12:49	200	197.75	28.87	4.88	28.87	_
			Pumping rate average for initial 200 minutes of pumping			33.6

Electronic data comprising all data collected in the course of aquifer testing would be provided to Otago Regional Council as part of any groundwater take consent process.

Appendix 3, Figure 1 illustrates the 0.5 minute points averaged in the table above.



App3-Figure 1: Plot of initial 250 minutes of CRT observation bore drawdown data and fitted logarithmic curve.

Appendix C Lowe Environmental Impact (LEI) Consent Design Report

Homestead Bay Consent Level Design

Wastewater Land Application

Prepared for

RCL

Prepared by

March 2025

Lowe Environmental Impact

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Homestead Bay Consent Level Design Wastewater Land Application

RCL

This report has been prepared for the RCL by Lowe Environmental Impact (LEI). No liability is accepted by this company or any employee or sub-consultant of this company with respect to its use by any other parties.

Quality Assurance Statement		
Task	Responsibility	Signature
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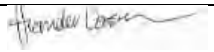
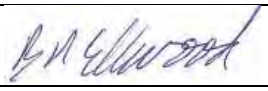
Prepared by:	Henry van der Vossen, Brian Ellwood	
Reviewed by:	Rob Potts	
Approved for Issue by:	Brian Ellwood	
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1 EXECUTIVE SUMMARY

The purpose of this report is to present the consent-level design for the wastewater land treatment system for RCL's Homestead Bay development. The proposed development will include approximately 2,580 residential lots/units, a commercial village, and possibly a school. The system is designed to minimise adverse environmental impacts while meeting community expectations for cost-effective and efficient wastewater management.

The wastewater treatment strategy incorporates land treatment via a pressure-compensating drip irrigation (PCDI) system for treated effluent discharge to an area of approximately 28.5 ha. This land-based system aligns with sustainable water and nutrient reuse principles while maintaining compliance with environmental standards. The development will occur in staged phases, with wastewater flows and treatment capacities increasing alongside residential and commercial expansion.

The consent level design assesses:

- Wastewater discharge characteristics, including influent and effluent quality.
- Site conditions, such as soil composition, groundwater flow, and surface water dynamics.
- Operational regime and monitoring requirements to ensure system compliance.

The selected system combines advanced wastewater treatment with land treatment areas (LTAs) to optimise nitrogen and phosphorus management while reducing leaching and environmental risks.

The flows have been based on NZS 4404 and QLDC Code of Practice. It is considered that these flows are conservative as they are greater per dwelling than measured flows from similar developments in the region. The adopted design dry weather flow at full development is 2,005 m^3/d, with a peak wet weather flow of 3,974 m^3/d, based on a gravity reticulation.

Options for four likely wastewater treatment plants (WWTP) have been identified, which are all variations of the activated sludge process and capable of producing a high quality effluent with quality in the order of $cBOD_5$ 20 mg/L, TSS 20 mg/L, TN 7.5 mg/L, TP 2.5 mg/L, and *E.coli* 100 to <1,000 MPN/100 mL. These WWTPs and the LTA can be staged as the development progresses.

Soil assessments have arrived at conservative average design loadings of 5 – 8 mm/d, depending on soil type and slope, at an application rate of approximately 2.67 mm/hr, which is well below the soil infiltration acceptance rates.

There are several factors that can be changed to manage the environmental impacts of a development such as this. These can include the selection of the LTA locations, the wastewater flow assessment and expected loading at the WWTP, the level of treatment within the plant and the operation of the LTA.

For the case of RCL, there may be limited available area for the LTAs, so the treatment in the WWTP and the operation of the LTA have been optimised to meet the land area requirements and achieve TN leaching to meet defined receiving water standards.

Groundwater is at a depth where mounding will not be an issue at the application rates proposed. All of the site ultimately drains to Lake Wakatipu. This lake has a very low trophic index of 2 – 3

(Oligotrophic), meaning that it has very low nutrient levels, and the design proposed seeks to maintain this high quality level.

Nitrogen loading to the land treatment area's after the WWTP treatment varies depending on land management, with an average of 193 kg N/ha/yr discharged to land at a WWTP discharge average quality of 7.5 mg/l. Land management varies from cut and leave, grazing, native planting and cut and carry (harvesting).

The current farming system over the 201 Ha has been estimated to leach an average of 9 kg N/ha/yr. The proposed system, including the urban development and wastewater treatment, has been modelled using the Overseer model to leach an average of 10 kg N/ha per year. The predicted losses are estimated to be similar and within modelling error to the current land use leaching loss of 9 kg N/ha/yr and less than the permitted nitrogen leaching in the ORC Regional Plan of 15 kg/ha/yr. The total nitrogen leached into Lake Wakatipu is modelled to be 31% less than the amount permitted under the Regional Plan.

Phosphorus applied from the treatment plant is modelled to average 64 kg P/ha/yr, with plant uptake and removal from the sites, any surplus in phosphorus is estimated to be retained in the soil. The soil has the capacity to receive at least 135 years of treated effluent application before P is expected to exceed the capacity of the soil and for phosphorus to leach below the first 1m and deeper into the soil profile. Therefore, little, if any, phosphorus is expected to leach into Lake Wakatipu or other water bodies via the groundwater system.

The proposed system is considered to be sustainable long-term, and thus consentable.

2 INTRODUCTION

2.1 Purpose

This report provides the consent level design for the land treatment of the wastewater from RCL's Homestead Bay development. This report describes the design regimes and presents reasonable and appropriate systems to align with the proposed development to minimise adverse environmental effects. This report does not detail the effects of wastewater application on the environment. The environmental effects of the activities and mitigation methods will be addressed in the consent application. The proposed design allows wastewater treatment and discharge to best meet the new community's expectations while optimising the capital and operational costs. Where the design has been modified to avoid or mitigate potential adverse environmental effects known at the time of writing, those matters have been included in this report.

RCL is investigating the development of Lot 8 DP 443832 (163.46 ha) and Lot 12, DP 364700 (41.6 ha), upon which one inhabited building is currently erected (as seen in Figure 3.1). RCL has identified areas within Lot 8 and Lot 12 for the potential of land treatment of wastewater, as seen in Figure 3.1.

The proposed activities include residential housing with a mix of densities, from apartment blocks to low-density housing. This includes approximately 2,580 residential lots/units, a commercial village shopping area along with a potential school site.

Light commercial activities will likely occupy 2.16 ha. The proposed activities are likely to include:

- Food retailing, including supermarket and food and beverage services such as cafés, restaurants and bars;
- Retailing, including personal accessories and services such as clothing and footwear, recreational bike/ski service activities, personal care services such as hairdressers, dentists, physiotherapists and the like; and
- Small scale office spaces.

A potential primary school allowing for up to 600 students has also been factored into the assessment.

New Zealand Standard 4404:2010 has been used as the basis for flow rates for light industrial and commercial activities at 0.4 litre/second/hectare (L/s/ha) for the 12-hour operational period.

For the site, the options for reticulation, wastewater treatment, and discharge have been assessed, and the proposed system has been selected. Developing a land-based discharge system is the preferred option for RCL, with the option of including high-rate subsoil trench discharge for high-flow management in the future if appropriate. This Consent Level Design focuses on the proposed option of land application of all RCL's treated wastewater via pressure-compensating drip irrigation (PCDI) to allow for further treatment in the soil/plant/atmosphere system via a communal discharge of treated wastewater to land.

2.2 Background

The proposed PCDI allows for the development of the discharge area in progressive stages. These stages will meet the discharge volume for each stage up to the design average dry weather daily discharge of 2,005 m^3/d and wet weather flow up to 3,973 m3/d with communal discharge to several small land treatment areas (LTAs) within the RCL-owned parcels.

LEI has developed the land treatment design using flows adopted with Stantec (10 October 2024), using QLDC subdivision development Code of Practice wastewater flows, allowing for the development of the flow profile for the LTA design. These flows are conservative compared to measured flows from similar developments in the region.

2.3 Scope

This Consent Level Design report contains the following information:

- Section 3 characterises the wastewater to be discharged;
- Section 4 outlines the critical receiving environment properties to be addressed by the system design;
- Section 5 describes the discharge system and staging of the Project;
- Sections' 6 and 7 explain the operational regime; and
- Section 7 Conclusions.

As stated above, this report describes the system design of the Project. This report does not include details of the proposed activities effects on the environment and mitigation methods. These details will be included in the consent application.

Criteria and parameters adopted in this report are considered conservative, and there will be scope for refinement at the detailed design stage.

3 DISCHARGE CHARACTERISTICS

3.1 Project

A number of options have been considered for the project, and from investigations there are a number of WWTP systems, and proposed land treatment areas that can meet the sites environmental opportunities and constraints.

A site visit was completed to understand the soils onsite, with results presented in the Soil Assessment (Appendix A).

The wastewater treatment from the development is proposed to occur via a combined treatment plant and be discharged to land for further treatment via several LTAs within the RCL-owned parcels. This proposed system is designed for a dry weather discharge rate of 2,005 m^3/d and wet weather flow rate of 3,973 m3/d.

The construction of the LTAs is to be undertaken as the wastewater flow increases. The full development loading rate has been calculated with a LTA area of 28.5 ha, with the areas shown in Figure 3.1.

The proposed land treatment system design combines population density, reticulation type, treatment level, and land application area to configure a scheme that minimises environmental effects.

3.2 Basis of Design

3.2.1 Wastewater Influent Quality

Most wastewater generated will be from each Lot's toilets, showers, laundry, and kitchen facilities and will, therefore, have the characteristics of conventional domestic sewage. Wastewater from some of the commercial areas, such as cafés or restaurants, will be stronger, similar to blackwater. The cafés and restaurants will require an additional grease trap.

Therefore, the typical influent wastewater constituents[1] are expected to have Biochemical Oxygen Demand (BOD_5) 220 mg/L, Suspended Soils (TSS) 220 mg/L, Total Nitrogen (TN) 40 mg/L and Total Phosphorus (TP) 8 mg/L.

3.2.2 Wastewater Effluent Quality

All wastewater treatment units considered in this report can be configured to achieve advanced tertiary treatment quality, providing the necessary nutrient reductions. Annual average treatment quality parameters will be proposed for consenting, as this allows some reduction in treatment efficiency during colder weather conditions.

The effluent quality required from the WWTP will depend on the selected area to be irrigated. The expected final stage effluent quality for the WWTP options on an annual average basis is $cBOD_5$ 20 mg/L, TSS 20 mg/L, TN 7.5 mg/L, TP 2.5 mg/L, and *E.coli* 100 MPN/100 mL. From discusss with WWTP designers at Apex Water and Stantec, it was confirmed that the treatment quality standards proposed for the full design are considered realistic to achieve.

[1] Metcalf and Eddy 3rd ed 1991

The WWTP is proposed to be configured to produce an effluent with low total nitrogen, i.e. 7.5 mg/L, and low total phosphorus, i.e. 2.5 mg/L, to match the annual application rate of up to 220 kg N/ha/yr and a maximum average application depth of 8 mm/day.

3.2.3 Wastewater Flows

For the calculation of wastewater flows, the proposed activities include cafés, retail activities and possibly a school, where flows are treated as a separate wastewater source. The New Zealand Standard 4404:2010 (Table 3.1) flow rate of 0.4 L/s/ha for the 12-hour operational period over the 2.16 ha of commercial space has been used. Note that this rate includes peaking factors, so no additional flow needs to be added for inflow and infiltration (I/I), or diurnal peaks.

The adopted design flows for the non-residential component of the development have not removed the peaking factors when looking at average daily flows or taken into account the working week only days for the commercial area and school. Therefore, the design dry weather daily flows for the commercial area could be reduced by a factor of 5 and the annual flow reduced by say 5.5/7. In the overall context of the development, removing the peaking factors will make little difference and have been left as they are to be conservative.

The design flow for the residential lots/units is based on a population density of three people/lot. The assessed population numbers are presented in Table 3.1. This based on the proposed subdivision layout design in October 2024.

Table 3.1: Estimated Population

Influent Location	Units	Population per day
General Activities		
School (600 students + 60 teachers/staff)		660
Subtotal (People/day)		660
Housing		
Apartments	592	1,776
Terraced Housing	764	2,292
Standalone Housing	1,222	3,666
Subtotal Housing (People/day)		7,734
Total		8,394

The design flow rates have been modified and calculated using standards relevant to domestic wastewater management using NZS 4404:2010 Land Development and Subdivision Infrastructure for communal systems incorporated into Queenstown Lakes District Council Land Development and Subdivision Code of Practice (2020) (QLDC COP) and NZS 1547:2012. Two methods of wastewater flow predictions have been used to assess the expected flows at RCL.

The first method (Method 1) uses the QLDC code of practice and requires the assessment to be undertaken using 3 people/house, with the Average dry weather flow of 250 L/p/d with standard fixtures.

The second method (Method 2) is based on the observed flows of similar subdivisions in the QLDC area. Some QLDC wastewater flow monitoring has been completed for Hanley's Farm and Shotover Country, which, are expected to be similar to the development proposed here. The figures LEI received indicated flows of 468 L/household equivalent/day (L/he/d) at Hanley's Farm and 513 L/he/d at Shotover Country, being somewhat below the QLDC COP assumption of 750 L/he/d (Queenstown Lakes District Council, 2024). It is understood that some of the measured

flow data are provisional and that more data would be desired for a lower design flow to be broadly accepted for the basis of design. It is nevertheless LEI's view that the 750 L/he/d assumption is likely to prove conservative. The design and management of the Homestead Bay system will present an opportunity to verify actual flows over time.

Two methods can be applied to estimate the total flow from the proposed development. Method 1 is considered conservative with a blanket 250 L/p/d. Method 2 (of 520 L/he/d) is considered more likely to be a realistic flow for the development. Using a staged development the installed WWTP capacity and LTA area can be matched to the actual flows.

The wastewater flows have been derived using Method 1, based on QLDC COP are shown in Table 3.2, the LTA has been sized using the Average Daily Flow (ADF) of 2,005 m^3/day. While also having the capacity to receive intermittently higher flows up to the Peak Wet Weather Flow (PWWF), which can occur during times of wet weather. It should be noted that the flow associated with diurnal variations will be stored and balanced as part of the WWTP.

Table 3.2: Estimated Population and Average Wastewater Volume (QLDC COP 2020)

Influent Location	Lots	Peak Population Numbers	Flow Rate (L/p/day)	Design Average Daily flow (m^3/day)	Design Peak Wet weather Flow (m^3/day)
General Activities					
Commercial Flows (Light) (Incl. Cafés, Retail and other)	2.16 ha	0.4 L/s/ha of Commercial Space (12 hour period)		37	37
School (600 students + 60 teachers/staff)		660	53[2]	35	69
Total General Activity Flow				72	106
Lot Type		3 P/lot	250 L/p/d		
Apartments	592	1,776	250	444	888
Terrace Houses	764	2,292	250	573	1,146
Standalone Houses	1,222	3,666	250	917	1,833
Subtotal Housing	2,578			1,934	3,867
Total		8,394		2,005	3,974

For comparison, the wastewater flows calculated using Method 2 and based on 520 L/he/d are shown in Table 3.3.

[2] The flow of 53 L/p/day – Per comms Stantec, based MOE design basis

Table 3.3: Estimated Population and Average Wastewater Volume (NZS4404:2010 and NZS 1547:2012)

Influent Location	Bedroom Mix		Peak population	Expected Average Daily Flow (m^3/day)	Peak Wet Weather flow (m^3/day)
General Activities					
Commercial Flows (Light) (Incl. Café, Retail and other)	2.16	0.4 L/s/ha for Commercial Space (12 hour period)		37.3	37.3
School (600 students + 60 teachers/staff)		660	53	34.7	34.7
Total People/day			52.5		
Options for Residential Development					Average Flow (L/household equivalent/day)
592 Apartments	10% 1 bedroom, 50% 2 bedroom, 40% 3 bedroom	1 - 2 bdrm ppl/unit of 2 and 3+ bdrm 3 ppl/unit	1,421	264	446
764 Terrace Houses	100% 2 bedroom	2 bdrm ppl/unit of 3	2,292	426	558
1,222 Standalone Houses	Mostly 3+	3 ppl	3,666	682	558
Total			7,379	1,444	520 L/he/d

3.3 Determinant Loading

The wastewater application rate to land will depend on soil's N loading, and soil's category (i.e. the ability of soil to percolate water which is known as soil's saturated and unsaturated hydraulic conductivity). The design average application depths across the proposed LTA areas ranges between 5 - 8 mm/day for the PCDI system adopted.

3.3.1 Land Treatment Area

The selection of the LTA locations and their total size allows for the following factors - the nutrient loading, total volume of wastewater generated, soil's saturated and unsaturated hydraulic conductivity. A total LTA area of 28.5 ha has been selected as seen in Figure 3.1. The land areas are detailed in Table 3.4.

Table 3.4: Areas of Discharge and Discharge Application

Overseer Block Groups	Land Treatment Area Label	Area (ha)	Average Discharge Application (mm/d)	Design Flow Rate (m^3/day)	Annual Flow Rate (m^3/year)
Area 1	B, C3, C4, C5, C6	4.5	5.4	250	89,089
Area 2	C1, C2, A, D, E, F, G	11.6	7.1	820	299,554
Area 3	H, I, J, K, L	7.2	7.1	515	187,716
Area 4	M	5.2	8.0	420	152,005
Total		28.5		2,005	728,364

The average discharge rate for the LTA sites are derived from the LEI's soil assessment report (Appendix A), and the proposed LTA's ability to remove nutrients.

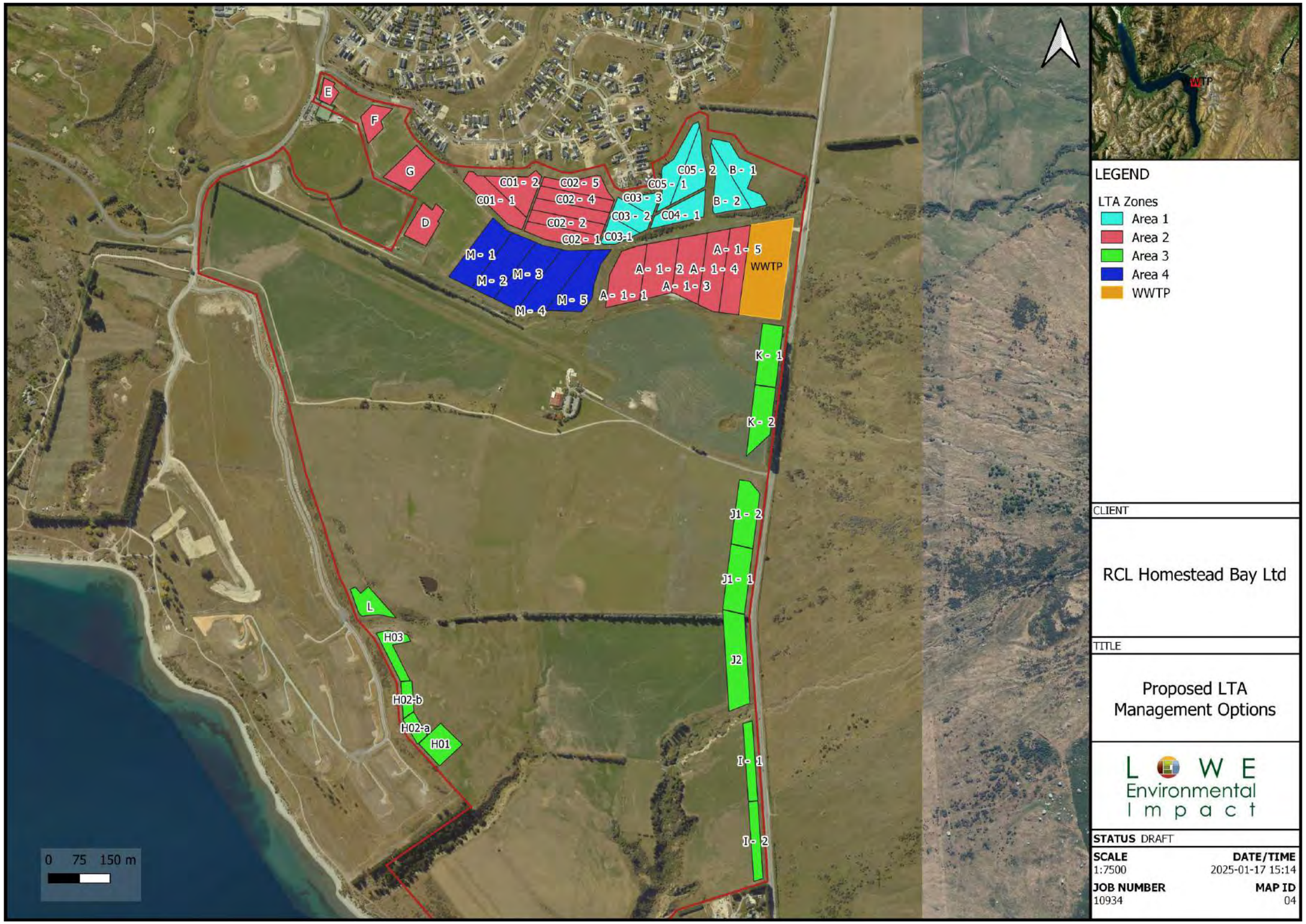

Figure 3.1: Proposed RCL Land Treatment Areas

It is emphasised that the above areas are, at this stage, indicative only. They have been nominated to create a plausible scenario using land owned by RCL that would not otherwise be developed. Over time some areas may not be needed (for example because the more conservative discharge rates are not observed) and there may be some reconfiguring of the size and locations of the LTAs through detailed design and through working with neighbouring landowners. It is therefore sought that any resource consent issued allow for flexibility as to the final locations of the LTAs, to allow pragmatic decisions to be made in the implementation of the scheme.

Using the wastewater effluent concentrations discussed in Section 3.2.2, the site loading for the development is assessed in Table 3.5.

Table 3.5: LTA Loading Scenario

Influent Source	Average Daily Flow (m^3/day)	Total Nitrogen @ 7.5 mg/L (kg/yr)	Total Phosphorus @ 2.5 mg/L (kg/yr)
General Activities			
Commercial Flows (Light) (Incl. Café, Retail and other)	37	102	34
School (600 students + 60 teachers/staff)	35	95	32
Sub Total	72	197	66
Domestic Activities			
592 Apartments	444	1,215	405
764 Terrace Houses	573	1,569	523
1,222 Standalone Houses	917	2,509	836
Sub Total	1,934	5,293	1,764
Total ADF	2,005	5,490	1,830
Land Treatment Area Selected			
LTA (ha)	28.5 (Hectares)		
Total Average Loading rate	7.1 mm/d	193 kg/ha/yr	64 kg/ha/yr

With the proposed PCDI system, further nutrient treatment is expected within the plant's root zone. A significant reduction in TSS and BOD_5, two key wastewater determinants, can also be expected, as well as removal of pathogens.

3.4 Wastewater Treatment Plant

There are numerous options for communal WWTPs suitable for RCL. Four activated sludge-type treatment systems have been considered, but others are available, including package plants or bespoke-designed plants.

The options considered include the following and are summarised in Table 3.6;

1. Submerged Aerated Filter (SAF);
2. Sequence Batch Reactor (SBR);
3. Membrane Bioreactor (MBR); and
4. Membrane Aerated Biofilm Reactor (MABR).

3.4.1 Submerged Aerated Filter (SAF)

The SAF system is a form of the activated sludge process (a wastewater treatment process characterised by a suspended growth of biomass), usually with a floating media to enhance biofilm development and with the settlement of solids taking place within a clarifier.

Wastewater enters a recirculating (primarily anaerobic) chamber where oxidising bacteria break down suspended solids; the influent is also mixed with returned activated aerated sludge from the clarifying chamber. This mixing stimulates bacteria and enhances the digestion of solids. Following primary treatment, wastewater enters an aeration chamber that contains submerged media on "bioblocks" (bioblocks allow for an increased surface area). Treated wastewater passes from the aeration chamber to a clarifying chamber, where the remaining particles of suspended solids settle out of suspension. The suspended solids that sink to the bottom of the chamber are drawn back to the first primary chamber for further processing or removed for disposal off-site.

The WWTP will be followed by further filtration (125 microns) and UV sterilisation to reduce pathogens.

3.4.2 Sequence Batch Reactor (SBR)

SBR is a form of activated sludge wastewater treatment. In a typical SBR process train, influent wastewater generally passes through screens and grit removal before the SBR. The wastewater then enters a partially filled reactor containing biomass, which is acclimated to the wastewater constituents during preceding cycles. Once the reactor is full, it behaves like a conventional activated sludge system but without a continuous influent or wastewater flow. The aeration and mixing are discontinued after the biological reactions are complete, the biomass settles, and the treated supernatant is removed. Excess biomass is wasted at any time during the cycle. Frequent biomass wasting holds the mass ratio of influent substrate to biomass nearly constant from cycle to cycle.

SBR technology generally requires a higher level of operator assistance to ensure the system is maintained and operating to a high standard; otherwise, it can be prone to failure and poor wastewater quality. SBRs are an aerated technology and, therefore, require a higher power input. They can reliably reduce nitrogen concentrations to low levels. As a result of the high level of aerobic microbial activity, a large volume of sludge is produced, requiring management and disposal.

SBRs have the ability to vary the treatment. The SBRs will be followed by further filtration (125 micron) and UV sterilisation to reduce pathogens.

3.4.3 Membrane Bioreactor (MBR)

A MBR system is a combination of the activated sludge process (a wastewater treatment process characterised by a suspended growth of biomass) with a micro or ultra-filtration system that rejects particles above 0.1 – 0.4micron in size (which is smaller than an individual bacteria). MBRs have two basic configurations: (1) an integrated configuration that uses membranes immersed in the bioreactor, and (2) a recirculating configuration where the mixed liquor circulates through a membrane module situated outside the bioreactor.

The key benefits of MBR technology for this application include:

- Reliably high level of treatment achieved
- Very compact process
- Good at handling seasonal loads
- Good at treating high strength wastewater
- Physical barrier prevents bacteria entering the treated water
- Physical barrier provides exceptionally clear, low turbidity permeate suitable for further disinfection via UV irradiation or chlorine disinfection
- Treated water is suitable for municipal reuse such as garden watering

3.4.4 Membrane Aerated Biofilm Reactor (MABR)

MABR is a modified activated sludge process, where the conversion of ammonia in raw wastewater to nitrate, known as nitrification is carried out in a compact and energy efficient manner. An MABR is characterized by submerged gas transfer membranes which provide air directly to a biofilm attached to the surface of the membrane. The gas transfer membrane allows for efficient oxygen transfer, applied directly to the biofilm carrying out the nitrification reaction.

In an MABR, the aeration membrane is not used to filter the water. Instead, it is used to provide oxygen-enriched air to the process biology, replacing the conventional fine bubble diffuser. In doing so the oxygen is introduced in the molecular, or 'bubbleless' form. This leads to highly efficient oxygen transfer, since the oxygen is no longer limited by diffusion from the inside of the air or gas bubble to the gas bubble surface and then across the surface to the surrounding water.

Because the membrane is being fed with molecular oxygen and is immersed in the tank being fed with the influent wastewater containing biodegradable organic matter, a biofilm forms on the membrane surface. An MABR is therefore an example of a 'fixed film' process - like a trickling filter or a moving bed bioreactor - as opposed to a purely suspended growth process (i.e. one based on activated sludge), as is the case for the MBR.

The MABR still has a mixed liquor of suspended particles, as with other fixed film processes such the moving bed bioreactor (MBBR), but at lower concentration than the MBR. Biological treatment is thus achieved both by the biofilm and by the suspended flocs.

As an MABR process is usually implemented as a part of a modified activated sludge process, it can often be used to improve the performance of other treatment processes that are based on the activated sludge process, such as SBR and MBR treatment plants. Improved performance, a smaller plant footprint, and improved OPEX costs can be gained through the addition of MABR treatment to these processes. This would allow the aeration membrane to be added over time allow staging enhancement of a SBR or MBR initial plant.

The major benefits of MABR treatment processes include:

- They are easily scalable and can be designed to be modular
- Extremely robust when faced with fluctuating flows and loads
- Excellent performance at low temperatures.
- They typically produce much less waste biological sludge due to the high efficiency of the biofilm requiring less biology to achieve the same rate of nitrification compared to other conventional treatment systems.
- Lower sludge production means lower operational, and disposal costs associated with sludge handling.
- By virtue of their energy efficient design, they offer better environmental performance when measured against other conventional treatment options

3.4.5 Summary of Communal System Options

The summary table below provides a qualitative assessment of the treatment system parameters, but weighting factors that are important to RCL need to be put against it.

The activated sludge is an appropriate technology for RCL that generally require a higher level of operator assistance to ensure the system is maintained and operating to a high standard. SBRs and MBRs are aerated technologies and, therefore, require a higher power input. As a result of the high level of aerobic microbial activity and the desire for Phosphorus removal, a large volume of sludge is produced, requiring management and disposal.

Table 3.6: Summary of Wastewater Treatment Options

Parameter	SAF	SBR	MBR	MABR
Capital expenditure	Moderate and high as capacity increases	Moderate	Moderate and high as capacity increases	Moderate and high as capacity increases
Running costs	Moderate to High	Moderate to High	High	Moderate
Additional carbon dosing	Possibly depending on required N conc	Possibly depending on required N conc	Unlikely	Unlikely
Power requirement	Moderate	Moderate	Moderate	Low
Modularity/staging	Moderate	Moderate	Good	Good
Maintenance requirement	Potentially High	Potentially High	Potentially High	Potentially High
Sludge production	Moderate to High	Moderate to High	Moderate	Moderate
Suitable for intermittent flow regimes	Moderate	Moderate	Low	Low
Remote servicing and trouble shooting	Yes	Unlikely	Unlikely	Unlikely
Operational complexity	Moderate	Moderate	High	High
Reliability	Moderate	Moderate to high	Moderate to high	Moderate to high
Wastewater treatment stability	Moderate	Good	High	High

The preferred WWTP type and supplier are likely to be determined following confirmation of the consented treatment standard, the LTA area, the development rate of wastewater flows (i.e. how modular the WWTP needs to be) and further evaluation attributes listed above.

Several suppliers and treatment processes are currently available to meet the likely final treatment standards (e.g. SBR, SAF MABr and Multistage Bardenpho). The systems generally have a low risk of odour; the treatment processes can be adjusted to meet possible future

increases in treatment standards; the treatment plant can be readily staged and scaled to suit growth; activated sludge treatment systems are well-known techniques and used to service 70% of New Zealand reticulated sewer networks population.

It is not proposed that the resource consent specify the exact type of WWTP to be selected. It is, however, understood that as a basis for initial high-level design, at the time of writing, the favoured technology is a combined MABR/MBR activated sludge process.

The WWTP treatment plant and LTA are considered an integrated treatment train for the wastewater. The land treatment system provides further nutrient and bacterial removal from the wastewater.

3.4.6 Staged Development

Adopting a staged approach to the WWTP and LTA area based on flow is possible. Stage One (up to 500 m^3/day) accommodates the plant's much lighter loading and the difficulty of operating an extensive, activated sludge treatment system with less than 50% design capacity compared to its final expected load.

Potential treatment standards and scenarios for possible staging the WWTP capacity and land treatment area are outlined in Table 3.7. The staging is to illustrate that there is flexibility in the WWTP capacity and LTA commissioning.

Table 3.7 Demonstrates possible scenarios, with differences in the number of lots, wastewater loading rate, and LTA area. This illustrates the options RCL has with timing to invest in the wastewater treatment plant and installed land treatment area.

Table 3.7: Potential Development Scenarios

WWTP	Stage 1	Stage 2		Stage 3		Stage 4		Stage 5	Stage 6
Lots or dwelling equivalents	500	750	1,000	1,250	1,500	1,750	2,000	2,250	2,578
Design Flow Rate (QLDC CoP) (m3/day)	375	563	750	938	1,125	1,313	1,500	1,688	2,005
Expected flow 520 L/lot (m^3/day)	260	390	520	650	780	910	1,040	1,170	1,390
Nitrogen concentration at WWTP (mg/L)	20	15	10	12	10	7.5	7.5	7.5	7.5
Nitrogen mass (kg/yr)	2,738	3,080	2,738	4,106	4,106	3,593	4,106	4,620	5,488
Area required to meet 220 kg N/ha (ha)	12.4	14.0	12.4	18.7	18.7	16.3	18.7	21.0	24.9
Hydraulic loading at minimum area (mm/day)	3.0	4.0	6.0	5.0	6.0	8.0	8.0	8.0	8.0
Likely LTA area (ha)	14.2 Area 1 and Pt Area 2			19.7 Plus Pt Area 3				21.5 Plus Pt Area 3	28.5 Plus Area 4 and Pt Area 2
Possible scenario loading (mm/day)	2.6	4.0	5.3	4.8	5.7	6.7	7.6	7.8	7.0
Consent hydraulic limit (PWWF) (mm/day)	5	8	11	10	11	13	15	16	14
Possible scenario nitrogen loading rate (kg N/ha/yr)	193	217	193	208	208	182	208	215	193
Proposed Consent limits (kg N/ha)	220								

By proposing a 220 kg N/ha/yr nutrient limit to any zone and a maximum hydraulic loading rate, RCL is seeking development flexibility by treating the WWTP and LTA area as a treatment train which can be built in stages in response to the speed of housing development occupation. This allows RCL to either improve wastewater treatment quality or increase LTA size as development occurs. Having a fixed input standard to the LTA for total nitrogen loading of 220 kg N/ha/yr and maximum hydraulic loading rates provides certainty about the standard of effluent (both quality and quantity) from the WWTP part of the treatment train, to both ORC as the regulator and RCL as the owner and operator of the WWTP system. The LTA part of the treatment chain is addressed later in section 5 and summarised in Table 5.6.

The likely LTA area for development and the order that LTA zones are brought online will be influenced by the subdivision staging, speed of property sales, subdivision stage title requirements and reticulation infrastructure.

4 DISCHARGE ENVIRONMENT

4.1 Soils Investigation

LEI undertook a soil investigation, which was completed between 4th and 7th June 2024. The soil profile at a number of sites was photographed and logged. The soil profiles typically comprised 0.35 m of weathered topsoil (organic silt) with roots throughout, underlain by a silt subsoil down to alluvial or colluvial gravels at depth. These soil profiles can be seen in more detail in the soil investigation report attached in Appendix A.

A summary of this work concluded a design irrigation rate (DIR) for each of the site's dominant soils, which the LTA area can assimilate on a continuous basis. These rates are given in Table 4.1 and the soil map for the site can be seen in Figure 4.1.

Table 4.1: Design Irrigation Rate for each Soil Type

Soil Type	DIR (mm/day)
Barrhill Soils	11
Pigburn Soils	41
Wakatipu Soils	7
Manmade Soils*	16

These DIR rates represent a percentage of the soil's saturated and unsaturated hydraulic conductivity rate and inform the system design along with the nutrient loading rate.

*Manmade soil refers to the area of RCL land which has received surplus soil material from the development at Hanleys Farm.

Table 4.2: Averaged LEI Test Pit Logs by Soil Family

m bgl	Pigburn	m bgl	Wakatipu	m bgl	Barrhill
SMap class	Weathered Fluvial Recent Soils		Typic Immature Pallic Soils (PIT)		Typic Immature Pallic Soils (PIT)
0 - 0.3	Moist, 10YR 3/2 (very dark greyish brown) coloured soil. Very slightly gravelly, sub-rounded, medium gravel. No mottles, non-sticky, non-plastic, silt loam. Apedal earthy. Soil strength is slightly firm, aggregate strength is weak and friable. Common fine roots. Boundary is abrupt and smooth.	0-0.35	Moist, 10YR 3/2 (very dark greyish brown) coloured soil. No gravels. No mottles, non-sticky, non-plastic, silt loam. Apedal earthy. Soil strength is slightly firm, aggregate strength is slightly firm and friable. Common fine roots. Boundary is distinct and occluded.	0-0.40	Moist, 10YR 4/2 (dark greyish brown) coloured soil. No gravels. No mottles, non-sticky, non-plastic, silt loam. Apedal earthy. Soil strength is slightly firm, aggregate strength is slightly firm and friable. Few fine roots. Boundary is sharp and occluded. Many worms and bioturbation into subsoil.
0.3-0.9	Moist, 10YR 6/2 (light brownish grey) coloured soil. No gravels. No mottles, non-sticky, non-plastic, sandy loam. Apedal single grain. Soil strength is weak, aggregate strength is weak and very friable. Few fine roots. Boundary is sharp and smooth. Some occlusions.	0.35-0.6	Moist, 10YR 5/8 (yellowish brown) coloured soil. Slightly gravelly, angular, medium gravel. No mottles, non-sticky, non-plastic, silt loam. Apedal massive. Soil strength is slightly firm, aggregate strength is slightly firm and brittle. Few fine roots. Boundary is sharp and smooth.	0.4-0.9	Moist, 10YR 5/4 (yellowish brown) coloured soil. Very slightly gravelly, angular, fine gravel. No mottles, non-sticky, non-plastic, silt loam. Apedal massive. Soil strength is firm, aggregate strength is weak and brittle. Few fine roots. Boundary is sharp and smooth. Oxide staining layers throughout the b horizon.
		0.6-1.8+	Slightly moist, 10YR 7/3 (very pale brown) coloured soil. Extremely gravelly, sub-rounded, very coarse gravel. No mottles, non-sticky, non-plastic, loamy sand. Apedal single grain. Soil strength is firm, aggregate strength is slightly firm and brittle. No roots. Concreted texture but water soaks away.		
0.9-1.1	Moist, 10YR 6/3 (pale brown) coloured soil. Very gravelly, angular, coarse gravel. No mottles, non-sticky, non-plastic, coarse sand. Apedal single grain. Soil strength is weak, aggregate strength is weak and very friable. Few fine roots. Boundary is sharp and smooth.			0.9-1	Slightly moist, 10YR 5/4 (yellowish brown) coloured soil. Extremely gravelly, angular, medium gravel. No mottles, non-sticky, non-plastic, coarse sand. Apedal single grain. Soil strength is very weak, aggregate strength is very weak and very friable. No roots. Boundary is sharp and smooth.
1.1-1.45	Moist, 10YR 6/1 (grey) coloured soil. Slightly gravelly, angular, fine gravel. No mottles, non-sticky, non-			1-1.4	Moist, 10YR 6/3 (pale brown) coloured soil. No gravels. Common fine 10YR 5/8 mottles, non-sticky, non-plastic, silt

m bgl	Pigburn	m bgl	Wakatipu	m bgl	Barrhill
SMap class	Weathered Fluvial Recent Soils		Typic Immature Pallic Soils (PIT)		Typic Immature Pallic Soils (PIT)
	plastic, fine sand. Apedal single grain. Soil strength is weak, aggregate strength is weak and friable. Few fine roots. Boundary is sharp and smooth.				loam. Apedal massive. Soil strength is slightly firm, aggregate strength is weak and brittle. Organic staining from roots. Boundary is sharp and smooth.
1.45-1.8+	Moist, 10YR 6/1 (grey) coloured soil. Very gravelly, angular, very coarse gravel. No mottles, non-sticky, non-plastic, coarse sand. Apedal single grain. Soil strength is very weak, aggregate strength is very weak and very friable. Few fine roots. Mixture of size class gravels.			1.4-1.7+	Moist, 10YR 6/3 (pale brown). Extremely gravelly, angular, very coarse gravel. No mottles, non-sticky, non-plastic, coarse sand. Apedal single grain. Soil strength is weak, aggregate strength is weak and friable. No roots. Mixed size of gravels and sand.

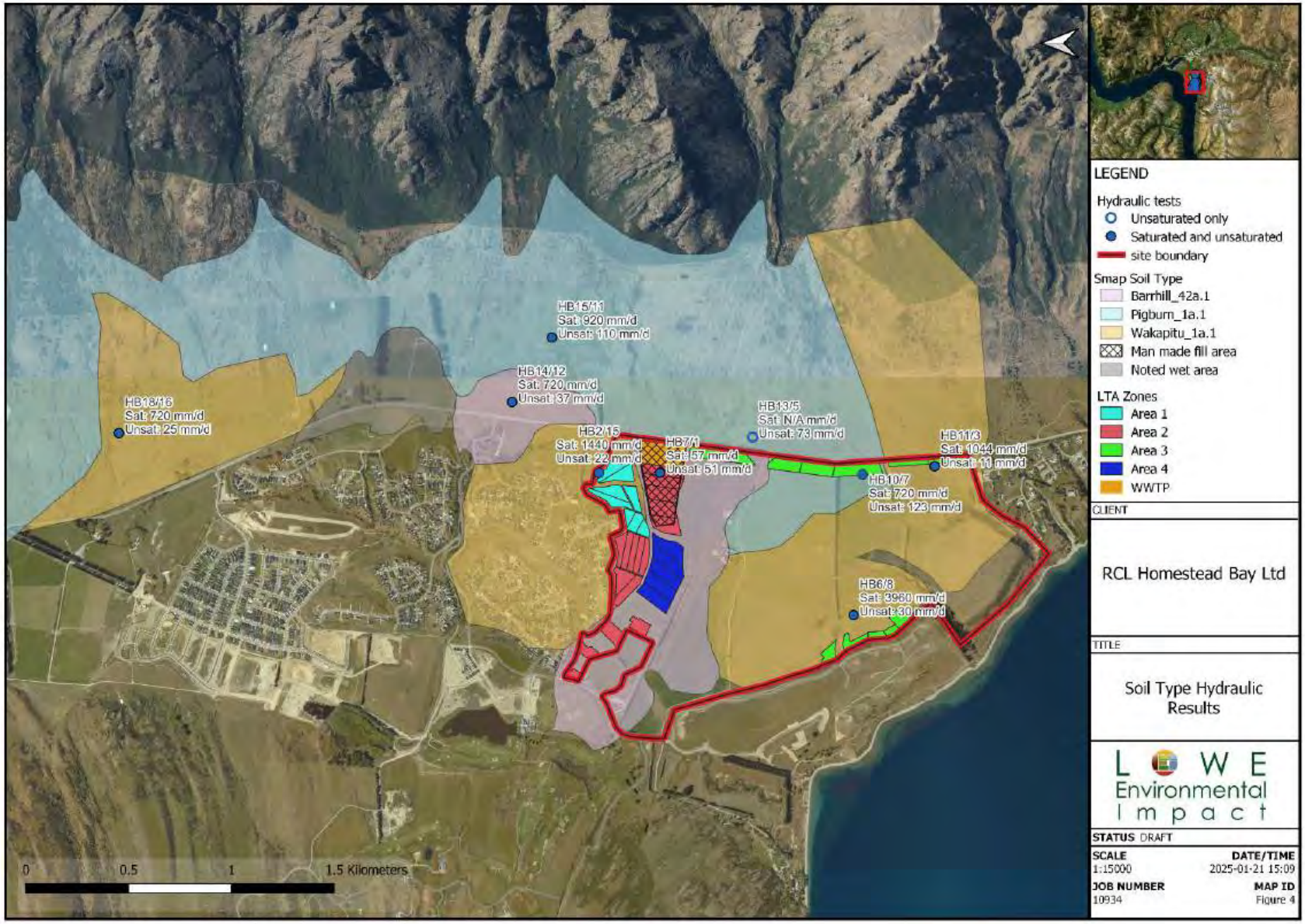

Figure 4.1: Soil Hydraulic Testing

4.2 Groundwater

4.2.1 Geology

Geological maps indicate that the site comprises Holocene alluvial fan and lake deposits overlaying a metamorphic basement of schist. The deposits have formed as part of an ancient outlet of Lake Wakatipu to the Kawarau River.

Bore logs indicate the alluvium likely extends to 40+m across the site, shallowing toward Jacks Point.

4.2.2 Hydrogeology

In the alluvial fan deposits and fluvial sediments, the groundwater is likely to act in an unconfined manner, with water levels controlled broadly by the lake level but varying with local recharge areas and topography. The Remarkables schist basement may provide a source of groundwater in basement rock fractures, but there is no information available for the site.

There is likely a groundwater divide within the surrounding surface catchment, with some shallow groundwater moving north toward the Kawarau River and some moving south to Lake Wakatipu.

There is some local confinement due to lake sediments (silts) toward the lake side of the property. Silts are recorded in Bore Logs' F42/0150 and F42/0150A near the surface (3 - 4 m), with water levels being in the order of 1 m below ground. These silts are not present in all the logs in the area and so may be of only local extent.

The direction of groundwater flow for the RCL's site is likely South-southwest, and Lake Wakatipu is the likely receiving environment of surface and shallow groundwater.

One aquifer test (F42/0150) has been undertaken in the area, indicating the sediments are relatively transmissive. Testing estimated an aquifer transmissivity (T) of 1,127 m^2/day.

Geosolve's geotechnical investigation drilled three bores for deep investigation, and 46 shallow test pits cross the Lot 8 land holding. The map of the testing locations is shown in Appendix C.

4.2.3 Water Levels

Based on water level data held by Otago Regional Council (ORC), groundwater levels are unlikely to be within 2 m of the ground surface across the site.

No groundwater was observed in the test pits to a depth of 1.8 m, with mottling only observed in one location.

Geosolve bore holes and test pits intercepted groundwater at depths in only some locations, as presented in Table 4.3.

Table 4.3: Geosolve Groundwater Data (Appendix C)

Bore Test pit	Water Depth bgl
BH1	5.2 m
BH2	7.3 m
BH3	4.9 m
TP07	4.2 m
TP09	3.1 m
TP14	4.1 m
TP41	2.6 m
TP42	1.9 m
TP47	0.9 m

The shallow water in TP42 and TP47 reflects the existing ephemeral stream surface water channels. No shallow groundwater was found in the other test pits undertaken by either LEI or Geosolve Ltd.

4.2.4 Well Distribution

Well depths range from very shallow (< 5 m deep), to the deepest at 55 m below ground level, located at Lakeside Estates, Southeast of the site.

4.2.5 Bore Logs

Appendix C contains drilling logs for the deeper wells in the area and the investigation wells drilled by Geosolve.

4.3 Surface Water

4.3.1 Water Conservation (Kawarau) Order 1997

Lake Wakatipu is listed in Schedule 2 of the Water Conservation (Kawarau) Order 1997, which sets out the characteristics of the waters to be protected because they are considered outstanding. Restrictions and prohibitions include fish passage to be maintained and water quality to be managed to Class AE (for aquatic ecosystem purposes), CR (for contact recreation purposes), F (for fishery purposes), and FS (for fish spawning purposes) standards. A detailed analysis of receiving water standards for different streams and lakes is presented in the LWP report (LWP 2025).

4.3.2 Lake Wakatipu Surface Water Catchment

Lake Wakatipu has an area of 291 km^2 with an average depth of 230 m. The total volume of the lake is 66,930 million cubic metres. All forms of recreational boating are undertaken on the lake. The shores of the lake are popular for picnicking, swimming, fishing and passive recreation.

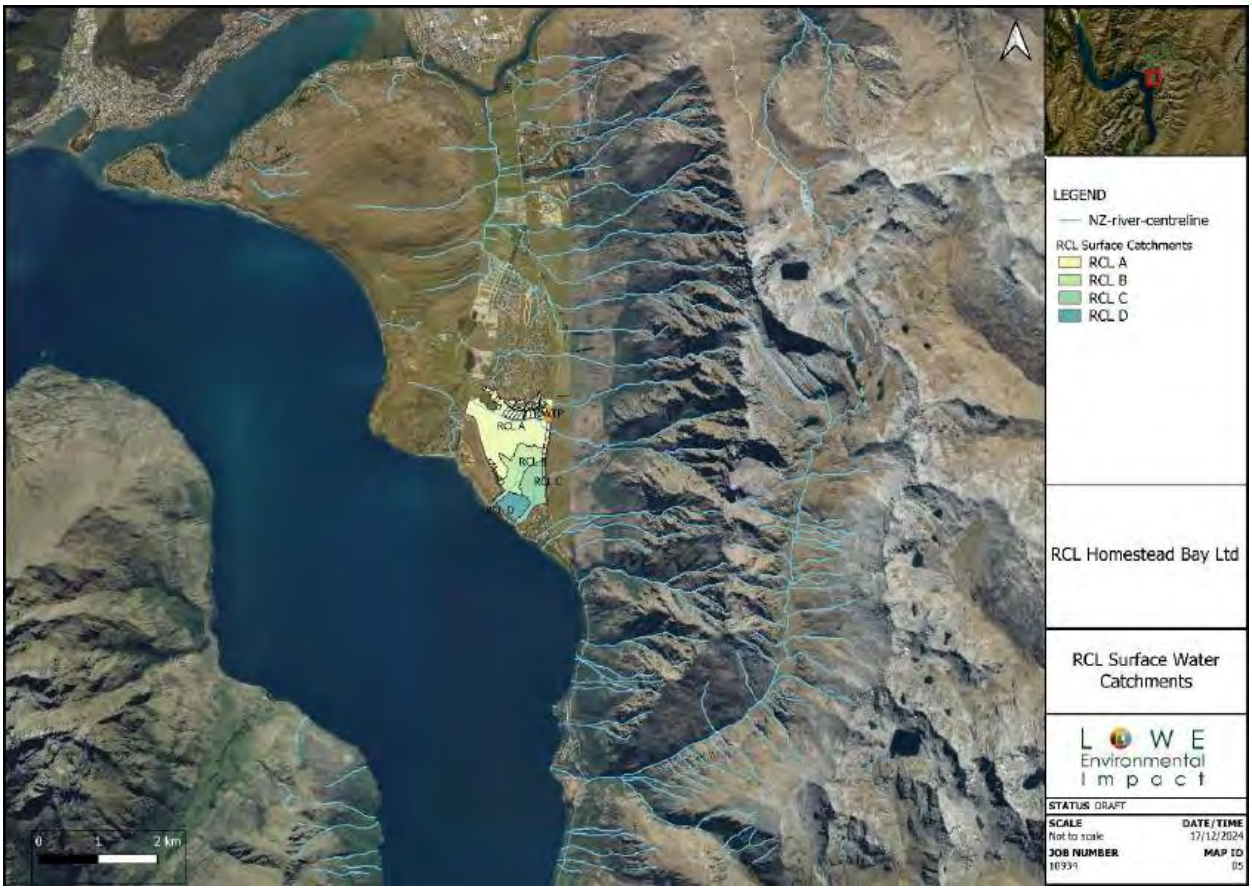

Figure 4.2: RCL Surface Water Catchments

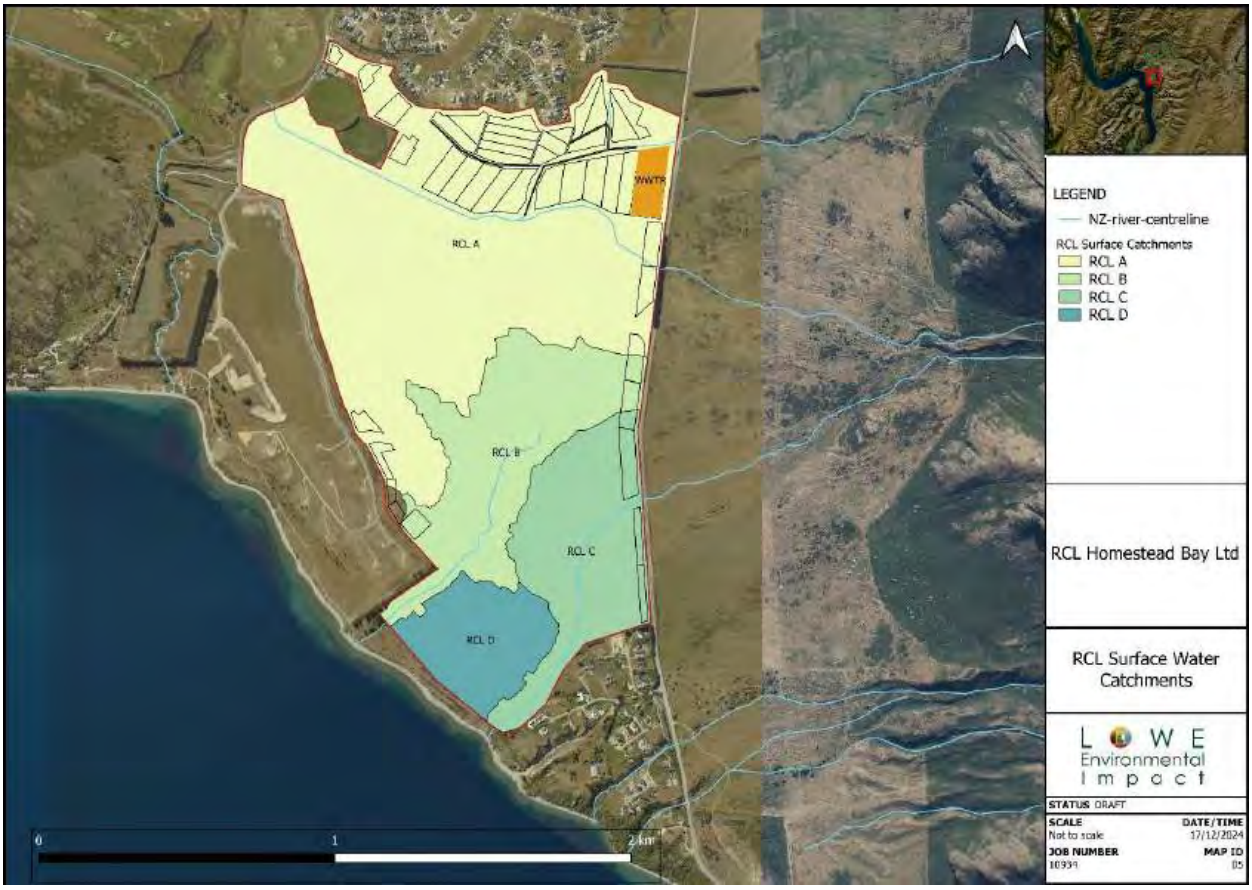

Figure 4.3: RCL Catchments and Potential LTA Locations

Table 4.4 Presents the area of each surface water catchment (derived from contour analysis) relative to the RCL site. Nutrient leaching for water applied to RCL A would contribute to groundwater, Lake Wakatipu and potentially surface water, if groundwater enters the lower reach of Jacks Point Stream.

Wastewater is also proposed to be applied in Catchments RCL B and RCL C. The associated drainage is expected to enter groundwater, and, ultimately Lake Wakatipu as presented in Figure 4.2 and Figure 4.3. Additionally, while thought to be an unlikely scenario, it is possible that some treated wastewater could indirectly enter into the unnamed watercourses 1 and 2 via groundwater. No wastewater is proposed to be applied in catchment RCL D which is only rainfall fed.

Table 4.4: RCL Surface Water Catchment Areas

Catchment	Lake Wakatipu Catchment (Ha)
RCL A	122
RCL B	36
RCL C	30
RCL D	16

4.3.3 ORC Water Quality Monitoring

Otago Regional Council carries out long-term water quality monitoring as part of its State of the Environment programme, and short-term monitoring programmes are carried out in some catchments to provide more detailed information. These programmes assist with regional planning and provide an understanding of the need to protect water quality.

Lake Wakatipu's average water quality readings between 2015 and 2022 are shown in Table 4.5 below. Lake Wakatipu is classified as Group 5 for receiving water, as categorised by the Regional Plan: Water for Otago (RWP) which sets limits as shown in Table 4. Sampling undertaken by ORC in the lake and at the outlet to the Kawarau River shows all the determinants are much lower than these limits. A mid-lake monitoring site has also been developed, the data from which will be included in the detailed assessment to support the consent application.

Table 4.5: Lake Wakatipu Median Water Quality at the Lake Wakatipu Open Water 10 m (2015 and 2022)

		Water Quality (Lake Wakatipu Open Water 10 m)	ORC-RWP Limits for Lake Wakatipu in RWP Schedule 15 (Table 15.2.5)
	Unit		
TP	g/m^3	0.002	0.005
TN	g/m^3	0.065	0.1
E. Coli	No./100 ml	<1.0	10
NH_4-N	g/m^3	0.003	0.01
Turbidity	g/m^3	0.6	3

Trophic level index (TLI) is a common method for describing the health of lakes. It is an indicator of how much growth or productivity occurs in the lake, with productivity directly related to nutrient availability. A microtrophic lake has a trophic level of less than 2. This indicates that the lake has low productivity, and the water quality is very good, with very low levels of nutrients and algae and high oxygen levels. Oligotrophic lakes have relatively low levels of nutrients, sparse growth

of algae and high oxygen levels. Lake Wakatipu has good water quality, with a trophic level of 2 – 3. Lake Wakatipu's TLI is shown in Figure 4.4 below.

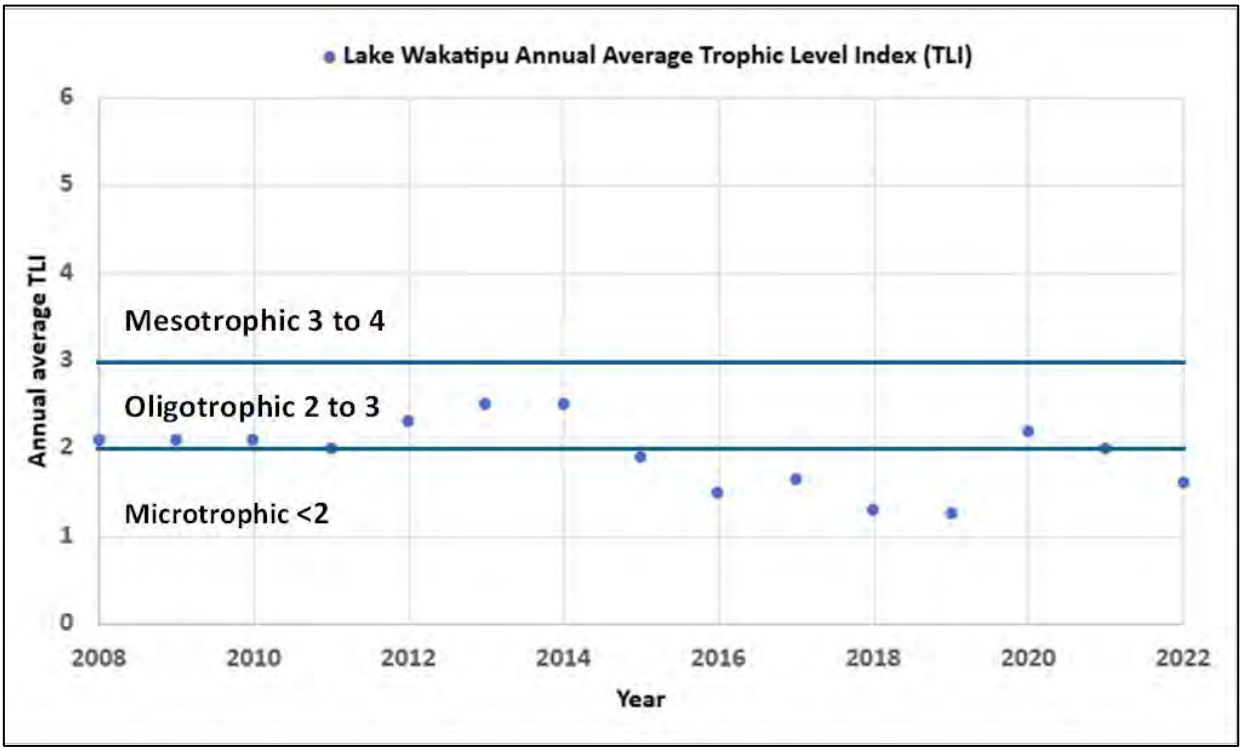

Figure 4.4: Lake Wakatipu Trophic Level Index (2008 to 2022, LAWA Data)

The Trophic Level Index (TLI) of Lake Wakatipu is low and reflects the current landuse and nutrient losses.

5 DISCHARGE SYSTEM

5.1 Discharge Within the LTA

5.1.1 Network

Within each LTA area, water will be discharged at the required pressure into a number of the submains from the treated wastewater mainline. From the mainline, an automated valve will actuate before the water flows through the submain to each zone.

Each of the zones considered will allow for low-rate discharge at a design dry weather loading rate of between 5.4 and 8 mm/d based on the DIR of each zone and proposed landuse, as seen in Figure 3.1.

5.1.2 Application Rate

The DIR of the proposed LTA areas are given in Table 5.1.

Table 5.1: Proposed Design Irrigation Rate for each LTA

LTA	Area (ha)	Soil Type	Modelled DIR (mm/day)	LTA Dry Weather Flow (CoP) (m^3/d)
A	5.5	Manmade	7.1	393
B	1.5	Wakatipu Soils	5.4	80
C01, 02	4.2	Wakatipu Soils	7.1	301
C03, 04, 05	3.0	Wakatipu Soils	5.4	149
D	0.6	Barrhill Soils	7.1	40
E	0.2	Barrhill Soils	7.1	14
F	0.4	Barrhill Soils	7.1	29
G	0.7	Barrhill Soils	7.1	48
H	1.4	Wakatipu Soils	7.1	114
I	0.9	Wakatipu Soils	7.1	64
J	3	Pigburn Soils	7.1	214
K	1.5	Barrhill Soils	7.1	107
L	0.4	Wakatipu Soils	7.1	31
M	5.2	Barrhill Soils	8	421
Total	28.5			2,005

The soil types and proposed DIR confirm that the estimated ADF for the RCL development option of 2,005 m^3/d can be discharged within the proposed 28.5 ha LTAs at sufficiently low DIRs.

5.1.3 Zone Dosing

The dose volume will be developed using the design daily volume of 2005 m^3/day. The submain will be laid below the ground level and have sealed toby boxes at each control valve.

The LTA areas listed in Table 5.1 will be further divided into zones suitable for the LTA layout and total size, to match the land form, with an average size of zone being approximately 0.7 ha (7,000 m^2) and a range of 0.2 to 1.4 ha. These zones will be grouped to allow dosing and rest periods to cycle around the LTA area, ensuring that the treated wastewater loading meets the soil infiltration and to allow nutrient assimilation.

By way of example, the average irrigation zone will have approximately 7,000 m of dripper line at 200 to 300 mm depth (below any freezing layer), with 0.6 m spacing between drippers and the lines laid 1 m apart. Each dripper has a flow rate of 1.6 L/hr resulting in the discharge specifications seen in Table 5.2.

Table 5.2: Application System Specification

Description	Units	Data
System Type	-	Land Treatment Application
Application Area (Net)	ha	28.5
Application System	-	Subsurface drip
Lateral & Emitter Type	-	Anti syphon Pressure compensating Subsurface Drip
Minimum Emitter Pressure	m	11.0 (to achieve good flushing)
Emitter Discharge	L/hr	1.6
Emitter Spacing	m	0.6
Lateral Spacing	m	1.0
Lateral depth	m	0.2 to 0.3
System Application Rate	mm/hr	~2.67
Daily application	mm/day	Up to 8.0
Average Duration of One Operation	hours	2.6 (Range 2.2 to 2.99)

5.1.4 Pumping Duty

It is proposed that WWTP include treated water storage to allow for batch discharge of wastewater to the LTA. The daily volume will be partially stored and based on the level of the treated water storage; irrigation will occur. The discharge rate will be automated based on the zones next available for irrigation. At times of higher inflow, additional zones and pumps would be used to discharge the daily volume at a rate of up to 53 L/s. The proposed system's duty under normal operation and wet weather flows is presented in Table 5.3. The actual pump/s duty will vary based on the zones irrigating at any one time.

Table 5.3: Irrigation System Duty

DUTY TABLE (@Point of Connection)			
		Average Dry Weather Flow	Peak Wet Weather Flow
Dispersal Area	ha	28.5	28.5
Target Daily Discharge	m^3/day	2,005	3,973
Dispersal Equivalent Application Depth	mm/day	7.0	13.9
Dispersal Application Rate	mm/hr	2.67	2.67
Duration of one Operation (depending on the Zone DIR)	hrs	2.02 to 2.99	4.04 to 6.0
Max. Daily Operation Duration	hrs	21.05	20.86
Estimated Discharge Required	m^3/h	95.2 (5 zone combinations)	190.5 (10 zone combinations)
Estimated Discharge Required	L/s	26.5	52.9

5.1.5 Flushing

Flushing submains will attach with a tap to the end of each lateral. The flushing submains may be connected back into a mainline that can be automated to discharge into the influent sewer and be returned to the WWTP or discharged to land at the end of the laterals, which is more common.

5.2 Nutrient Loading Rate

Plant and microbial removal and the soil cation exchange capacity are the primary mechanisms for the assimilation of nutrients and water by land application systems. The plant system's total assimilative capacity depends on the land area utilised, with the loading rate refined based on the crop type and its management. Table 5.4 provides example nutrient uptake rates for different crop types.

Table 5.4: Crop Nutrient Uptake

Crop / Land use	N uptake (kg/ha/year)	P uptake (kg/ha/year)	Reference
Pasture – irrigated, cut and carry	500 - 600	130 – 160	Morton *et al.* (2000)
Pastoral – irrigated grazed system	200 - 240	52 – 64	FLRC (2009), Williams and Haynes (1990)
Standard Rotation Forestry – Pine	100 (kg/ha/year)	30 (kg/ha/year)	Nicholas (2003)
Standard Rotation Forestry – Eucalypt	50 (kg/ha/year)	10 (kg/ha/year)	Myers *et al.* (1999)
Native planting	100 - 200	35	Ongoing research by ESR and Canterbury University, initial findings that it is similar uptake to grazed pasture

Land use of the communal LTA is generally one of the following three methods stated in the order of preference for nitrogen renovation:

1. Cut and Carry (including complementary farming activities (crop));
2. Sheep grazing; and
3. Landscaped areas or cut and leave (including community green spaces and indigenous vegetation planting (biodiversity restoration)).

5.2.1 Cut and Carry

"Cut" refers to mowing grass or grass-type crops, tree felling (replanting with juvenile plants) or pruning vegetation back to stimulate regrowth; "carry" refers to removing all dry matter from the site for sale or grazing elsewhere. The removal of the cut material from the site will result in lower nitrogen leaching into groundwater.

5.2.2 Sheep Grazing

Sheep grazing removes dry matter (and thus nutrients) but recycles some nutrients back to the soil store; however the net input of nutrients from sheep urine and faeces back to the soil will be less than that eaten by the sheep and turned into meat, wool and energy. Sheep are generally rotated around the site to optimise grazing and vegetation removal.

5.2.3 Landscaped or Cut and Leave

This option is suitable if the lawn and landscaped areas are managed for aesthetic reasons for which vegetation growth and removal are undesirable. The net result is limited nutrient removal off-site if the clippings are not collected; the plant life cycle of regeneration and decay will inevitably result in most nutrients taken up by the plants re-entering the soil matrix during the decay phase. However, plant uptake will slow the rate of nutrient leaching, and nitrogen losses occur due to denitrification. In addition, evapotranspiration will reduce hydraulic pressure on the soil. Some landscaping plants, such as Manuka, appear to have other benefits in wastewater LTAs. If Manuka or similar plants are added to the site, these are going to not only accumulate N and P but also have been shown to emit nitrification inhibiting and bactericide chemicals, reducing N_2O emission and killing harmful pathogens while enhancing native ecosystems.

5.2.4 LTA Management Summary

The LTA management can be a combination of all land use types with the wastewater application rate and timing matched to the above-ground land use. "Cut and Carry" lucerne or pasture where the site is not too steep for harvesting machinery provides a suitable supplementary feed source, while grazing or irrigation of regenerative vegetation is also feasible.

5.3 LTA Nitrogen Loading Rate

The management for Area 1 (Table 3.4) is planted native vegetation or light grazing, while other areas will be mown landscaped areas with grass cut and carried off site. Considering the information in the Table 5.4, it is assumed at full development that the proposed average loading rate of 193 kg N/ha/yr is a sustainable loading rate in the aforementioned LTA's.

During the initial stages, as housing connections come online and flows are less than 30% of the WWTP stage's capacity, the ability to remove nitrogen may be limited within the WWTP. This is proposed to be managed by applying higher nitrogen concentration wastewater to the LTA over a larger area, meeting an agreed capped nitrogen load (suggested to be 220 kg N/ha/yr). As the number of connections increases, there will be improved treatment quality, so that once flows exceed 30% of the WWTP capacity the system will be operating at progressively higher treatment standards and ultimately a treatment quality of a 12-month average total nitrogen quality of 7.5 mg/L.

5.4 Phosphorus Loading Rate

The P loading rate to the LTA surface is proposed to be up to 64 kg P/ha/yr. Phosphorus losses across the site will depend not only on plant uptake but also on soil adsorption capacity. The plant uptake and export within the supplement or turf clippings is estimated using Overseer to be 30 kg P/ha/yr. Allowing for plant uptake and export off the LTA area, the full design capacity net P loading to the soil matrix is 34 kg P/ha/yr.

5.5 Current Land Use and Permitted Baseline Loss

Wastewater systems

The Otago Regional Council (ORC) manages small-scale discharges from small-scale septic tanks, wastewater systems (discharge of less than 2000 litres per day) and long drops using Permitted Activity Rules 12.A.1.1 to 12.A.1.4 in the Regional Plan: Water for Otago (RPW) Plan. These permitted activity rules allow discharge of effluent, provided certain conditions are met. Within the permitted activity rule, the lot size is not a condition of the rule.

Application of Nitrogen

A landholding's diffuse N loss is managed under RPW. Under Rule 12.C.1.3 (a) (i) and Map H6 of the RWP, from 1 April 2026 it will be a permitted activity to apply nitrogen or use land in a way (across the total area of land managed by a landholder) that leaches up to 15 kg N/ha/yr. The nitrogen application rate is not limited under the rule, provided the residual leaching rate is less than 15 kg N/ha/yr modelled using Overseer® version 6 or later.

By way of comparison, this permitted N loss of 15 kg N/ha/yr across the proposed housing development area and Land Treatment Areas (LTA) could plausibly occur under a more intensive cropping and dry stock operation on this land. It is, therefore, a useful comparison of the proposal against what will be permitted by the RPW.

The permitted activity rule sets the landholding's permitted nitrogen mass that can be lost without consent. This means that the currently permitted leaching equates to a mass of 3,015 kg N/yr, being (201 ha x 15 kg/ha/yr) from the new subdivision and LTA area.

In relation to this proposal, this mass can be allocated between the loss associated with the new subdivision area and the loss from areas used for LTA.

The subdivision area is expected to leach 0 - 3 kg N/ha/yr from stormwater and gardens; for this development, the area is 172 ha equalling up to 517 kg N/yr, the remaining nitrogen mass of 2,498 kg N (3,015-517) can be applied to the LTA area of 28.5 ha LTA, allowing a permitted leaching rate from the LTA's of 87.9 kg N/ha/yr.

Table 5.5 shows the proposed loadings and N losses using OverseerFM modelling.

5.6 Overseer Outcomes

In addition to looking at the existing and permitted nutrient loss for the area, nutrient modelling using OverseerFM was undertaken. The current landuse nutrient budget and proposed system LTA nutrient budget were produced to indicate the potential leaching from the proposed application of treated wastewater on the LTAs. The input Nitrogen loading was applied at a rate of 149 to 222 kg N/ha/yr evenly across the year.

Nitrogen loading was applied as a soluble fertiliser, such as nitrate, to 28.5 ha of blocks. Using nitrate is conservative, as some of the WWTP effluent nitrogen will be in an ammoniacal form that is more tightly adsorbed onto soil cation exchange sites than soluble nitrate.

In the proposed LTA system, OverseerFM modelling applied the wastewater as irrigation in the form of drip irrigation. The total application depth modelled varied evenly across the year from 2,064 mm to 3,060 mm. There is no seasonal variability in the modelled irrigation depth.

A cut and carry system involves removing cut pasture and removing it off the site, which is applied to 24 ha of the land treatment area, with the remaining 4.4 ha modelled as lightly grazed by stock. The sheep grazing is to replicate irrigation of native plantings, and this cannot be modelled in OverseerFM.

The cut and carry is modelled as baleage or similar. For the OverseerFM model, 10 t DM/ha/yr of pasture silage was cut and exported off the 24 ha irrigated block. This model shows the effects of a typical cut-and-carry system, which could be conventional baleage or collected pastoral or turf grass cuttings.

The OverseerFM nutrient budget shows a total leaching value for the 4 different LTA areas to range from 60 to 91 kg N/ha/yr . This leaching is dominated by winter losses, as is to be expected, as irrigation is applied all year round (the nitrogen loss profile is similar to summer vs winter loss with the current farming operation). The total leaching value for phosphorus is 1.4 to 2.1 kg P/ha/yr. Table 5.5 presents a summary of the RCL OverseerFM modelling. Additional Overseer modelling is presented in Appendix B.

Table 5.5: Nitrogen and Phosphorus Leaching - RCL LTA Scenario Summary

Scenario	Description	N added or removed	(Kg/ha/yr)	P added or removed	(Kg P/ha/yr)
LTA	RCL Land Treatment Area (28.5 ha)	N Added:	193	P Added:	64
		N removed as supplements:	185	P removed as supplements:	30
		N lost to water:	62	P lost to Water (overland flow)	1.8
Balance of the land holding	Lot 8 and 12 housing area (172 ha)	N lost to water:	2.2	P lost to Water (overland flow)	<0.1
Total Land Area Summary	201.5 ha	Total Development Area Average	10.2	Area Average	0.3

With the development of the WWTP and LTA's, there will be a potential increase of 212 kg nitrogen from what is currently occurring with the land and a reduction of 964 kg N able to enter the environment every year compared with the RPW allowable N loss. This equates to an 11 % increase over current landuse, and a decrease of 31% compared to the RWP "baseline" leaching[3].

[3] ORC Regional Water Plan permits leaching of 15 kg N/ha/yr for land in nitrate sensitive catchments

The calculation of Nitrogen loading pre and post proposed development are presented in Table 5.6. During the initial development period, as stages of the new subdivision are developed, the net reduction is expected to be greater.

Table 5.6: Nitrogen Budget Pre and Post-Development Nitrogen Leaching Estimate Land Use Area (ha) N Leached (kg/ha/yr) (kg/yr)

Pre-Development Nitrogen Leaching Estimate			
Land Use	Area (ha)	N Leached (kg/ha/y)	(kg/y)
Farmed area of subdivision and LTA permitted	201	15	3,015
Current landuse uses	201	9.1	1,839
Post-Development Nitrogen Leaching Estimate			
Land Use	Area (ha)	Overseer estimated N Leached (kg/ha/yr)	(kg/yr)
LTA (now including town and new housing development)	28.5	72	1,656
New housing development and recreational areas	172.6	2	395
Total Post-development	201		2,051

OverseerFM also presented the drainage nitrogen concentration associated with leaching. In the current farming system the drainage volume represents the balance between rainfall and evaporation. The concentration of N is reported to decrease with the LTA development due to increased drainage from the irrigation, adding to the water balance.

5.7 Alternative Literature Assessment Method

An alternative analysis to OverseerFM to estimate the leaching from the land treatment area is to consider research undertaken by Beggs et. al. (2011). Beggs found that wastewater applied to land undergoes further biological processes, with research trials indicating that the concentration of nitrogen applied to the soil by wastewater treatment systems via subsurface drip irrigation is not 100% lost via leaching.

In the soil, many other processes utilise the nitrogen that is applied. Secondary treated wastewater systems can be used with sub-subsurface drip irrigation. Subsurface drip irrigation is more effective at removing nitrogen as it is located around 200 mm below ground and applies around 7 mm of treated wastewater per day to the active subsoil layer. Biological processes can further break down the nitrogen in the sub-surface layer, taken up by plant roots for growth, and exported by cut and carry harvesting systems.

The soils of the land treatment area are considered to be equivalent to a silt loam soil (Loam). Based on the findings of Beggs et. al., (2011) (see Figure 5.1), the fate of wastewater nitrogen applied to land via subsurface drip irrigation in a Loam soil is:

- 0 – 32% lost via root uptake from plants;
- 40 – 62% lost via Denitrification; and
- 30% lost via leaching

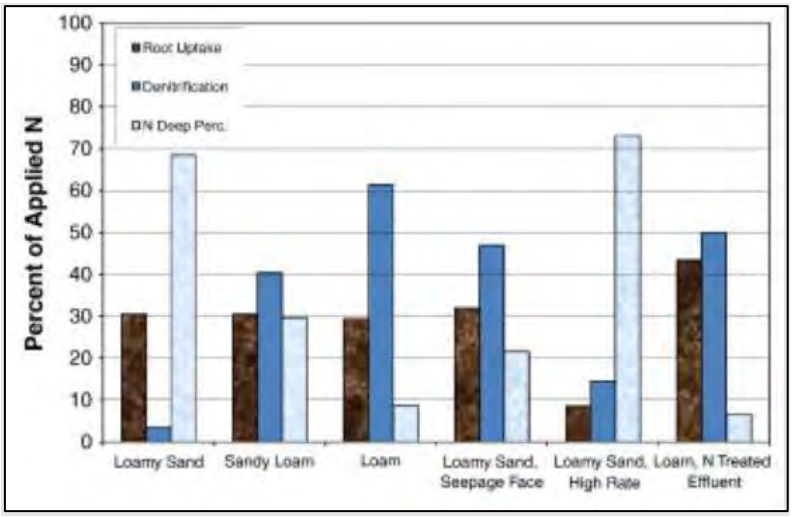

Figure 5.1: Fate of Nitrogen in Wastewater Effluent Applied to Land (Beggs, et. al., 2011)

For the proposed LTA system, if 193 kg N/Ha/yr is applied to 28.5 ha LTA, using Beggs et al., (2011), 8% to 30% estimation being leached below the root zone equates to 15 to 57 kg N/ha/yr. This is comparable to the OVERSEER® estimate in the section above for cut and carry of 72 kg N/ha.

Table 5.7 shows the total nutrient loss for the baseline current farming system on the RCL land, which, with QEII, is operated as one farming unit, and future scenarios of removing the RCL land from agricultural production and adding the different LTA areas.

The nitrogen is removed in the cut and carry process, and a proportion of nitrogen is lost to the water (leached). The difference between the nitrogen gained and lost is due to other losses that occur, for example, the transfer of nitrogen into the atmosphere.

Table 5.7: Total Nutrient Losses for Baseline and the RCL Scenarios

	Total losses				
Analyses	N (kg/y)	N (kg/ha/y)	P(kg/y)	P (kg/ha)	GHG (t)
Year 23-24 farm use and a combined QEII and RCL operation	8,039	9.0	128	0.1	3,121.7
23-24 RCL- Only Blocks*	1,839	9.1	7	0.1	
RCL LTA	2,052	10.2	61	0.3	91.9

* Refers to the total N losses/y from those located at RCL (Lot 8, lucerne, barley and Lot 12)

5.8 Phosphorus

As previously discussed in Section 3, the proposed application rate will be approximately 64 kg P/ha/yr. This rate is less than the suggested phosphorus plant uptake capacity of 130 kg P/ha/yr – 160 kg P/ha/yr (Morton et al., 2000) for a cut and carry regime and but greater than estimated for the current farming operation by OVERSEER® of 34 kg P/ha/yr.

The soil's P retention properties were investigated to assess the fate of the surplus P (30 kg P/ha if using the 34 kg/ha uptake from OVERSEER®). Phosphorus is a cation (unlike nitrate, an anion)

and is not very mobile within the soil profile. The soil test analysis shows that the proposed LTA soil profile can retain large amounts of added P before the P migrates further down the soil/subsoil profile. In Table 5.8, the P retention has been calculated for the first 1.5 m of the soil/subsoil profile based on the Landcare Research laboratory analysis. Using 1.5 m is considered conservative, and depending on the depth of groundwater, there is a potentially greater subsoil depth for P storage.

The P retention analysis suggests that P supplied over 135 years at full loading rates can be stored within the first 1.5 m of the soil profile before significant P migration to lower subsoils. This storage potential is much greater than the proposed consent duration of 35 years. Providing the land application of treated effluent is discontinued before the soil's capacity to absorb phosphorus is reached, the phosphorus would be expected to remain embedded in the soil, posing no environmental risk.

Table 5.8: Phosphorus Storage Capacity

Parameter	Manmade Soil	Pigburn (Sites: HB 8/2, HB 9/6, HB 10/7)	Wakatipu (Sites: HB 6/8, HB 5/9, HB 1/14, HB 2/15)
Bulk Density (kg/m^3)	1,300	1,300	1,300
Average P Sorption (mg/kg)	321	235	508
Treatment Soil Depth (m)	1	1	1
P Storage Capacity (kg P/ha)	4,175	3,052	6,607
Design P Storage Capacity (kg P/ha)	4,611		
P Loading Rate less DM export (kg P/ha/yr)	34		
Site Life (years)	135		

Therefore, the leaching/runoff of total phosphorus and DRP off the LTA is expected to be low given:

- The conservative average hydraulic rate application rate (average 7 mm/d);
- The large P retention capacity of the soil;
- The added wastewater P is the primary source of phosphorus for the plant uptake; and
- There is a considerable vertical distance to any ground or surface water.

There is a low potential for phosphorus leaching to groundwater due to the large depth of soil matrix before any potential groundwater, and most, if not all, phosphorus will be retained within the soil profile and not be leached to groundwater and ultimately, Lake Wakatipu.

5.9 Service Structure

The WWTP will likely be constructed in the ground and designed to mitigate the aesthetic effects. It will also be fenced and planted to limit access to maintenance and monitoring staff.

The use of subsurface drip irrigation allows the treated wastewater to be discharged into the topsoil layer within the root zone, allowing flow through natural soil (silts, sands, and gravels), adsorption, and dispersion of the contaminants of concern within the ground and groundwater before flowing into the surface water receiving environment.

The effluent discharged into LTAs will be safe for recreational contact, meaning co-use with passive recreation activity can be a practical outcome.

The Remote Telemetry Control (TCOM) will allow various functions, including remote monitoring capability, electronic logging of effluent flows, pump run times and alarm logs with audible and visual alarm features.

6 OPERATION REGIME

6.1 Daily Operation

The maximum daily discharge at the site will be the wet weather flow volume, as discussed in Section 5. The proposed staged flows for the LTA will be determined based on the staging of the development, as seen in Figure 3.1. Each zone will be designed for the discharge at a rate of 2.6 mm/hr, i.e. to apply 7 mm/day. The irrigation system will operate in that zone for 2.7 hrs. The duration of irrigation each day or return period determines the daily average discharge during dry weather flow based on the irrigation depths specified in Section. 5.1.2 and 12 to 16 mm/d for short periods of wet weather.

The dose volume can be managed to each zone, allowing the resting of the LTA and zone rotation. This operation is proposed to be automated to meet each zone's infiltration capabilities and will allow the control of the volume discharged per day.

Further information on the daily operation will be included in an Operation and Management Plan (OMP). The OMP is typically proposed as a condition of consent and incorporates information needed to demonstrate compliance with consent conditions.

6.2 Seasonal Operation

The daily operations will remain very similar throughout the year. However, the flows for the WWTP are likely to fluctuate with the higher stormwater I/I. This profile will result in the frequency of the dosing to each zone increasing up to the daily discharge depth or shorter return cycle.

During times of high flows, the water will be treated, and some buffering storage will occur within the WWTP.

6.3 Monitoring

Surface water quality in the streams and groundwater monitoring may be a requirement of the consent. Further information on the monitoring will be included in the OMP required as part of the consent compliance.

6.4 Surface Flow

The proposed PCDI discharge is to the subsurface soils at rates which are well below the soils hydraulic capacity, so there will be no ponding of treated wastewater. The DIR will also ensure that the breakout of the treated wastewater does not occur.

The recommended LTAs include some sloping sites. As an extra assurance, on the more highly sloped land associated with Area 1 irrigation zones and along the hill slope toe for Area 2, the proposal is to include subsurface French drains (Figure 6.1) to intercept any lateral flow and allow for this to infiltrate into the deep subsoil or to be collected for discharge into a wetland system. The conceptual location of the drains is shown in Figure 6.2.

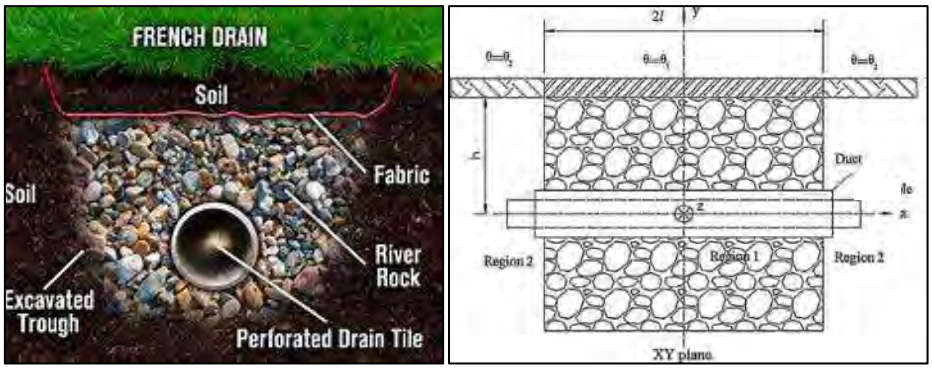

Figure 6.1: Indicative French Drain Design

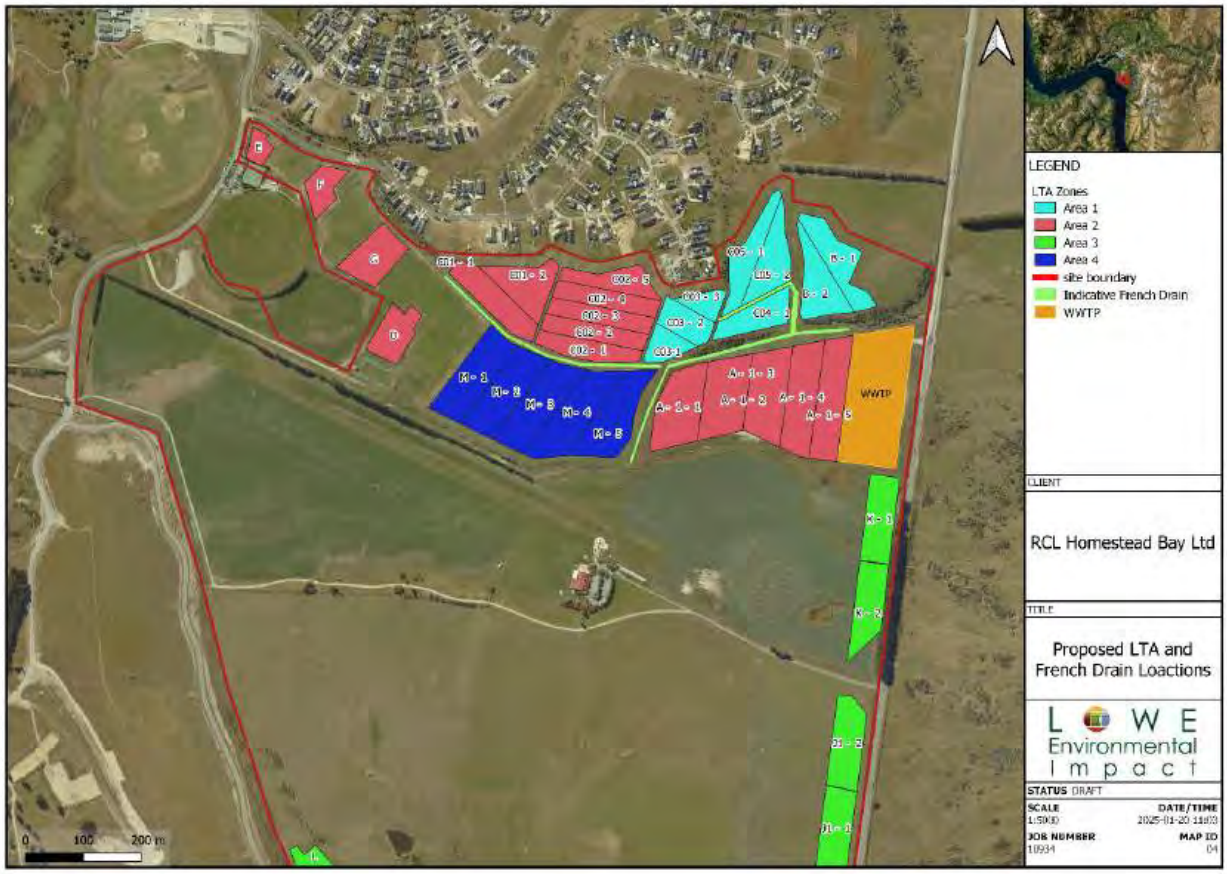

Figure 6.2: Indicative French Drain Location

7 CONCLUSIONS AND RECOMMENDATIONS

This concept design report demonstrates there is a feasible treatment chain involving a WWTP and LTA discharge options that can be configured, flexibly implemented and managed to treat the development's WW to achieve a very small increase in current total losses of nutrients from the site if the QLDC COP flows occur, while being considerably (about 30%) lower than the total site loading calculated as being permitted under the RWP. Designing the wastewater treatment and discharge system the system to align with the expected nutrient losses from this landform enable social, economic, and cultural well-being of the Queenstown Lakes District Council (QLDC) community to be met while minimising adverse environmental effects.

Key conclusions include:

1. Sustainability: The system facilitates the beneficial reuse of water and nutrients. The staged development approach ensures flexibility as wastewater flows increase.
2. Nitrogen Management: The system manages total nitrogen (TN) leaching potential through a combination of optimised treatment at the WWTP and efficient land application.
3. Environmental Protection: Subsurface drip irrigation and conservative hydraulic loading rates minimise the risk of groundwater contamination and surface water impacts.
4. Future Steps: The next phase involves preparing the discharge consent application, detailed nutrient loss assessment, and environmental effects studies. .

Overall, the proposed design is intended to meet regulatory requirements while providing a robust and scalable wastewater treatment solution for the Homestead Bay development.

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9 APPENDICES

Appendix A Soil Assessment
Appendix B Overseer Modelling
Appendix C Geosolve Logs

APPENDIX A
Soil Assessment

MEMORANDUM Job 10934

To: Dan Wells, RCL

From: Millie Taylor and Shamim Al Mamun, Lowe Environmental Impact

Date: 23 September 2024

Subject: Homestead Bay Development Soils Site Investigation

Dear Dan,

The following information outlines the results of the site investigation into the potential of wastewater dispersal at the Homestead Bay and QEII sites, based on LEI staff's visit on June 4th to 7th, 2024.

OVERVIEW

RCL Homestead Bay Limited (RCL) is investigating the Homestead Bay and QEII properties south of Jacks Point on Kingston Road SH6 to discharge community-treated wastewater to multiple land treatment areas (LTA). The sites have been earmarked due to their proximity to the proposed subdivision and available suitable land.

The sites are currently owned separately by RCL and QE11. The RCL site is located on Lot 8 DP 443832 (163.46 ha), while the QEII farming block is located on titles Part Lot 1 DP 26261 (656.94 ha) and Lot 2 DP 26261 (205.98 ha). Part of the RCL lot has been used previously for clean fill, but the rest of the site is low-sloping to rolling pasture with some cattle grazing. The QEII site is generally steeper at the foot of the Remarkables and is pasture with a small area of cropping and deer/cattle grazing. The QEII land is dominated by gravels due to the relative proximity to the mountains, whereas the RCL land has a deeper loess profile. Both sites are consistent with the S-map descriptions and what is expected from the current classification.

DESKTOP SOIL CHARACTERISTICS

Landcare Research Soils Map

An assessment of the area's Landcare Research soil map (S-Map) suggests the soil is classified as Typic Immature Pallic Loam with well-drained rapid permeability, as attached in Appendix B. The S-Map also suggests a very low water logging vulnerability and medium nitrogen leaching vulnerability.

The soil type specific to the site was confirmed in the LEI site investigation (this report).

Jacks Point Soils Investigation

The Homestead Bay residential zoned area occupies sloping topography from the east down to the flats of the central plain area south of the Jacks Point development. In the assessment of the soils from Jacks Point, the land consists of four main soil types.

Table 1: Soil Information

Soil Family	Characteristics (S-Map)	Irrigation Suitability
Wakatipu	This soil belongs to the Pallic soil order of the New Zealand soil classification. Pallic Soils have pale coloured subsoils, due to low contents of iron oxides, have weak soil structure and high density in subsurface horizons. Pallic Soils tend to be dry in summer and wet in winter. It is formed in a blanket deposit of silt sized windblown materials overlying poorly stratified poorly sorted gravel sand and mud deposited from glacial ice or meltwater, from schist parent material. The topsoil typically has loam texture and is stoneless. The subsoil has dominantly loam textures, with a very gravelly layer from less than 45 cm mineral soil depth to more than 100 cm. The plant rooting depth is 20 - 45 (cm), due to densely packed gravels that mechanically impedes root growth. Generally, the soil is well drained with moderate vulnerability of water logging in non-irrigated conditions and has moderate to low soil water holding capacity. Inherently these soils have a high structural vulnerability and a moderate N leaching potential, which should be accounted for when making land management decisions.	Subsoil infiltration limitation; Year-round irrigation possible
Pigburn	This soil belongs to the Recent soil order of the New Zealand soil classification. Recent Soils are weakly developed, showing limited signs of soil-forming processes although a distinct topsoil is present, a B horizon is either absent or only weakly expressed. It is formed in alluvial sand silt or gravel deposited by running water, from schist parent material. The topsoil typically has loam texture and is slightly stony. The subsoil has dominantly loam textures, with very gravelly layer from less than 45 cm mineral soil depth to more than 100 cm. The plant rooting depth extends beyond 1m. Generally, the soil is well drained with very low vulnerability of water logging in non-irrigated conditions and has moderate to high soil water holding capacity. Inherently these soils have a high structural vulnerability and a moderate N leaching potential, which should be accounted for when making land management decisions.	Limited to nil Subsoil infiltration limitation; Year-round irrigation possible
Barrhill	This soil belongs to the Pallic soil order of the New Zealand soil classification. Pallic Soils have pale coloured subsoils, due to low contents of iron oxides, have weak soil structure and high density in subsurface horizons. Pallic Soils tend to be dry in summer and wet in winter. It is formed in a blanket deposit of silt sized windblown materials overlying	Some subsoil infiltration limitation; Year-round irrigation possible

Soil Family	Characteristics (S-Map)	Irrigation Suitability
	alluvial sand silt or gravel deposited by running water, from schist parent material. The topsoil typically has loam texture and is stoneless. The subsoil has dominantly loam textures, with gravel content of less than 3%. The plant rooting depth extends beyond 1m. Generally, the soil is moderately well drained with very low vulnerability of water logging in non-irrigated conditions and has high soil water holding capacity. Inherently these soils have a high structural vulnerability and a low N leaching potential, which should be accounted for when making land management decisions.	
Tucker	This soil belongs to the Recent soil order of the New Zealand soil classification. Recent Soils are weakly developed, showing limited signs of soil-forming processes although a distinct topsoil is present, a B horizon is either absent or only weakly expressed. It is formed in weathered soil and rock material mantling slopes, from schist parent material. The topsoil typically has sand texture and is moderately stony. The subsoil has dominantly sand textures, with a very gravelly layer from less than 45 cm mineral soil depth to more than 100 cm. The plant rooting depth extends beyond 1m. Generally, the soil is well drained with very low vulnerability of water logging in non-irrigated conditions and has moderate to low soil water holding capacity. Inherently these soils have a very high structural vulnerability and a high N leaching potential, which should be accounted for when making land management decisions	Potential for year-round irrigation at low application rates

At Jacks Point, the dominant soils have been classified as AS/NZS1547 Category 3.

These soils generally aligned with those seen at Homestead Bay across both the RCL and QEII sites, and contain the following soil types:

- Wakatipu soils – cover the greatest area and are typically flat to gently sloping soils, which are formed in glacial deposits;
- Barrhill soils – are soils located in the central valley and also east of Jacks Point on the QEII property; and
- Pigburn soils – occupy a large area of the QEII property and are typically characterised as being a recent soil which is weakly developed.

The Tucker soils were not found at the Homestead Bay area.

Homestead Bay Soil Investigations

A comprehensive soil investigation was undertaken by LEI at these two sites on behalf of RCL between 4 to 7 June 2024. It comprised of the machine excavation of 17 test pits, nine of which also included hydraulic testing, as shown in Figure 1. These test pits were excavated down to a depth of approximately 2 m, with hydraulic testing completed at a depth of 0.2 m.

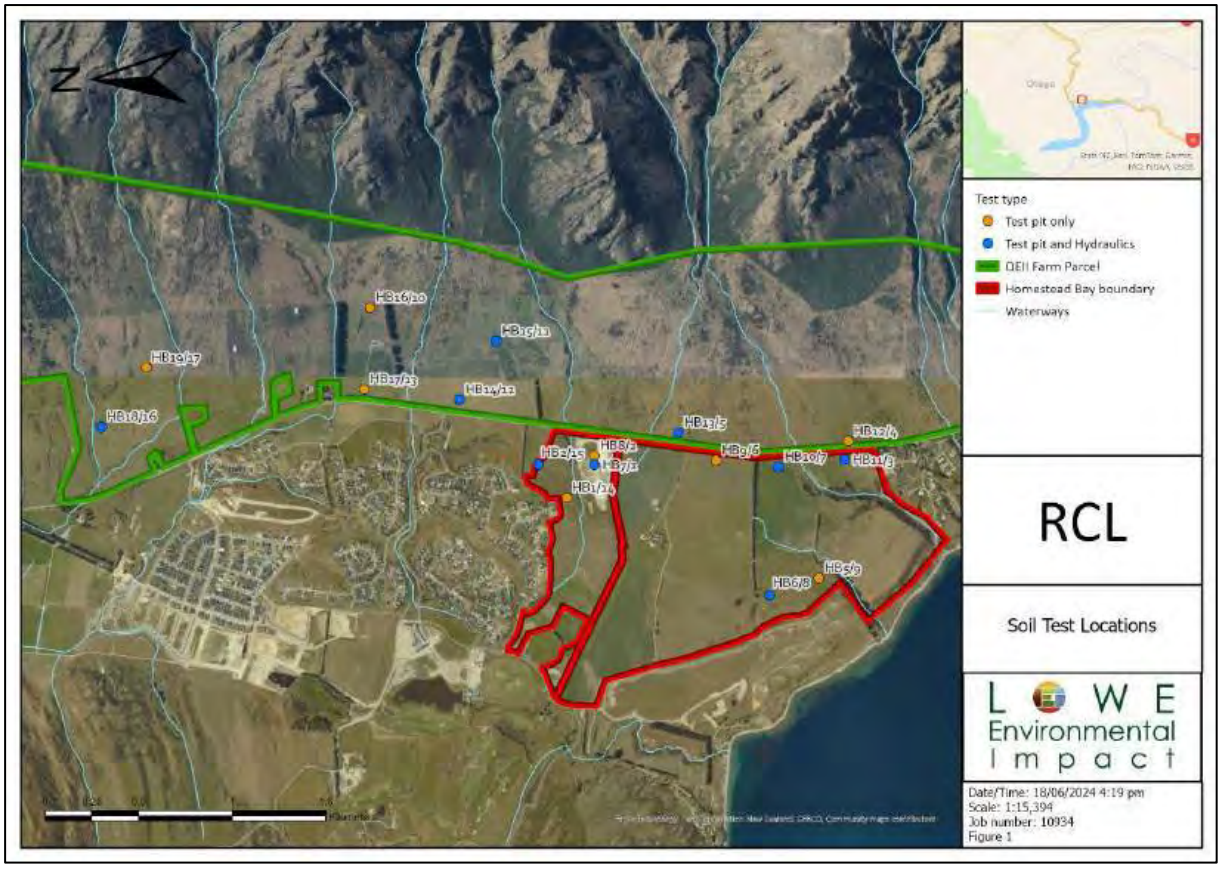

Figure 1: Location of Soil Test Sites

The RCL and QEII sites both contain a mixture of all three soil types, Barrhill, Pigburn, and Wakatipu, as noted in Error! Reference source not found.. The area of sites HB7/1 and HB8/2 is the clean fill site of the nearby Jacks Point subdivision, so it is classed differently due to this human interfered soil profile. The area of HB17/13 is also classed differently due to the note from the farmer of the presence of groundwater springs during wet periods, as well as the appearance of mottling in the profile, despite the Barrhill classification.

The soil profile at each site was photographed and logged with these individual profiles included as an attachment to this report. The summary of average soil profiles for each soil type is supplied in Table 2. The soil profiles typically comprised of 0.35 m of weathered topsoil (organic silt) with roots throughout, underlain by a silt subsoil down to alluvial or colluvial gravels at depth.

These soil logs show a consistent silt loam down to 0.9 m, with ranging stratification of gravels below this. Soil Categories 2 and 3 within AS/NZS 1547:2012 are representative of sands and loams.

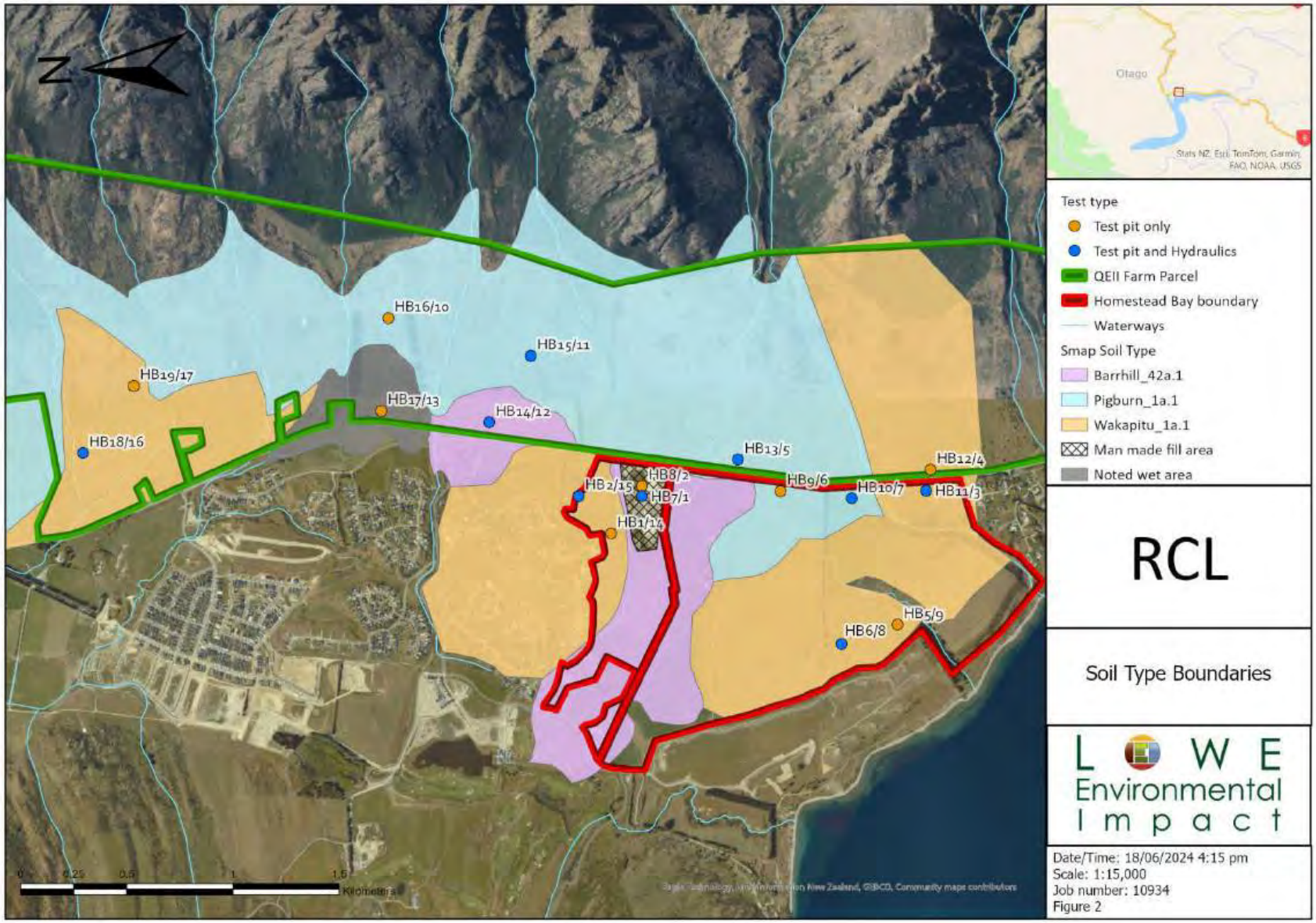

Figure 2: Soil Type Boundaries

Table 2: Averaged LEI Test Pit Logs by Soil Family

Below ground level (m)	Pigburn	Below ground level (m)	Wakatipu	Below ground level (m)	Barrhill
S-Map class	Weathered Fluvial Recent Soils		Typic Immature Pallic Soils (PIT)		Typic Immature Pallic Soils (PIT)
0 - 0.3	Moist, 10YR 3/2 (very dark greyish brown) coloured soil. Very slightly gravelly, sub-rounded, medium gravel. No mottles, non-sticky, non-plastic, silt loam. Apedal earthy. Soil strength is slightly firm, aggregate strength is weak and friable. Common fine roots. Boundary is abrupt and smooth.	0-0.35	Moist, 10YR 3/2 (very dark greyish brown) coloured soil. No gravels. No mottles, non-sticky, non-plastic, silt loam. Apedal earthy. Soil strength is slightly firm, aggregate strength is slightly firm and friable. Common fine roots. Boundary is distinct and occluded.	0-0.40	Moist, 10YR 4/2 (dark greyish brown) coloured soil. No gravels. No mottles, non-sticky, non-plastic, silt loam. Apedal earthy. Soil strength is slightly firm, aggregate strength is slightly firm and friable. Few fine roots. Boundary is sharp and occluded. Many worms and bioturbation into subsoil.
0.3-0.9	Moist, 10YR 6/2 (light brownish grey) coloured soil. No gravels. No mottles, non-sticky, non-plastic, sandy loam. Apedal single grain. Soil strength is weak, aggregate strength is weak and very friable. Few fine roots. Boundary is sharp and smooth. Some occlusions.	0.35-0.6	Moist, 10YR 5/8 (yellowish brown) coloured soil. Slightly gravelly, angular, medium gravel. No mottles, non-sticky, non-plastic, silt loam. Apedal massive. Soil strength is slightly firm, aggregate strength is slightly firm and brittle. Few fine roots. Boundary is sharp and smooth.	0.4-0.9	Moist, 10YR 5/4 (yellowish brown) coloured soil. Very slightly gravelly, angular, fine gravel. No mottles, non-sticky, non-plastic, silt loam. Apedal massive. Soil strength is firm, aggregate strength is weak and brittle. Few fine roots. Boundary is sharp and smooth. Oxide staining layers throughout the b horizon.
		0.6-1.8+			

Below ground level (m)	Pigburn	Below ground level (m)	Wakatipu	Below ground level (m)	Barrhill
S-Map class	Weathered Fluvial Recent Soils		Typic Immature Pallic Soils (PIT)		Typic Immature Pallic Soils (PIT)
0.9-1.1	Moist, 10YR 6/3 (pale brown) coloured soil. Very gravelly, angular, coarse gravel. No mottles, non-sticky, non-plastic, coarse sand. Apedal single grain. Soil strength is weak, aggregate strength is weak and very friable. Few fine roots. Boundary is sharp and smooth.		Slightly moist, 10YR 7/3 (very pale brown) coloured soil. Extremely gravelly, sub-rounded, very coarse gravel. No mottles, non-sticky, non-plastic, loamy sand. Apedal single grain. Soil strength is firm, aggregate strength is slightly firm and brittle. No roots. Concreted texture but water soaks away.	0.9-1	Slightly moist, 10YR 5/4 (yellowish brown) coloured soil. Extremely gravelly, angular, medium gravel. No mottles, non-sticky, non-plastic, coarse sand. Apedal single grain. Soil strength is very weak, aggregate strength is very weak and very friable. No roots. Boundary is sharp and smooth.
1.1-1.45	Moist, 10YR 6/1 (grey) coloured soil. Slightly gravelly, angular, fine gravel. No mottles, non-sticky, non-plastic, fine sand. Apedal single grain. Soil strength is weak, aggregate strength is weak and friable. Few fine roots. Boundary is sharp and smooth.			1-1.4	Moist, 10YR 6/3 (pale brown) coloured soil. No gravels. Common fine 10YR 5/8 mottles, non-sticky, non-plastic, silt loam. Apedal massive. Soil strength is slightly firm, aggregate strength is weak and brittle. Organic staining from roots. Boundary is sharp and smooth.
1.45-1.8+	Moist, 10YR 6/1 (grey) coloured soil. Very gravelly, angular, very coarse gravel. No mottles, non-sticky, non-plastic, coarse sand. Apedal single grain. Soil strength is very weak, aggregate strength is very weak and very friable. Few fine roots. Mixture of size class gravels.			1.4-1.7+	Moist, 10YR 6/3 (pale brown). Extremely gravelly, angular, very coarse gravel. No mottles, non-sticky, non-plastic, coarse sand. Apedal single grain. Soil strength is weak, aggregate strength is weak and friable. No roots. Mixed size of gravels and sand.

LEI SOILS TESTING RESULTS

Hydraulic Conductivity Tests

Saturated and unsaturated hydraulic conductivity tests were undertaken at nine sites (Figure 1) at a depth of 0.2 m using a combination of double-ring infiltrometers and unsaturated plate permeameters. This depth was assessed as the drippers would be laid due to this depth. Table 3 presents the saturated hydraulic conductivity (total flow through the soil, including macropores, such as root and wormholes) for the sites.

Saturated hydraulic conductivity describes the ease with which water moves through soil when all its pores are completely filled with water. In this fully saturated state, water movement is driven primarily by gravity and the pressure gradient, as there are no air-filled pores to impede the flow. The larger pores, or macropores, such as those created by root channels, cracks, and spaces between soil aggregates, dominate water flow under saturated conditions. Water flows through these macropores quickly due to the low resistance and the direct path they provide. Soil texture, structure, and the presence of organic matter significantly influence the rate of water movement, with sandy soils generally exhibiting higher saturated conductivity than clayey soils due to their larger pore spaces. The conductivity is also influenced by the degree of soil compaction and the connectivity of the pore network. In undisturbed, well-structured soils and in soils where a lot of sands and gravels are present, the rate of water percolation is higher, while in compacted or poorly structured soils, it is lower due to the reduction in macropore space.

The saturated tests are likely to provide a more representative result of the gravity drainage through the larger macropores. The faster draining soils in the saturated tests are the Wakatipu soils, which all displayed an extremely gravelly, concreted type soil beyond around 0.6 m depth. This natural concreted type layer, quickly percolate water when applied, supporting this high infiltration rate.

The testing at site HB 13/5 was unsuccessful because the soil was too gravelly to install the double rings properly, preventing LEI from obtaining an additional reading. The manmade clean fill site had the lowest saturated conductivity, likely due to the anthropic nature of the site experiencing artificial compaction with heavy machinery. Pigburn and Barrhill gave similar saturated hydraulic conductivity readings.

Table 3: Soil Saturated Hydraulic Conductivity (K_{sat})

Serial no.	Site	Soil Type	Topsoil Average K_{sat} (mm/day)
1	Site HB2/15	Wakatipu	1,440
2	Site HB6/8	Wakatipu	3,960
3	Site HB7/1	Manmade	150
4	Site HB10/7	Pigburn	720
5	Site HB11/3	Wakatipu	1,044
6	Site HB13/5	Pigburn	*Too gravelly to conduct testing
7	Site HB14/12	Barrhill	720
8	Site HB15/11	Pigburn	920
9	Site HB18/16	Wakatipu	720

Table 4 presents the unsaturated hydraulic conductivity (represents the flow through meso and micropores, i.e. full matrix flow through the soil) for the nine sites. Field tests using the plate permeameters ($K_{-40\ mm}$) found that the rate moving through the soil indicated a strongly unified soil texture which showed only small increments of change across the different pressures. The unsaturated tests are well grouped between the soil types, with the faster draining soils being the Pigburn, compared with the slower draining Wakatipu and Barrhill.

Unsaturated hydraulic conductivity, which describes how water moves through soil when the soil is not fully saturated, primarily occurs through the soil's micro and mesopores. Micropores are the small pores in the soil, often found within soil aggregates or between tightly packed soil particles. They play a significant role in retaining water against gravity due to capillary forces, and they control water movement when the soil is at lower moisture levels.

Mesopores are slightly larger pores than micropores, and they facilitate water movement when the soil is at moderate moisture levels. In unsaturated conditions, mesopores allow water to flow through the soil more readily than micropores, but they still retain water that plants can access.
Together, the micro and mesopores regulate the unsaturated conductivity in soils, with the rate of water movement depending on the pore size distribution and soil moisture content. At lower soil moisture levels, water primarily moves through micropores, while at higher unsaturated conditions, mesopores become more active in conducting water.

Table 4: Soil Unsaturated Hydraulic Conductivity ($K_{-40\ mm}$)

Serial no.	Site sample number	Soil Type	Field investigation of topsoil average unsaturated hydraulic conductivity, K_{-40} (mm/day)	Landcare Research laboratory result unsaturated hydraulic conductivity, K_{-40} (mm/day)
1	Site HB2-15	Wakatipu	22	360
2	Site HB6-8	Wakatipu	30	768
3	Site HB11-3	Wakatipu	11	336
4	Site HB18-16	Wakatipu	25	624
5	Site HB7-1	Manmade	53.5	96
6	Site HB10-7	Pigburn	123	312
7	Site HB13-5	Pigburn	73	336
8	Site HB15-11	Pigburn	110	480
9	Site HB14-12	Barrhill	37	72

The value of unsaturated hydraulic conductivity in the topsoil of the sites ranged from 11 to123 mm/day. The unsaturated hydraulic conductivity of the sample cores of the sites those were

sent to Landcare Research ranged from 72 to 768 mm/day. The variation between field observation and laboratory tests are expected as the plate permeameter (field observation) method usually are conducted by using one to four replications which considers variability of unsaturated hydraulic conductivity in 2-4 spots and the average results are considered whereas in laboratory studies only one sample has been considered. The variability in the properties of soils in field conditions is also common.

The hydraulic results based on soil distribution are shown below in Error! Reference source not found.. The distribution of these rates supports the proposal to irrigate based on soil type.

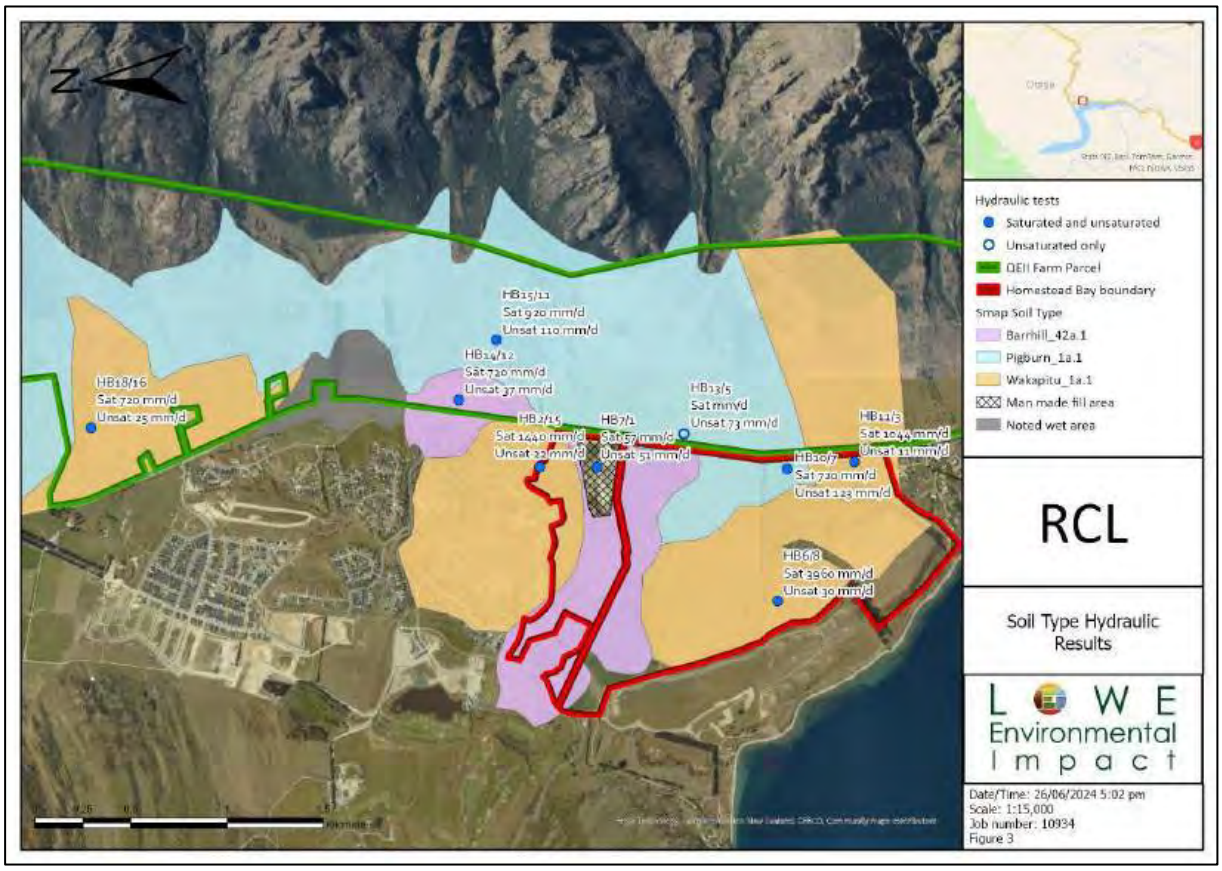

Figure 3: Soil Hydraulic Distribution

Field measurements typically only observe clean water effects, but the impact of wastewater constituents must also be considered. Organic material, solids and nutrients in the wastewater can allow the development of microbial growth, commonly referred to as biofilm, which in turn can result in a 'clogging' effect of the soil pores, particularly near the irrigation line outlets. This can reduce the soil's infiltration capacity. In addition, the salt concentration will influence the soil wetting by altering the water tension.

Crites and Tchobanoglous (1998) recommend a value of 10 - 30% of the K_{sat} to provide a Design Irrigation Rate (DIR). LEI has conservatively adopted a value of 10% of the K_{sat} and 30% of the K_{unsat} to provide a DIR.

Due to the previously mentioned consistent grouping by soil type, the design application rates have been prepared separately for Barrhill, Pigburn, and Wakatipu soil types. These are shown below in Table 5, Table 6, and Table 7.

DIR DEPENDING ON SOIL TYPES

Barrhill Soils

The Barrhill soil DIR is calculated from on-site measurements and from past investigations on the neighbouring Jacks Point development.

Table 5: Barrhill Design Irrigation Rate

Items	Saturated hydraulic conductivity (K_{sat})	Unsaturated hydraulic conductivity (K_{-40})
Field Measurement low permeability subsoil (mm/day)	720 ± 0	37
Adjustment (%)	10	30
DIR (mm/day)	72 ± 0	11.0

DIR recommended by the investigation is up to 11 mm/day.

Pigburn Soils

The Pigburn soils dominate the higher elevations of the QEII site and part of the RCL site. These soils show a high saturated infiltration rate and unsaturated hydraulic conductivity.

Table 6: Pigburn Design Irrigation Rate

	Saturated (K_{sat})	Unsaturated (K_{-40mm})
Field Measurement low permeability subsoil (mm/day)	820 ± 173	137 ± 61
Adjustment (%)	10	30
DIR (mm/day)	82 ± 17	41 ± 18

The DIR recommended from the investigation is up to 41 mm/day.

Wakatipu Soils

The Wakatipu soils experience higher saturated infiltration rates due to the rapid infiltration at around 0.6 m depth. The lower unsaturated infiltration rate is similar to that of the Barrhill soils, which are also pallic soils.

Table 7: Wakatipu Design Irrigation Rate

	Saturated (K_{sat})	Unsaturated (K_{-40mm})
Field Measurement low permeability subsoil (mm/day)	1,791 ± 1,300	24.2 ± 10.7
Adjustment (%)	10	30
DIR (mm/day)	179 ± 130	7.3 ± 3.2

The DIR recommended from the investigation is up to 7 mm/day.

Manmade Soils

The manmade soils are imported as clean fill of unsuitable construction foundation material from the nearby developments. This area has been identified for the location of the WWTP but could also be used for an LTA.

Table 8: Manmade Design Irrigation Rate

	Saturated (K_{sat})	Mean Unsaturated (K_{40mm})
Field Measurement low permeability subsoil (mm/day)	150 ± 52	53.5 ± 15.5
Adjustment (%)	10	30
Maximum DIR (mm/day)	15 ± 5.2	16.1 ± 4.7

The DIR recommended from the investigation is up to 15 mm/day (Table 9). However, due to the nature of the parent material and the mechanical/landfilling compaction that has been undertaken, a lower infiltration rate of 5 mm/day is recommended as a conservative approach.

Proposed Design Irrigation Rate

The soil investigation has indicated that all of the site's soils have a high hydraulic capacity to assimilate the wastewater. Based on this information, LEI concludes that DIR should be further informed based on land treatment area, nitrogen leaching and catchment nitrogen effects. Proposed DIRs for this community system need to consider the land area available, land use and catchment sensitivities. Table 9 presents recommended rates for the basis of the scheme design and nutrient modelling.

Table 9: Proposed Design Application Rate

	Proposed DIR (mm/day)
Barrhill Soils	7
Pigburn Soils	7
Wakatipu Soils	7
Manmade Soils	5

Depending on the LTA area, final selected DIR will be recommended in the Conceptual Design report.

Soil's Physical properties in relation to hydraulic conductivity

The Table 10 provides a detailed overview of the soil physical properties across various sites, including particle density, dry bulk density, total porosity, macro-porosity, and micro-porosity. These parameters are essential in understanding the soil's ability to retain water, support plant growth, and allow for air and water movement through the soil profile (Brady et al., 2008; McLaren and Cameroon, 1996).

Table 10: Soil physical properties

Site no.	Particle Density (g/cm^3)	Dry Bulk (g/cm^3)	Total porosity (%)	Macro-porosity (%)	Micro-porosity (%)
HB 7/1	2.72	1.60	41	13	28
HB 8/2	2.72	1.28	53	16	37
HB 11/3	2.79	1.49	47	13	34
HB 12/4	2.75	1.43	48	11	37
HB 13/5	2.80	1.34	52	10	43
HB 9/6	2.82	1.33	53	8	45
HB 10/7	2.78	1.44	48	10	38
HB 6/8	2.67	1.43	47	15	31
HB 5/9	2.68	1.32	51	15	36
HB 16/10	2.76	1.33	52	15	37
HB 15/11	2.80	1.36	52	13	39
HB 14/12	2.82	1.45	49	9	40
HB 17/13	2.77	1.27	54	12	43
HB 1/14	2.65	1.30	51	11	40
HB 2/15	2.69	1.34	50	14	36
HB 18/16	2.77	1.33	52	14	38
HB 19/17	2.79	1.41	50	13	37

Particle Density and Dry Bulk Density:

Particle density is a measure of the mass of soil particles per unit volume, typically excluding pore spaces. In this dataset, the particle density ranges from 2.65 g/cm^3 to 2.82 g/cm^3, indicating slight variations in the mineral composition of the soils across the sites. Soils with higher particle density, such as Site HB 9/6 and HB 14/12 (2.82 g/cm^3), may contain heavier minerals, possibly contributing to different soil behaviour compared to those with lower particle density, such as Site HB 1/14 (2.65 g/cm^3).

Bulk density is a measure of soil compaction, expressed as the mass of soil per unit volume. Dry bulk density, on the other hand, measures the mass of soil, including pore spaces, and it is a key indicator of soil compaction. Lower bulk density values generally indicate better soil structure with more pore spaces, which are crucial for root penetration and water infiltration. Dry bulk density ranges from 1.27 g/cm^3 at Site HB 17/13 to 1.60 g/cm^3 at Site HB 7/1. Soils with higher bulk density, such as Site HB 7/1, may be more compacted, reducing porosity and potentially limiting water movement and root growth. For pasture soils, the target bulk density typically falls within the range of 0.7 to 1.4 g/cm^3 (Sparling et al., 2008). At these levels, soil is considered to have an adequate balance between compactness and porosity, allowing for sufficient root growth and water infiltration.

A bulk density below 0.7 g/cm^3 indicates that the soil is too loose, which can lead to issues such as erosion or insufficient support for plants. On the other hand, a bulk density above 1.4 g/cm^3 suggests that the soil is becoming too compacted, potentially restricting root penetration, reducing water infiltration, and impairing overall soil health. Managing bulk density within this target range helps maintain soil structure conducive to healthy pasture

growth. In the investigated site the in soils ranged from 1.27 to 1.60 g/cm³. Th bulk density in site HB 17/13 was the lowest (1.27 g/cm³) whereas the bulk density in site HB 7/1 was the highest (1.60 g/cm³). Site HB 19/17, HB 12/4, HB 6/8, HB 10/7, HB 14/12, HB 11/3 and HB 7/1 had higher bulk density than the prescribed level (Sparling et al., 2008). This high bulk density needs to be decreased for better plant growth and environmental wellbeing.

Total Porosity

Total porosity, which represents the proportion of soil volume occupied by pores, is inversely related to bulk density. Higher porosity values suggest a greater ability of the soil to store water and air, which is essential for healthy plant growth and water infiltration. The sites show a range of total porosity from 41% at Site HB 7/1 to 54% at Site HB 17/13. Higher porosity, as seen in Site HB 17/13, indicates that the soil has more spaces available for air and water, which could enhance plant growth and water percolation.

Macro-porosity and Micro-porosity

Macro-porosity refers to the larger pores in the soil that allow for rapid drainage and air exchange, whereas micro-porosity includes smaller pores that retain water for plant use. In this dataset, macro-porosity ranges from 8% at Site HB 9/6 to 16% at Site HB 8/2, while micro-porosity varies between 28% and 45%. Sites with higher macro-porosity, such as HB 8/2, are likely to have better drainage but may also be more prone to drying out, especially in periods of low rainfall. Conversely, higher micro-porosity, as seen in Site HB 9/6 (45%), suggests a greater capacity to hold water, which can be crucial during dry periods but may also slow down drainage, potentially leading to waterlogging under higher rates of water application.

Macroporosity are essential for water drainage, air exchange, and root growth. For pasture soils, the target range for macroporosity is 6 to 30% (Sparling et al., 2008), with 30% considered high and ideal for most agricultural purposes. Adequate macroporosity (within the 6-30% range) ensures that the soil has enough large pores to allow for efficient water movement and root development, critical for sustaining pasture productivity. A macroporosity below 6% is considered low, indicating that the soil may be too compacted, leading to poor drainage and limited oxygen availability to plant roots, which can stifle growth and reduce pasture yield.

In the tested sites, all the sites macroporosity was more than 6% which implies that sites macroporosity is in reasonable condition. The lowest macro porosity was observed in site HB 9/6 (8%) and highest was observed in site HB 8/2 (16%).

Implications for Soil Management

Understanding these physical properties is critical for effective soil management. Soils with lower bulk density and higher porosity, like those at Site HB 17/13, are generally more favourable for root growth and water infiltration, making them suitable for a wide range of crops. However, these soils might require more frequent irrigation due to their higher drainage capacity. On the other hand, soils with higher bulk density and lower porosity, such as those at Site HB 7/1, may need management practices that improve structure, such as adding organic matter or reducing compaction through appropriate tillage practices.

Water holding capacity

Field Capacity (FC)

FC is crucial when applying treated wastewater to soils because it represents the maximum amount of water the soil can hold after excess water has drained away. Applying wastewater up to the FC level ensures that the soil is sufficiently moist without causing waterlogging, which could lead to runoff, leaching of nutrients, and potential contamination of groundwater.

Available Water Capacity (AWC)

AWC indicates the range of water available for plant use between field capacity and the wilting point. In treated wastewater applications, knowing the AWC helps in determining the appropriate amount and frequency of wastewater irrigation, ensuring that plants receive enough moisture without over-irrigation, which could cause nutrient imbalances or pollution.

Gravimetric Water Content

This measure provides insights into the actual water content in the soil as a percentage of its dry weight. It is useful in assessing how much treated wastewater has been retained by the soil after application. Monitoring gravimetric water content helps in optimizing water use efficiency and preventing excessive buildup of moisture that could lead to anaerobic conditions or soil degradation.

Volumetric Water Content

Volumetric water content, expressed as a percentage of the soil's total volume, is key to understanding how much water is present in the soil at various moisture levels. It is particularly important in the context of treated wastewater application, as it helps in tracking how the soil's moisture profile changes with irrigation, ensuring that the soil maintains adequate moisture for plant growth without reaching saturation levels that could result in surface runoff or nutrient leaching.

Table 11 presents, Field Capacity (%), which provides insight into the water-holding capacity of the soil after excess water has drained away and the soil has reached a point where it holds water against gravity. The values range from 27% to 41%, indicating significant variability among the samples field capacity. The highest field capacity was observed in sample HB 9/6 (41%) whereas the lowest field capacity was observed in sample HB 7/1 with 27%.

Available Water Capacity (AWC % v/v), represents the volume of water available for plant uptake, calculated as the difference between the water content at Field Capacity and the Permanent Wilting Point. AWC values in these samples range from 15% to 37%, reflecting the soil's ability to supply water to plants. Higher AWC values, such as 37% in sample HB 9/6, indicate that a significant portion of the retained water is accessible to plants, making this soil highly suitable for agricultural purposes. Conversely, lower AWC values, like the 15% observed in sample HB 7/1, suggest that even though the soil may hold water, less of it is available for plants to absorb, potentially leading to stress during dry spells.

The gravimetric water content (GWC) of the soils across the different sites shows considerable variability, reflecting their differing capacities to retain water under various conditions. At saturation, the GWC at saturation ranges from a low of 26% at Site HB 7/1 to a high of 43% at Site HB 17/13, indicating that some soils, like HB 17/13, can hold significantly more water when fully saturated compared to others.

Table 11: Gravimetric Water Content

Plot	Field Capacity (%)	AWC (% v/v) (-10 to -1500 kPa)	Gravimetric Water Content (%w/w)				
			At field condition	At saturation	@ -5 kPa	@ -10 kPa	@ -1500kPa
			(%w/w)	(%w/w)	(%w/w)	(%w/w)	(%w/w)
HB 7/1	27	15	12	26	18	17	7
HB 8/2	33	26	18	41	29	26	5
HB 11/3	30	21	11	31	23	20	6
HB 12/4	34	29	16	34	26	24	4
HB 13/5	37	27	12	39	32	27	7
HB 9/6	41	37	12	40	34	30	2
HB 10/7	35	31	13	33	26	24	3
HB 6/8	29	24	17	33	22	20	4
HB 5/9	33	24	16	39	27	25	7
HB 16/10	34	26	19	39	28	25	6
HB 15/11	36	31	17	38	28	26	4
HB 14/12	38	26	20	33	28	26	8
HB 17/13	40	29	28	43	34	32	9
HB 1/14	35	24	19	39	31	27	8
HB 2/15	31	23	17	38	27	23	7
HB 18/16	35	23	20	39	28	26	8
HB 19/17	34	24	18	35	26	24	8

As the soil begins to drain and reaches -5 kPa, the GWC decreases, with values ranging from 18% at Site HB 7/1 to 34% at Site HB 17/13, again highlighting the superior water retention ability of Site HB 17/13.

At -10 kPa, which is closer to the soil's field capacity, the GWC further decreases, with the lowest value at 17% for Site HB 7/1 and the highest at 32% for Site HB 17/13.

Finally, at -1500 kPa, which represents the wilting point where water is no longer available to plants, the GWC ranges from 2% at Site HB 9/6 to 9% at Site HB 17/13.

This data indicates that soils like those at HB 17/13 consistently exhibit higher water retention across all moisture levels, making them more resilient during dry periods. In contrast, soils at HB 7/1, with consistently lower GWC values, are likely to dry out faster and may require more frequent irrigation to sustain plant growth, highlighting the need for tailored water management practices based on the specific characteristics of each site.

It is also important to note here that the gravimetric water content in site HB 7/1 was only 52 to 60% of the gravimetric water content in site 17/13 at saturation to field capacity (saturation to -10kPa)

A similar result was observed when the volumetric water content was considered. That is site HB 17/13 had the highest water retention capability which implies that volumetric water content and gravimetric water content are actually showing the similar result.

Table 12: Volumetric Water Content

Sites	Volumetric Water Content (% v/v)				
	At field moisture	At saturation	@ -5 kPa	@ -10 kPa	@ -1500kPa
HB 7/1	20	41	28	27	12
HB 8/2	24	53	37	33	7
HB 11/3	17	47	34	30	9
HB 12/4	23	48	37	34	5
HB 13/5	16	52	43	37	10
HB 9/6	16	53	45	41	3
HB 10/7	19	48	38	35	4
HB 6/8	24	47	31	29	6
HB 5/9	22	51	36	33	9
HB 16/10	26	52	37	34	8
HB 15/11	23	52	39	36	5
HB 14/12	29	49	40	38	12
HB 17/13	36	54	43	40	11
HB 1/14	24	51	40	35	10
HB 2/15	22	50	36	31	9
HB 18/16	26	52	38	35	11
HB 19/17	26	50	37	34	11

The Table 12 provides a detailed overview of the Volumetric Water Content (% v/v) across various sites, measured at different soil moisture conditions: field moisture, saturation, and specific matric potentials (-5 kPa, -10 kPa, and -1500 kPa). The data shows significant variation in water content across the sites, with field moisture values ranging from 16% to 36%, indicating differences in the soil's ability to retain water under natural conditions. The saturation values, which range from 41% to 54%, highlight the maximum water content the soils can hold, reflecting the soil's porosity.

At the matric potentials of -5 kPa and -10 kPa, the water content decreases as the soil dries, with notable declines in water retention. The water content at -1500 kPa, representing the permanent wilting point ranges between 3% and 12%.

This variation across the sites suggests differences in soil texture, structure, and organic matter content, influencing the soil's water retention and availability to plants. The site HB 7/1 has the lowest available water content but the highest water percentage at wilting point implying that to manage water application in this site will need special care so that no ponding or waster logging happens that might affect the management of wastewater and plant growth negatively.

PHOSPHORUS

Maximum Phosphorus (P) sorption capacity of soils calculated from Landcare Research tests data

At different concentration of Phosphorus (P) in solution, there is a corresponding P sorption by the soil. The P sorption capability in soils is a key indicator of how effectively a soil can absorb and hold phosphorus, a critical nutrient for plant growth. This percentage represents the proportion of added phosphorus that is adsorbed by the soil, preventing it from being lost through leaching or runoff. High phosphorus adsorption is particularly important in preventing environmental issues such as eutrophication. Several factors influence phosphorus retention in soils, including soil texture, pH, organic matter content, and mineral composition. Soils with a high clay content generally have higher phosphorus sorption due to the greater surface area and charge of clay particles, which provide more binding sites for phosphorus. The pH of the soil also plays a significant role, with high and low pH impacting availability and leaching; in acidic soils (low pH <5.8), phosphorus tends to bind with iron and aluminium oxides, increasing sorption, whereas, at high pH >7, P tends to react with Ca and becomes unavailable.

Organic matter usually increases phosphorus sorption depending on the specific organic compounds present and their interactions with soil minerals. Soils rich in iron and aluminium oxides typically exhibit high phosphorus retention. Understanding phosphorus retention percentages is crucial for effective nutrient management in agriculture. In soils with high retention, more phosphorus may need to be applied to meet crop needs, while in soils with low retention, careful management is required to prevent phosphorus loss. By optimizing phosphorus retention through the soil and wastewater management practices, it is possible to improve crop yields while protecting the environment.

Phosphorus (P) sorption in soils (Error! Reference source not found.) is a critical factor in determining the availability of this essential nutrient for plant uptake and its potential impact on the environment. Phosphorus plays a crucial role in plant growth, contributing to processes like energy transfer, photosynthesis, and the synthesis of nucleic acids. However, phosphorus is often a limiting nutrient in soils due to its strong tendency to bind to soil particles, making it less available to plants. Understanding phosphorus sorption dynamics is vital for effective soil management, optimizing fertilization practices, and preventing environmental issues like eutrophication.

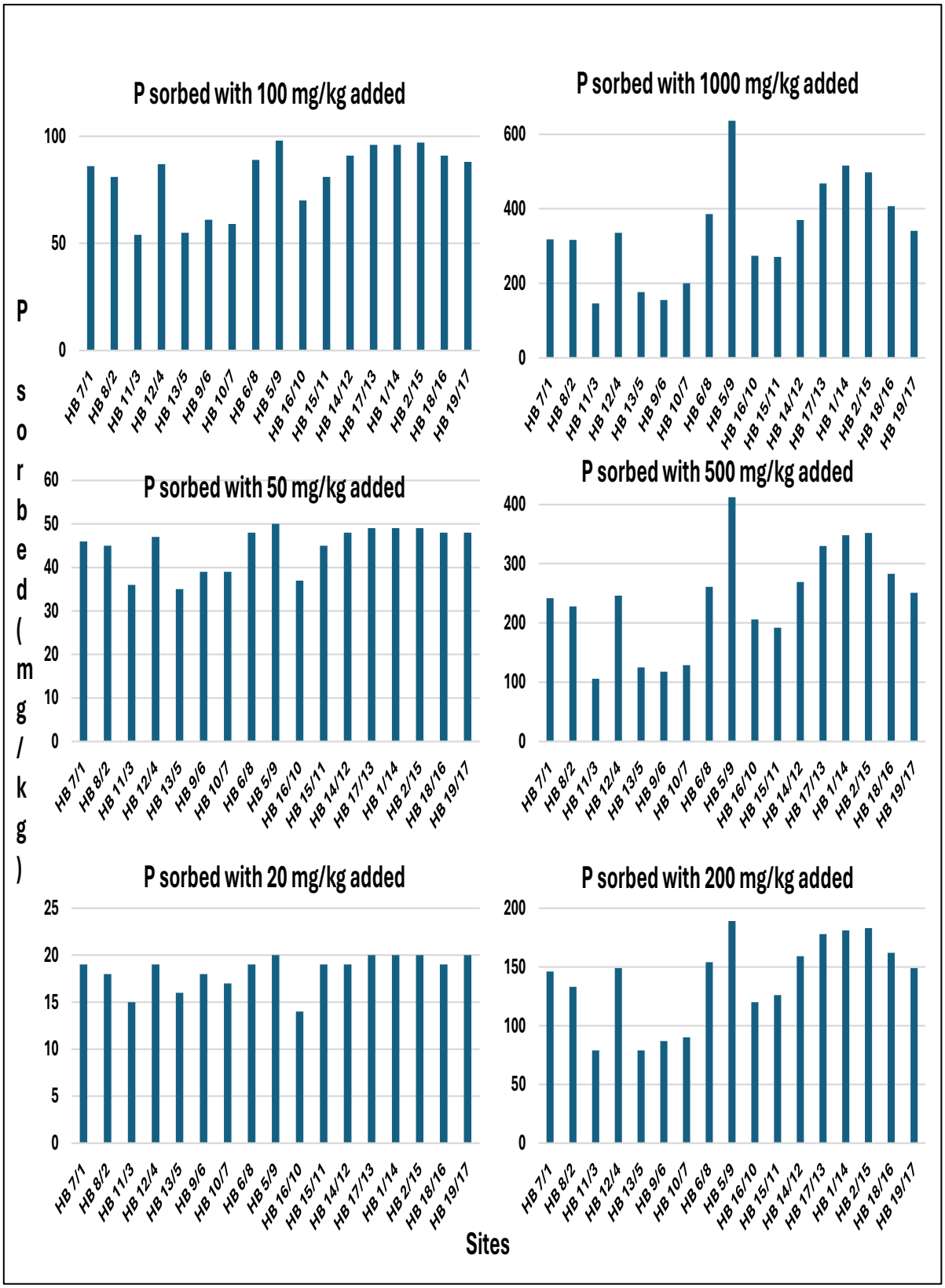

Figure 4: P sorption (mg/kg) by Soils at Different P Concentration in Solution (mg/kg)

The low sorption values of some sites suggest that the soils at these sites are less effective at retaining phosphorus, making it more susceptible to phosphorus leaching. This can lead to nutrient loss and increased environmental risks, particularly in areas where phosphorus runoff might contribute to water pollution. Soils with low phosphorus could be amendeded with biochar as biochar has been reported to increase phosphorus retention in soils and supply of P to plants when plants need it (Glaser & Lehr, 2019).

The Maximum Phosphorus Sorption Capacity (MPSC) (mg/kg) in soil samples ranged from 1,887-8,507 mg/kg soil (Table 13) which has been calculated by using the data from Landcare Research.

The highest MPSC was observed at Site HB 5/9, with a value of 8,507 mg/kg, suggesting a superior ability to adsorb phosphorus, which could be attributed to factors such as high clay content, organic matter, or the presence of minerals like iron and aluminum oxides known for high phosphorus sorption. In contrast, the lowest capacity was recorded at Site HB 11/3, with an MPSC of 1,887 mg/kg, indicating a lower potential to retain phosphorus, possibly due to lower reactive surface area or different mineralogical composition.

Several other sites exhibited relatively high phosphorus sorption capacities, such as HB 1/14 (6,575 mg/kg) and HB 17/13 (5,881 mg/kg), which are likely influenced by similar soil properties that enhance phosphorus retention. On the other hand, sites like HB 9/6 (1,958 mg/kg) and HB 13/5 (2,534 mg/kg) had lower capacities, highlighting variability in soil characteristics across the locations.

The significant variability in MPSC among the sites emphasizes the need for site-specific soil management practices to optimize phosphorus use efficiency. Understanding these variations can help in designing appropriate soil amendments and management strategies that enhance phosphorus sorption, reduce leaching, and mitigate environmental impacts associated with phosphorus runoff.

The significant difference between these sites highlights the variability in phosphorus sorption across different soil types. Managing these differences is crucial for optimizing fertilization practices and minimizing environmental impact.

Table 13: Maximum Phosphorus Sorption Capacity (mg/kg) of Soils in different Sites

Site number	Maximum Phosphorus Sorption Capacity (mg/kg)
HB 7/1	4,175
HB 8/2	4,429
HB 11/3	1,887
HB 12/4	4,380
HB 13/5	2,534
HB 9/6	1,958
HB 10/7	2,769
HB 6/8	5,097
HB 5/9	8,507
HB 16/10	4,035
HB 15/11	3,499
HB 14/12	4,764
HB 17/13	5,881
HB 1/14	6,575
HB 2/15	6,248
HB 18/16	5,324
HB 19/17	4,464

Implications for Soil Management

The significant variation in phosphorus sorption between different sites underscores the importance of understanding and managing soil-specific phosphorus dynamics. Soils with high sorption capacities, like those at HB 5/9, are effective at retaining applied phosphorus, which is beneficial for long-term nutrient availability and environmental protection. However, these soils may require higher phosphorus inputs to meet crop needs, as a substantial portion of the applied phosphorus is immobilized within the soil matrix and is not immediately available to plants.

On the other hand, soils with low phosphorus sorption capacities, such as those at HB 11/3, pose a different set of challenges. These soils are more susceptible to phosphorus loss through leaching, which can lead to reduced phosphorus availability for crops and increased risk of environmental pollution. Effective management strategies for these soils might include the use of phosphorus sorption enhancing amendments eg. Biochar (Glaser & Lehr, 2019; Jindo, et al. 2020), more frequent but smaller phosphorus applications, or the implementation of buffer zones to prevent runoff.

Summary:

The summary given below that has been derived from the discussion of the report.

- The DIR (Design Irrigation Rates) has been recommended as 7 mm/day for all sites except HB 7/1 (manmade site) where the DIR has been recommended as 5 mm/day.
- For increasing the sites water holding capacity, P retention and P sorption capability, the soils are recommended to use a biochar (if necessary) to increase the discharge rates especially where the infiltration rate was seen slow eg. HB 11/3, HB 9/6 and HB 7/1.

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Appendices

Appendix A Field Investigation Soil Profile Descriptions
Appendix B Landcare Research Soil Reports

APPENDIX A
Field Investigation Soil Profile Descriptions

LEI Soil Profile Description		
June 6, 2024 3:46 PM	*HB1/14*	
Millie	*Elevated rolling hills*	
fine, calm		
Soil Core # (if collected)	Top soil:	Sub soil: 903

Soil	Wakapitu 1a.1
NZSC	Typic Immature Pallic Soils (PIT)
Drainage	Well Drained (Fundamental Soil Layer)
Location (NZGD2000)	-45.08185743, 168.75313995

Horizon	Depth (cm)	Description	Image
Topsoil	30 cm	Groundcover: Pasture	
A	0 - 30 cm	*Moist, 10YR 4/2 (dark greyish brown)* coloured soil. *No gravels*. No *mottles*, *non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is slightly firm and friable. *Common fine roots. Boundary is distinct and occluded*.	
B1	30 - 50 cm	*Moist, 10YR 5/8 (yellowish brown)* coloured soil. *Slightly gravelly, angular, fine gravel. No mottles*, *non-sticky, non-plastic, silt loam. Apedal massive*. Soil strength is slightly firm, aggregate strength is slightly firm and friable. *Common fine roots. Boundary is diffuse and convolute*. *B horizon merging into bw*.	

B2	50 - 80 cm	*Moist, 10YR 8/4 (very pale brown)* coloured soil. *Very gravelly, angular, fine gravel. No mottles*, *non-sticky, non-plastic, loamy sand. Apedal massive*. Soil strength is firm, aggregate strength is weak and friable. *Few fine roots. Boundary is abrupt and wavy*. *Mixed zone of b and bw horizon. Compacted sand with mixed-in gravels.*	
C	80 - 180 cm	*Moist, 10YR 8/2 (very pale brown)* coloured soil. *Extremely gravelly, angular, coarse gravel. No mottles*, *non-sticky, non-plastic, loamy sand. apedal massive*. Soil strength is firm, aggregate strength is slightly firm and brittle. *No roots. Cemented type texture but water drains away fine*	

HB14/12
HB15/11
HB2/15
HB1/14
HB7/1
HB13/5
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 6, 2024 4:28 PM	*HB2/15*	
Millie	*Elevated rolling hills closest to highway*	
overcast, calm	*Much the same as HB1/14 but bigger boulders in b horizon*	
Soil Core # (if collected)	Top soil:	Sub soil: 832

Soil	Wakapitu 1a.1
NZSC	Typic Immature Pallic Soils (PIT)
Drainage	Well Drained (Fundamental Soil Layer)
Location (NZGD2000)	-45.08058172, 168.75546644

Horizon	Depth (cm)	Description	Image
Topsoil	25 cm	Groundcover: Pasture/browntop	
A	0 - 25 cm	*Moist, 10YR 3/2 (very dark greyish brown)* coloured soil. *No gravels. No mottles*, *non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is weak and friable. *Common fine roots. Boundary is sharp and occluded*.	
B1	25 - 50 cm	*Moist, 10YR 3/6 (dark yellowish brown)* coloured soil. *Moderately gravelly, sub-rounded, boulders. No mottles*, *non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is weak, aggregate strength is weak and friable. *Common fine roots. Boundary is abrupt and convolute*. *Some boulders amongst smaller gravels in this layer.*	

B2	50 - 90 cm	*Slightly moist, 10YR 7/3 (very pale brown)* coloured soil. *Extremely gravelly, sub-rounded, coarse gravel. No mottles*, *non-sticky, non-plastic, loamy sand. Apedal single grain*. Soil strength is firm, aggregate strength is slightly firm and brittle. *Few fine roots. Boundary is distinct and wavy*. *Patches of above layer interspersed into this intermediate layer. The layer is concreted in hardness and texture, but water still soaks away when profile is wetted.*	
C	90 - 180 cm	*Slightly moist, 10YR 7/3 (very pale brown)* coloured soil. *Extremely gravelly, sub-rounded, very coarse gravel. No mottles*, *non-sticky, non-plastic, loamy sand. Apedal single grain*. Soil strength is firm, aggregate strength is slightly firm and brittle. *No roots. Concreted texture but water soaks away.*	

HB14/12
HB15/11
HB2/15
HB1/14
HB7/1
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 5, 2024 4:49 PM	*HB5/9*	
Millie	*Flat mound*	
overcast, calm		
Soil Core # (if collected)	Top soil:	Sub soil: 691

Soil	Wakapitu 1a.1
NZSC	Typic Immature Pallic Soils (PIT)
Drainage	Well Drained (Fundamental Soil Layer)
Location (NZGD2000)	-45.09377604, 168.74686383

Horizon	Depth (cm)	Description	Image
Topsoil	25 cm	Groundcover: Pasture	
A	0 - 25 cm	*Moist, 10YR 4/2 (dark greyish brown)* coloured soil. N*o gravels. No mottles*, *non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is weak and friable. *Common fine roots. Boundary is sharp and occluded*.	
B	25 - 55 cm	*Moist, 10YR 5/8 (yellowish brown)* coloured soil. *Slightly gravelly, angular, medium gravel. No mottles*, *non-sticky, slightly plastic, sandy clay loam. Apedal massive*. Soil strength is slightly firm, aggregate strength is slightly firm and brittle. *Few fine roots. Boundary is sharp and smooth*.	

C	55 - 150 cm	*Dry, 10YR 6/1 (grey)* coloured soil. *Very gravelly, sub-rounded, coarse gravel. No mottles*, *non-sticky, non-plastic, coarse sand. Apedal massive*. Soil strength is hard, aggregate strength is hard and brittle. *No roots. Cemented type later same as site 6.*	

HB9/6
HB6/8
HB10/7
HB5/9
HB11/3
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 5, 2024 3:49 PM	*HB6/8*	
Millie	*Rolling hills closest to lake*	
overcast, calm	*Wanaka soil*	
Soil Core # (if collected)	Top soil:	Sub soil: 693

Soil	Wakapitu 1a.1
NZSC	Typic Immature Pallic Soils (PIT)
Drainage	Well Drained (Fundamental Soil Layer)
Location (NZGD2000)	-45.09138058, 168.74586377

Horizon	Depth (cm)	Description	Image
Topsoil	20 cm	Groundcover: Pasture	
A	0 - 20 cm	*Moist, 10YR 3/3 (dark brown)* coloured soil. *No gravels*. No *mottles*, *non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is slightly firm and friable. *Many fine roots. Boundary is sharp and irregular*.	
B	20 - 60 cm	*Moist, 10YR 5/8 (yellowish brown)* coloured soil. *Moderately gravelly, sub-rounded, very coarse gravel. No mottles*, *non-sticky, slightly plastic, sandy clay loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is slightly firm and friable. *Abundant roots. Boundary is sharp and smooth*.	

C	60 - 170 cm	*Dry, 10YR 6/1 (grey)* coloured soil. *Extremely gravelly, sub-rounded, coarse gravel. No mottles, non-sticky, non-plastic, coarse sand. Apedal single grain*. Soil strength is hard, aggregate strength is very firm and brittle. *Common fine roots. Concreted texture but water soaks away on it. Consolidated sand and gravels. Roots down to around 70cm.*	

HB13/5
HB9/6
HB6/8
HB10/7
HB5/9
HB11/3
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 4, 2024 12:22 PM	*HB7/1*	
Millie	*Flat fill site*	
fine, calm	*Anthropic soil, clay starting at 50cm*	
Soil Core # (if collected)	Top soil:	Sub soil: 738

Soil	Anthropic Soil on top of Pigburn 1a.1
NZSC	Anthropic Soil / Weathered Fluvial Recent Soils (RFW)
Drainage	Clay starting at 50 cm, Well Drained below (Fundamental Soil Layer)
Location (NZGD2000)	-45.08324649, 168.75527559

Horizon	Depth (cm)	Description	Image
Topsoil	50 cm	Groundcover: Poor pasture and bare soil	
A	0 - 50 cm	*Moderately moist, 10YR 4/3 (brown)* coloured soil. *Moderately gravelly, angular, coarse gravel. No mottles*, *non-sticky, non-plastic, silty clay. Apedal cloddy*. Soil strength is slightly firm, aggregate strength is slightly firm and brittle. *Few fine roots. Boundary is sharp and smooth*.	

B	50 - 85 cm	*Moderately moist, 10YR 5/2 (greyish brown)* coloured soil. *Slightly gravelly, angular, medium gravel. Few fine 10YR 5/8 mottles*, *slightly sticky, slightly plastic, clay*. *Apedal massive*. Soil strength is firm, aggregate strength is slightly firm and brittle. *Few fine roots. Boundary is sharp and smooth*. *Soil colour 5/10Y greenish gray gley chart 1*	
C	85 - 180 cm	*Slightly moist, 10YR 5/2 (greyish brown)* coloured soil. *Slightly gravelly, angular, medium gravels. Common medium 10YR 5/8 mottles*, *slightly sticky, slightly plastic, loamy clay. Apedal cloddy*. Soil strength is firm, aggregate strength is slightly firm and brittle. *No roots.*	

HB14/12
HB15/11
HB2/15
HB1/14
HB7/1
HB13/5
HB9/6
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 4, 2024 2:26 PM	*HB8/2*	
Millie	*Flat backfill closest to alps*	
fine, calm		
Soil Core # (if collected)	Top soil:	Sub soil: 829

Soil	Anthropic Soil on top of Pigburn 1a.1
NZSC	Anthropic Soil / Weathered Fluvial Recent Soils (RFW)
Drainage	Clay starting at 50 cm, Well Drained below (Fundamental Soil Layer)
Location (NZGD2000)	-45.08327028, 168.75587617

Horizon	Depth (cm)	Description	Image
Topsoil	40 cm	Groundcover: Poor pasture	
A	0 - 40 cm	*Moist, 10YR 4/3 (brown)* coloured soil. *Very slightly gravelly, angular, medium gravel. No mottles, non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is slightly firm and friable. *Few fine roots. Boundary is sharp and smooth*.	
B	40 - 90 cm	*Moist, 2.5y6/3 light yellowish brown coloured soil. Moderately gravelly, angular, coarse gravel. Few fine 10YR 5/8 mottles, slightly sticky, slightly plastic, clay. Apedal massive*. Soil strength is firm, aggregate strength is firm and semi-deformable. *Few fine roots. Boundary is sharp and smooth*.	

C	90 - 180 cm	*Moist, 2.5y6/3 light yellowish brown coloured soil*. M*oderately gravelly, angular, coarse gravel. Few coarse 10YR 5/8 mottles, slightly sticky, slightly plastic, loamy clay. Apedal massive*. Soil strength is firm, aggregate strength firm and semi-deformable. *No roots.*	

HB14/12
HB15/11
HB2/15
HB1/14
HB7/1
HB13/5
HB9/6
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 5, 2024 11:15 AM	*HB9/6*	
Millie	*Pasture beside airfield*	
overcast, calm	*Generally homogeneous profile*	
Soil Core # (if collected)	Top soil:	Sub soil: 697

Soil	Pigburn 1a.1
NZSC	Weathered Fluvial Recent Soils (RFW)
Drainage	Well Drained below (Fundamental Soil Layer)
Location (NZGD2000)	-45.08911557, 168.75516592

Horizon	Depth (cm)	Description	Image
Topsoil	30 cm	Groundcover: Pasture	
A	0 - 30 cm	*Moist, 10YR 4/2 (dark greyish brown)* coloured soil. *Very slightly gravelly, angular, medium gravel. No mottles, non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is weak and friable. *Common fine roots. Boundary is sharp and smooth*.	
B1	30 - 80 cm	*Moist, 10YR 6/3 (pale brown)* coloured soil. *No gravels*. No *mottles, non-sticky, slightly plastic, silty clay. Apedal massive*. Soil strength is weak, aggregate strength is weak and brittle. *Few fine roots. Boundary is sharp and smooth*.	

B2	80 - 90 cm	*Moist, 10YR 6/2 (light brownish grey)* coloured soil. *gravels, moderately gravelly, angular, fine gravel no mottles, non-sticky, non-plastic, clay loam. apedal single grain*. Soil strength is slightly firm, aggregate strength is slightly firm and brittle. *No roots. Boundary is sharp and smooth*.	
B3	90 - 130 cm	*Moist, 10YR 6/3 (pale brown)* coloured soil. *No gravels*. No *mottles, non-sticky, slightly plastic, silty clay. Apedal massive*. Soil strength is weak, aggregate strength is weak and brittle. *Few fine roots. Boundary is sharp and smooth*.	
B4	130 - 140 cm	*Moist, 10YR 6/2 (light brownish grey)* coloured soil. *Very gravelly, angular, fine gravel. No mottles, non-sticky, non-plastic, coarse sand. Apedal single grain*. Soil strength is very weak, aggregate strength is very weak and very friable. *No roots. Boundary is sharp and smooth. Coloured stones.*	

B5	140 - 150 cm	*Moist, 10YR 6/2 (light brownish grey)* coloured soil. *No gravels. No mottles*, *non-sticky, non-plastic, medium sand. Apedal single grain*. Soil strength is slightly firm, aggregate strength is slightly firm and brittle. *No roots. Boundary is sharp and smooth*.	
B6	150 - 160 cm	*Moist, 10YR 6/2 (light brownish grey)* coloured soil. *Moderately gravelly, angular, fine gravel. No mottles*, *non-sticky, non-plastic, coarse sand. Apedal single grain*. Soil strength is weak, aggregate strength is weak and friable. *No roots. Boundary is sharp and smooth*.	
B7	160 - 180 cm	*Moist, 10YR 6/1 (grey)* coloured soil. *Slightly gravelly, angular, fine gravel. No mottles*, *non-sticky, non-plastic, fine sand. Apedal single grain*. Soil strength is weak, aggregate strength is weak and friable. *Few fine roots. Boundary is sharp and smooth*.	

C	180 cm +	*Moist, 10YR 6/1 (grey)* coloured soil. *Very gravelly, angular, very coarse gravel. No mottles*, *non-sticky, non-plastic, coarse sand. Apedal single grain*. Soil strength is very weak, aggregate strength is very weak and very friable. *Few fine roots. Mixture of size class gravels.*	

HB7/1
HB13/5
HB9/6
HB6/8
HB10/7
HB5/9
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 5, 2024 1:42 PM	*HB10/7*	
Millie	*Flats closest to stream*	
overcast, calm	*Possible rabbit burrow at 70cm*	
Soil Core # (if collected)	Top soil:	Sub soil: 714

Soil	Pigburn 1a.1
NZSC	Weathered Fluvial Recent Soils (RFW)
Drainage	Well Drained below (Fundamental Soil Layer)
Location (NZGD2000)	-45.09209636, 168.75452343

Horizon	Depth (cm)	Description	Image
Topsoil	20 cm	Groundcover: Mixed pasture	
A	0 - 20 cm	*Moist, 10YR 4/2 (dark greyish brown)* coloured soil. *No gravels. No mottles*, *non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is slightly firm and friable. *Common fine roots. Boundary is sharp and smooth*.	
B1	20 - 45 cm	*Moist, 10YR 6/3 (pale brown)* coloured soil. *Slightly gravelly, angular, fine gravel. No mottles*, *non-sticky, non-plastic, sandy clay loam. Apedal massive*. Soil strength is slightly firm, aggregate strength is weak and brittle. *Few fine roots. Boundary is sharp and smooth*.	

B2	45 - 90 cm	*Moist, 10YR 6/3 (pale brown)* coloured soil. *No gravels. No mottles*, *non-sticky, slightly plastic, silty clay. Apedal massive*. Soil strength is slightly firm, aggregate strength is weak and brittle. *Few fine roots. Boundary is sharp and smooth*.	
B3	90 - 105 cm	*Moist, 10YR 6/3 (pale brown)* coloured soil. *Very gravelly, angular, coarse gravel. No mottles*, *non-sticky, non-plastic, coarse sand. Apedal single grain*. Soil strength is weak, aggregate strength is weak and very friable. *Few fine roots. Boundary is sharp and smooth*.	
B4	105 - 145 cm	*Moist, 10YR 6/3 (pale brown)* coloured soil. *No gravels*. No *mottles*, *non-sticky, non-plastic, silt loam. Apedal massive*. Soil strength is slightly firm, aggregate strength is slightly firm and brittle. *Few fine roots. Boundary is sharp and smooth*. *Much the same as 3rd horizon.*	

C	145 cm +	*Moist, 10YR 6/3 (pale brown)* coloured soil. *Very gravelly, angular, coarse gravel.*	

HB13/5
HB9/6
HB6/8
HB10/7
HB5/9
HB11/3
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 4, 2024 4:00 PM	*HB11/3*	
Millie	*Farmland*	
fine, calm		
Soil Core # (if collected)	Top soil:	Sub soil: 688

Soil	Pigburn 1a.1
NZSC	Weathered Fluvial Recent Soils (RFW)
Drainage	Well Drained below (Fundamental Soil Layer)
Location (NZGD2000)	-45.09526211, 168.75478687

Horizon	Depth (cm)	Description	Image
Topsoil	35 cm	Groundcover: Pasture	
A	0 - 35 cm	*Slightly moist, 10YR 3/2 (very dark greyish brown)* coloured soil. *Very slightly gravelly, angular, fine gravel. No mottles, non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is slightly firm and friable. *Common fine roots. Boundary is sharp and occluded*.	
B	35 - 85 cm	*Slightly moist, 10YR 5/6 (yellowish brown)* coloured soil. *Moderately gravelly, angular, very coarse gravel. No mottles, non-sticky, non-plastic, silt loam. Apedal massive*. Soil strength is firm, aggregate strength is weak and brittle. *Few fine roots. Boundary is sharp and smooth*.	

C	85 - 180 cm	*Moderately moist, 10YR 7/2 (light grey)* coloured soil. *Very gravelly, angular, very coarse gravel. No mottles*, *non-sticky, non-plastic, fine sand. Apedal single grain*. Soil strength is hard, aggregate strength is slightly firm and brittle. *No roots. Quite concreted from 85cm and large rocks.*	

HB9/6
HB6/8
HB10/7
HB5/9
HB11/3
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 4, 2024 4:46 PM	*HB12/4*	
Millie	*Base of alluvial fan*	
fine, calm	*Likely landslide material from 70cm*	
Soil Core # (if collected)	Top soil:	Sub soil: 680

Soil	Pigburn 1a.1
NZSC	Weathered Fluvial Recent Soils (RFW)
Drainage	Well Drained below (Fundamental Soil Layer)
Location (NZGD2000)	-45.09549271, 168.75602208

Horizon	Depth (cm)	Description	Image
Topsoil	25 cm	Groundcover: Browntop and ryegrass	
A	0 - 25 cm	*Moist, 10YR 3/2 (very dark greyish brown)* coloured soil. *Very slightly gravelly, angular, medium gravel. No mottles*, *non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is weak and friable. *Many fine roots. Boundary is sharp and occluded*. *Earthworms observed*	

B	25 - 50 cm	*Moist, 10YR 5/6 (yellowish brown)* coloured soil. *Very gravelly, angular, coarse gravel. No mottles*, *non-sticky, non-plastic, silt loam. Apedal massive*. Soil strength is firm, aggregate strength is slightly firm and brittle. *Many fine roots. Boundary is sharp and smooth*.	
C	50 - 90 cm	*Moist, 10YR 5/4 (yellowish brown)* coloured soil. *Moderately gravelly, angular, boulders. No mottles*, *non-sticky, non-plastic, loamy clay. Apedal massive*. Soil strength is firm, aggregate strength is slightly firm and brittle. *Few fine roots. Very large boulders 30cm wide. Hard to dig down with digger.*	

HB9/6
HB6/8
HB10/7
HB5/9
HB11/3
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 5, 2024 10:08 AM	*HB13/5*	
Millie	*Lower fan*	
overcast, calm	*At hydraulic sites, the was a ranging amount of gravels. Several holes were dug to find non gravelly soils to do unsats. Unable to conduct saturated tests*	
Soil Core # (if collected)	Top soil:	Sub soil: 850

Soil	Pigburn 1a.1
NZSC	Weathered Fluvial Recent Soils (RFW)
Drainage	Well Drained below (Fundamental Soil Layer)
Location (NZGD2000)	-45.0873764, 168.75717342

Horizon	Depth (cm)	Description	Image
Topsoil	25 cm	Groundcover: Pasture	
A	0 - 25 cm	*Moist, 10YR 3/2 (very dark greyish brown)* coloured soil. *Slightly gravelly, angular, medium gravel. No mottles, non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is weak and friable. *Many fine roots. Boundary is sharp and smooth*.	

B1	25 - 45 cm	*Moist, 10YR 6/2 (light brownish grey)* coloured soil. *No gravels. No mottles*, *non-sticky, non-plastic, sandy loam. Apedal single grain*. Soil strength is weak, aggregate strength is weak and very friable. *Few fine roots. Boundary is sharp and smooth*. *Some occlusions.*	
B2	45 - 60 cm	*Moist, 10YR 5/2 (greyish brown)* coloured soil. *Very slightly gravelly, angular, fine gravel. No mottles*, *non-sticky, non-plastic, fine sand. Apedal single grain*. Soil strength is weak, aggregate strength is weak and friable. *Few fine roots. Boundary is sharp and smooth*.	
B3	60 - 75 cm	*Moist, 10YR 7/1 (light grey)* coloured soil. *Slightly gravelly, angular, fine gravel. No mottles*, *non-sticky, non-plastic, medium sand. Apedal single grain*. Soil strength is very weak, aggregate strength is very weak and very friable. *Few fine roots. Boundary is sharp and smooth*.	

B4	75 - 90 cm	*Moist, 10YR 4/1 (dark grey)* coloured soil. *No gravels. No mottles*, *non-sticky, non-plastic, sandy loam. Apedal single grain*. Soil strength is slightly firm, aggregate strength is slightly firm and friable. *Few fine roots. Boundary is sharp and smooth*.	
B5	90 - 105 cm	*Moist, 10YR 6/1 (grey)* coloured soil. *Very gravelly, angular, very coarse gravel. No mottles*, *non-sticky, non-plastic, medium sand. Apedal single grain*. Soil strength is very weak, aggregate strength is very weak and very friable. *Few fine roots. Boundary is sharp and smooth*.	
B6	105 - 145 cm	*Moist, 10YR 6/1 (grey)* coloured soil. *Slightly gravelly, angular, fine gravel. No mottles*, *non-sticky, non-plastic, fine sand. Apedal single grain*. Soil strength is weak, aggregate strength is weak and friable.*Few fine roots. Boundary is sharp and smooth*. *A layer of fine gravels through the middle, uncompacted.*	

C	145 - 180 cm	*Moist, 10YR 6/1 (grey)* coloured soil. *Very gravelly, angular, very coarse gravel. No mottles*, *non-sticky, non-plastic, coarse sand. Apedal single grain*. Soil strength is very weak, aggregate strength is very weak and very friable. *Few fine roots. Mixture of size class gravels.*	

HB2/15
HB1/14
HB7/1
HB13/5
HB9/6
HB6/8
HB10/7
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 6, 2024 12:23 PM	*HB14/12*	
Millie	*Lower flats beside Jacks Point entrance driveway*	
overcast, calm		
Soil Core # (if collected)	Top soil:	Sub soil: 730

Soil	Barrhill 42a.1
NZSC	Typic Immature Pallic Soils (PIT)
Drainage	Moderately Well Drained (Fundamental Soil Layer)
Location (NZGD2000)	-45.07694565, 168.7601236

Horizon	Depth (cm)	Description	Image
Topsoil	25 cm	Groundcover: Pasture/browntop	
A	0 - 25 cm	*Moist, 10YR 4/2 (dark greyish brown)* coloured soil. *No gravels. No mottles, non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is slightly firm and friable. *Common fine roots. Boundary is sharp and occluded*.	

B1	25 - 90 cm	*Moist, 10YR 5/4 (yellowish brown)* coloured soil. *Very slightly gravelly, angular, fine gravel. No mottles*, *non-sticky, non-plastic, silt loam. Apedal massive*. Soil strength is firm, aggregate strength is weak and brittle. *Few fine roots. Boundary is sharp and smooth*. *Oxide staining layers throughout the b horizon.*	
C	90 - 100 cm	*Slightly moist, 10YR 5/4 (yellowish brown)* coloured soil. *Extremely gravelly, angular, medium gravel. No mottles*, *non-sticky, non-plastic, coarse sand. Apedal single grain*. Soil strength is very weak, aggregate strength is very weak and very friable. *No roots. Boundary is sharp and smooth*.	
B2	100 - 180 cm	*Moist, 10YR 5/4 (yellowish brown)* coloured soil. *No gravels. No mottles*, *non-sticky, non-plastic, silt loam. Apedal massive*. Soil strength is slightly firm, aggregate strength is weak and brittle. *No roots. Iron oxide staining layers at 110-125cm.*	

HB17/13
HB16/10
HB14/12
HB15/11
HB2/15
HB1/14
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 6, 2024 10:36 AM	*HB15/11*	
Millie	*Flat alluvial fan*	
fine, calm	*Gravels beyond 180cm*	
Soil Core # (if collected)	Top soil:	Sub soil: 689

Soil	Pigburn 1a.1
NZSC	Weathered Fluvial Recent Soils (RFW)
Drainage	Well Drained below (Fundamental Soil Layer)
Location (NZGD2000)	-45.07883283, 168.76397055

Horizon	Depth (cm)	Description	Image
Topsoil	25 cm	Groundcover: Poor pasture	
A	0 - 25 cm	*Moist, 10YR 3/2 (very dark greyish brown)* coloured soil. *Very slightly gravelly, sub-rounded, medium gravel. No mottles, non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is weak and friable. *Common fine roots. Boundary is abrupt and smooth*.	
B1	25 - 50 cm	*Moist, 10YR 5/4 (yellowish brown)* coloured soil. *No gravels. No mottles, non-sticky, non-plastic, silt loam. Apedal massive*. Soil strength is slightly firm, aggregate strength is slightly firm and brittle. *Few fine roots. Boundary is sharp and smooth. Some occlusions*	

B2	50 - 70 cm	*Dry, 10YR 5/4 (yellowish brown)* coloured soil. *Extremely gravelly, angular, fine gravel. No mottles*, *non-sticky, non-plastic, coarse sand. Apedal single grain*. Soil strength is very weak, aggregate strength is very weak and very friable. *Many fine roots. Boundary is sharp and smooth*.	
B3	70 - 110 cm	*Dry, 10YR 5/4 (yellowish brown)* coloured soil. *Extremely gravelly, angular, coarse gravel. No mottles*, *non-sticky, non-plastic, coarse sand. Apedal single grain*. Soil strength is very weak, aggregate strength is very weak and very friable. *Few fine roots. Boundary is sharp and smooth*.	
C1	110 - 145 cm	*Slightly moist, 10YR 5/4 (yellowish brown)* coloured soil. *No gravels. No mottles*, *non-sticky, non-plastic, silt loam. Apedal massive*. Soil strength is slightly firm, aggregate strength is slightly firm and brittle. *No roots. Boundary is sharp and smooth*.	

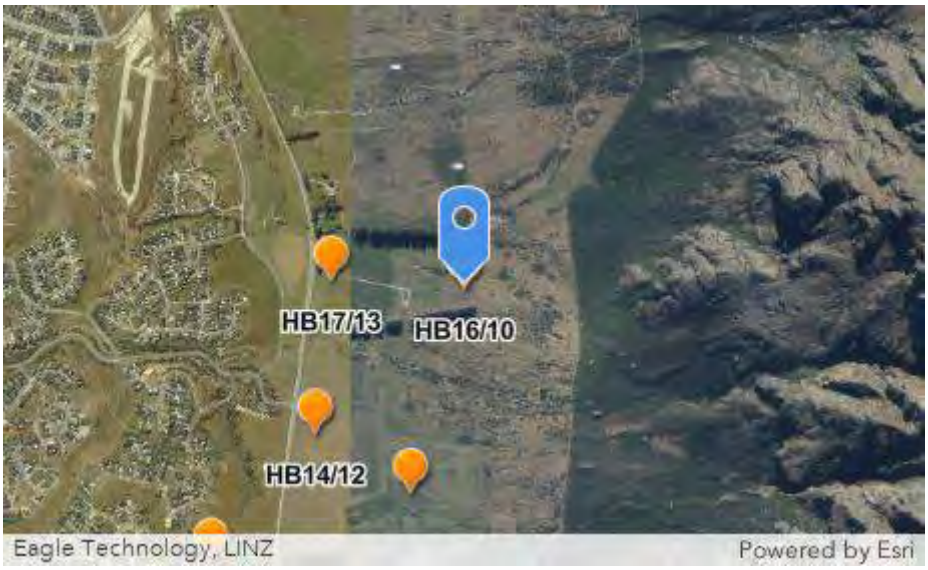
C2	145 - 160 cm	*Slightly moist, 10YR 5/4 (yellowish brown)* coloured soil. *Extremely gravelly, angular, medium gravel. No mottles*, *non-sticky, non-plastic, coarse sand. apedal single grain*. Soil strength is very weak, aggregate strength is very weak and very friable. *No roots. Boundary is sharp and smooth*. *Mixed size gravels and sand.*	
C3	160 - 180 cm	*Moderately moist, 10YR 5/4 (yellowish brown)* coloured soil. *Very slightly gravelly, angular, medium gravel. No mottles*, *non-sticky, non-plastic, silt loam. Apedal massive*. Soil strength is slightly firm, aggregate strength is slightly firm and brittle. *No roots.*	

HB17/13
HB16/10
HB14/12
HB15/11
HB2/15
HB1/14
HB7/1
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 6, 2024 8:53 AM	*HB16/10*	
Millie	*Alluvial fan in deer paddock*	
overcast, calm	*Topsoil core at 80mm due to gravels*	
Soil Core # (if collected)	Top soil: 672	Sub soil: 687

Soil	Pigburn 1a.1
NZSC	Weathered Fluvial Recent Soils (RFW)
Drainage	Well Drained below (Fundamental Soil Layer)
Location (NZGD2000)	-45.07288304, 168.76664941

Horizon	Depth (cm)	Description	Image
Topsoil	20 cm	Groundcover: Poor pasture	
A	0 - 20 cm	*Moist, 10YR 3/2 (very dark greyish brown)* coloured soil. *No gravels. No mottles*, *non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is weak and friable. *Many fine roots. Boundary is indistinct and smooth*.	
B	20 - 170 cm	*Moist, 10YR 5/4 (yellowish brown)* coloured soil. *Extremely gravelly, sub-angular, boulders. No mottles*, *non-sticky, non-plastic, sandy loam. Apedal single grain*. Soil strength is weak, aggregate strength is weak and friable. *Common fine roots. Roots down to 70cm. Very mixed grades of gravels not well stratified. Site is at base of mountains on possible fan.*	


HB17/13
HB16/10
HB14/12
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 6, 2024 2:21 PM	*HB17/13*	
Millie	*Turnip paddock*	
overcast, calm	*Farmer mentioned that this paddock experiences overflow drainage and springs can pop up in winter. this is confirmed with the presence of mottles*	
Soil Core # (if collected)	Top soil:	Sub soil: 739

Soil	Barrhill 42a.1
NZSC	Typic Immature Pallic Soils (PIT)
Drainage	Moderately Well Drained (Fundamental Soil Layer)
Location (NZGD2000)	-45.07240964, 168.76113465

Horizon	Depth (cm)	Description	Image
Topsoil	40 cm	Groundcover: Turnips	
A	0 - 40 cm	*Moist, 10YR 4/2 (dark greyish brown)* coloured soil. *No gravels. No mottles*, *non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is slightly firm and friable. *Few fine roots. Boundary is sharp and occluded*. *Many worms and bioturbation into subsoil.*	

B1	40 - 90 cm	*Moist, 10YR 6/4 (light yellowish brown)* coloured soil. *Very slightly gravelly, angular, fine gravel Common fine 10YR 5/8 mottles*, *non-sticky, non-plastic, silt loam. Apedal massive*. Soil strength is slightly firm, aggregate strength is slightly firm and brittle. *Few fine roots. Boundary is sharp and smooth*. *Thin layer of small gravels at 55-60cm. Mottling throughout b horizon.*	
B2	90 - 100 cm	*Moist, 10YR 6/4 (light yellowish brown)* coloured soil. *Extremely gravelly, angular, fine gravel. No mottles*, *non-sticky, non-plastic, silt loam. Apedal single grain*. Soil strength is slightly firm, aggregate strength is slightly firm and brittle. *No roots. Boundary is sharp and smooth*.	
B3	100 - 140 cm	*Moist, 10YR 6/3 (pale brown)* coloured soil. *No gravels. Common fine 10YR 5/8 mottles*, *non-sticky, non-plastic, silt loam. Apedal massive*. Soil strength is slightly firm, aggregate strength is weak and brittle. *Organic staining from roots. Boundary is sharp and smooth*.	

C	140 - 170 cm	*Moist, 10YR 6/3 (pale brown)*. *Extremely gravelly, angular, very coarse gravel. No mottles*, *non-sticky, non-plastic, coarse sand. Apedal single grain*. Soil strength is weak, aggregate strength is weak and friable. *No roots. Mixed size of gravels and sand.*	

HB17/13
HB16/10
HB14/12
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 7, 2024 9:57 AM	*HB18/16*	
Millie	*Flats closest to farm house*	
overcast		
Soil Core # (if collected)	Top soil:	Sub soil: 707

Soil	Wakapitu 1a.1
NZSC	Typic Immature Pallic Soils (PIT)
Drainage	Well Drained (Fundamental Soil Layer)
Location (NZGD2000)	-45.05969167, 168.7594749

Horizon	Depth (cm)	Description	Image
Topsoil	30 cm	Groundcover: Browntop	
A	0 - 30 cm	*Moist, 10YR 3/2 (very dark greyish brown)* coloured soil. *Very slightly gravelly, angular, medium gravel. No mottles, non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is weak and friable. *Common fine roots. Boundary is abrupt and occluded*.	
B1	30 - 65 cm	*Moist, 10YR 6/4 (light yellowish brown)* coloured soil. *Very slightly gravelly, angular, fine gravel. No mottles, non-sticky, non-plastic, silt loam. Apedal massive*. Soil strength is slightly firm, aggregate strength is weak and brittle. *Few fine roots. Boundary is indistinct and occluded*.	

B2	65 - 95 cm	*Moist, 10YR 7/2 (light grey)* coloured soil. N*o gravels. No mottles*, *non-sticky, non-plastic, silt loam. Apedal massive*. Soil strength is slightly firm, aggregate strength is weak and brittle. *Few fine roots. Boundary is sharp and smooth*. *Some occlusions from above.*	
C	95 - 185 cm	*Moist, 10YR 7/2 (light grey)* coloured soil. *Extremely gravelly, sub-rounded, very coarse gravel. No mottles*, *non-sticky, non-plastic, coarse sand. Apedal single grain*. Soil strength is firm, aggregate strength is weak and friable. *No roots. Ranging sizes of gravels up to boulders. Seam of iron coating at 120-130cm but same material. Water drains away easily*.	

HB18/16
HB19/17
Eagle Technology, LINZ
Powered by Esri

LEI Soil Profile Description		
June 7, 2024 11:16 AM	*HB19/17*	
Millie	*Elevated flats*	
fine, calm		
Soil Core # (if collected)	Top soil:	Sub soil: 898

Soil	Wakapitu 1a.1
NZSC	Typic Immature Pallic Soils (PIT)
Drainage	Well Drained (Fundamental Soil Layer)
Location (NZGD2000)	-45.06198426, 168.76333246

Horizon	Depth (cm)	Description	Image
Topsoil	30 cm	Groundcover: Browntop	
A	0 - 30 cm	*Moist, 10YR 3/2 (very dark greyish brown)* coloured soil. *No gravels. No mottles*, *non-sticky, non-plastic, silt loam. Apedal earthy*. Soil strength is slightly firm, aggregate strength is slightly firm and friable. *Common fine roots. Boundary is distinct and occluded*.	
B1	30 - 75 cm	*Moist, 10YR 6/6 (brownish yellow)* coloured soil. *Slightly gravelly, sub-rounded, medium gravel. No mottles*, *non-sticky, non-plastic, silt loam. Apedal massive*. Soil strength is slightly firm, aggregate strength is slightly firm and brittle. *Few fine roots. Boundary is sharp and smooth*. *Patches of gravels at around 45-55cm. Topsoil occlusions down to 70cm.*	

B2	75 - 93 cm	*Moist, 10YR 7/2 (light grey)* coloured soil. *Extremely gravelly, sub-angular, medium gravel. No mottles*, *non-sticky, non-plastic, coarse sand. Apedal single grain*. Soil strength is weak, aggregate strength is weak and friable. *Few fine roots. Boundary is sharp and smooth*. *Potential slip material.*	
C	93 - 190 cm	*Moist, 10YR 6/3 (pale brown)* coloured soil. *No gravels. No mottles*, *non-sticky, non-plastic, silt loam. Apedal massive*. Soil strength is slightly firm, aggregate strength is slightly firm and brittle. *No roots. Seams of iron coatings throughout the horizon as well as a darker orange seam at 128cm but not a hard pan. No gravels struck at 190cm.*	

HB18/16
HB19/17
Eagle Technology, LINZ
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APPENDIX B
Landcare Research Soil Reports

Environmental Chemistry Laboratory
Analytical Report – Soils

Manaaki Whenua – Landcare Research
Riddet Rd, Massey University Campus, Private Bag 11052, Palmerston North 4442
Phone: +64 6 353 4800

Job number: LJ24009

Date received: 15 July 2024

Customer: Henry van der Vossen, Lowe Environmental Impact
PO Box 4667, Palmerston North 4442

Date reported: 14 August 2024

Notes: Samples were dried and ground by the MW-LR Physics Laboratory in Palmerston North.

Analysis was carried out between the 17th and 26th of July 2024.

Client ID	Sample No.	Air dry soil water content (calculation)* (%)	Phosphate retention (method 132) (%)
738 HB 7/1	M24/0598	1.1	22
829 HB 8/2	M24/0599	1.4	17
688 HB 11/3	M24/0600	0.8	12
680 HB 12/4	M24/0601	1.4	8
850 HB 13/5	M24/0602	0.7	6
697 HB 9/6	M24/0603	0.8	12
714 HB 10/7	M24/0604	0.9	0
693 HB 6/8	M24/0605	1.3	16
691 HB 5/9	M24/0606	1.8	33
687 HB 16/10-2	M24/0607	1.2	21
689 HB 15/11	M24/0608	0.8	17
730 HB 14/12	M24/0609	1.4	22
739 HB 17/13	M24/0610	1.4	25
903 HB 1/14	M24/0611	1.7	29
832 HB 2/15	M24/0612	1.3	29
707 HB 18/16	M24/0613	1.5	25
898 HB 19/17	M24/0614	1.2	18

Ngaire Foster, Lab Manager

Results apply to the samples as received and are expressed on an oven-dry (105°C) basis. Details of method codes are available online at https://www.landcareresearch.co.nz/partner-with-us/laboratories-and-diagnostics/environmental-chemistry-laboratory/soil-testing. This report may not be reproduced, except in full, without the consent of the signatory.

Job number: LJ24009

Date reported: 14 August 2024

Manaaki Whenua
Landcare Research

Client ID	Sample No.	Final conc with 2 mg/L added (method 134) mg/L	Final conc with 5 mg/L added (method 134) mg/L	Final conc with 10 mg/L added (method 134) mg/L	Final conc with 20 mg/L added (method 134) mg/L	Final conc with 50 mg/L added (method 134) mg/L	Final conc with 100 mg/L added (method 134) mg/L
738 HB 7/1	M24/0598	0.12	0.36	1.41	5.42	25.8	68.2
829 HB 8/2	M24/0599	0.22	0.52	1.94	6.74	27.2	68.3
688 HB 11/3	M24/0600	0.45	1.40	4.60	12.1	39.4	85.4
680 HB 12/4	M24/0601	0.07	0.27	1.26	5.10	25.4	66.4
850 HB 13/5	M24/0602	0.42	1.53	4.51	12.1	37.5	82.3
697 HB 9/6	M24/0603	0.23	1.13	3.90	11.3	38.2	84.5
714 HB 10/7	M24/0604	0.28	1.13	4.10	11.0	37.1	80.0
693 HB 6/8	M24/0605	0.08	0.23	1.06	4.57	23.9	61.4
691 HB 5/9	M24/0606	0.02	0.05	0.23	1.07	8.78	36.4
687 HB 16/10-2	M24/0607	0.61	1.28	2.99	8.04	29.4	72.6
689 HB 15/11	M24/0608	0.11	0.47	1.94	7.41	30.8	72.9
730 HB 14/12	M24/0609	0.05	0.23	0.93	4.14	23.1	63.0
739 HB 17/13	M24/0610	0.01	0.10	0.42	2.15	17.0	53.2
903 HB 1/14	M24/0611	0.01	0.12	0.38	1.90	15.2	48.4
832 HB 2/15	M24/0612	0.03	0.10	0.34	1.72	14.8	50.2
707 HB 18/16	M24/0613	0.06	0.23	0.90	3.79	21.7	59.3
898 HB 19/17	M24/0614	0.02	0.24	1.16	5.07	24.9	65.9

Client ID	Sample No.	P sorbed with 20 mg/kg added (method 134) (mg/kg)	P sorbed with 50 mg/kg added (method 134) (mg/kg)	P sorbed with 100 mg/kg added (method 134) (mg/kg)	P sorbed with 200 mg/kg added (method 134) (mg/kg)	P sorbed with 500 mg/kg added (method 134) (mg/kg)	P sorbed with 1000 mg/kg added (method 134) (mg/kg)
738 HB 7/1	M24/0598	19	46	86	146	242	318
829 HB 8/2	M24/0599	18	45	81	133	228	317
688 HB 11/3	M24/0600	15	36	54	79	106	146
680 HB 12/4	M24/0601	19	47	87	149	246	336
850 HB 13/5	M24/0602	16	35	55	79	125	177
697 HB 9/6	M24/0603	18	39	61	87	118	155
714 HB 10/7	M24/0604	17	39	59	90	129	200
693 HB 6/8	M24/0605	19	48	89	154	261	386
691 HB 5/9	M24/0606	20	50	98	189	412	636
687 HB 16/10-2	M24/0607	14	37	70	120	206	274
689 HB 15/11	M24/0608	19	45	81	126	192	271
730 HB 14/12	M24/0609	19	48	91	159	269	370
739 HB 17/13	M24/0610	20	49	96	178	330	468
903 HB 1/14	M24/0611	20	49	96	181	348	516
832 HB 2/15	M24/0612	20	49	97	183	352	498
707 HB 18/16	M24/0613	19	48	91	162	283	407
898 HB 19/17	M24/0614	20	48	88	149	251	341

Job number: LJ24009

Date reported: 14 August 2024

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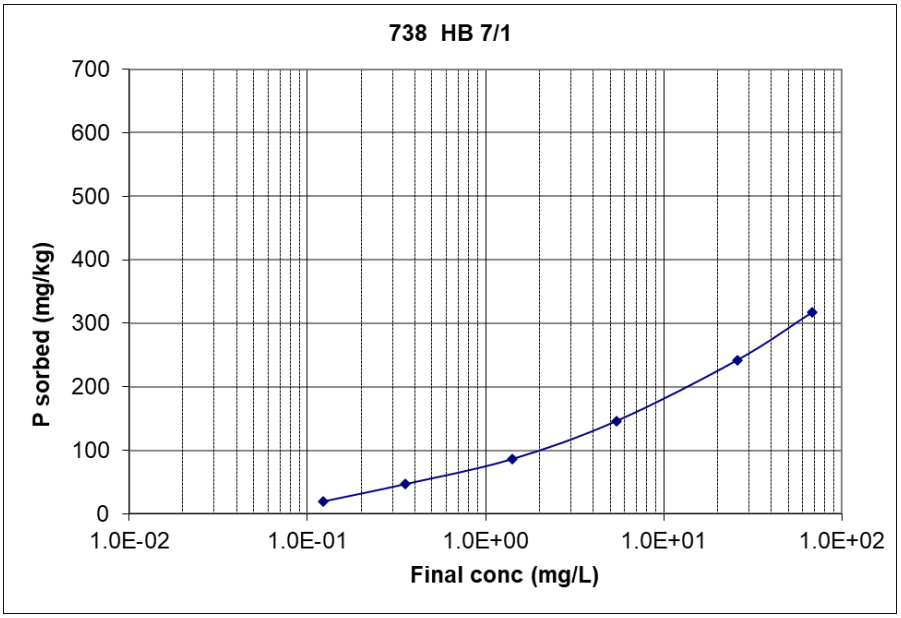

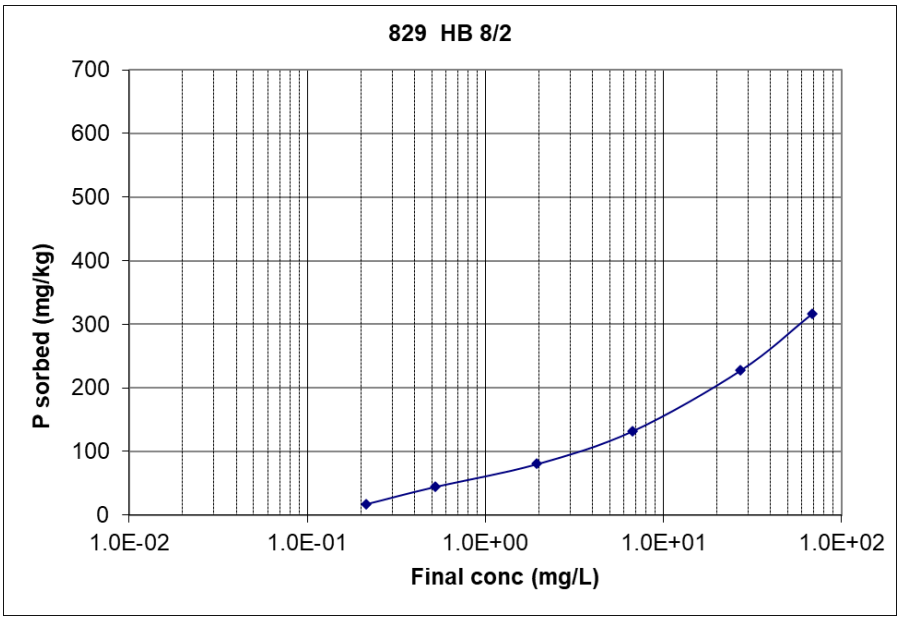

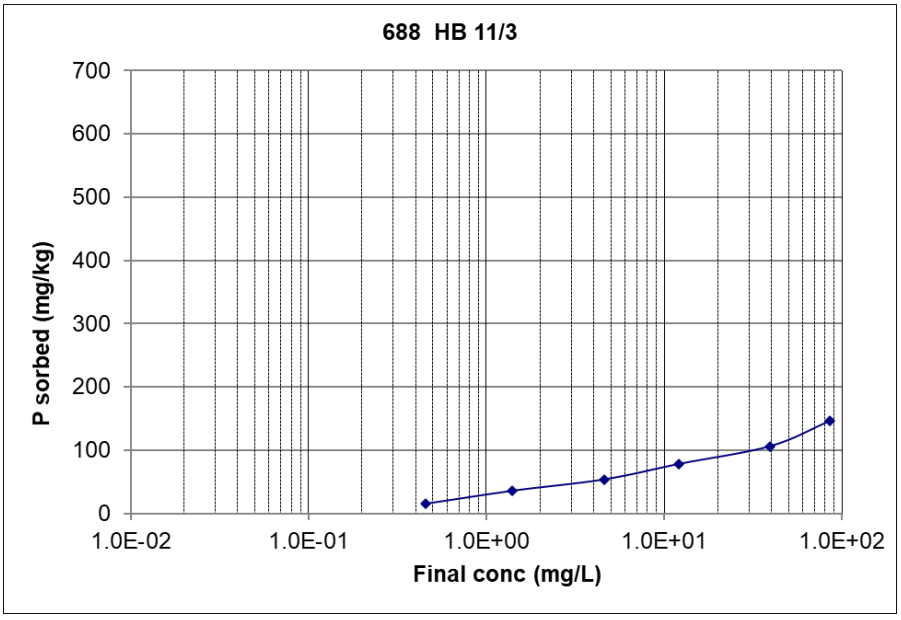

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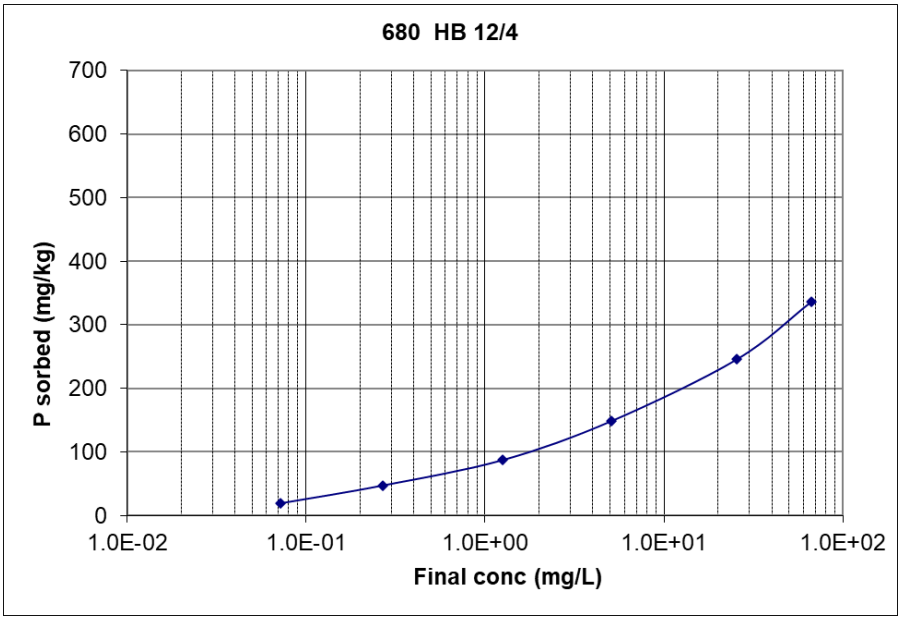

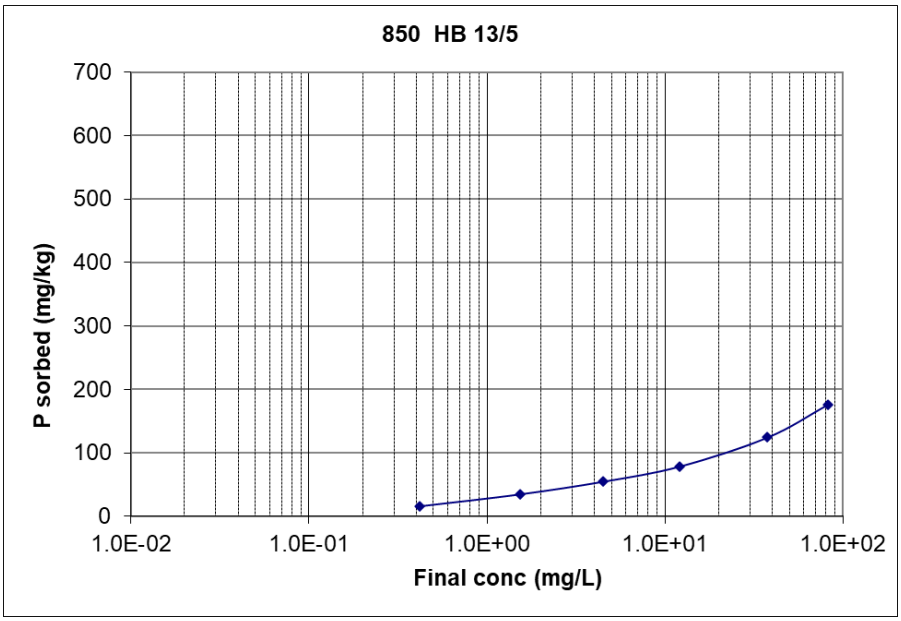

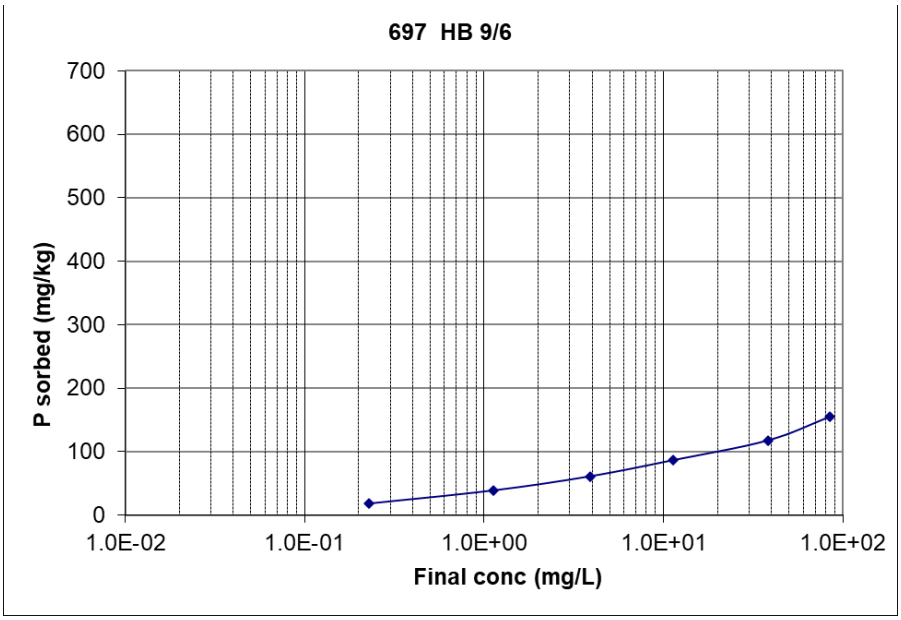

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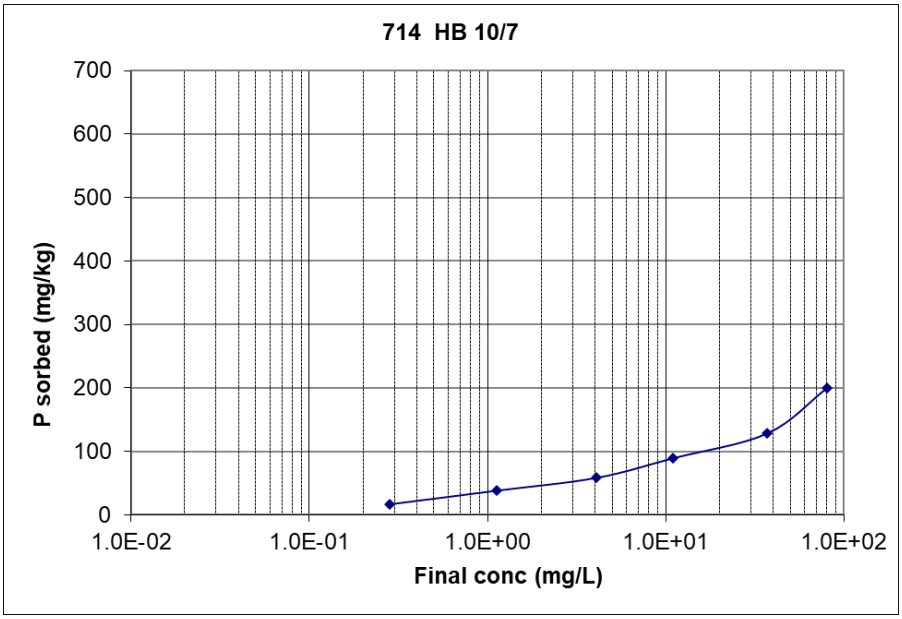

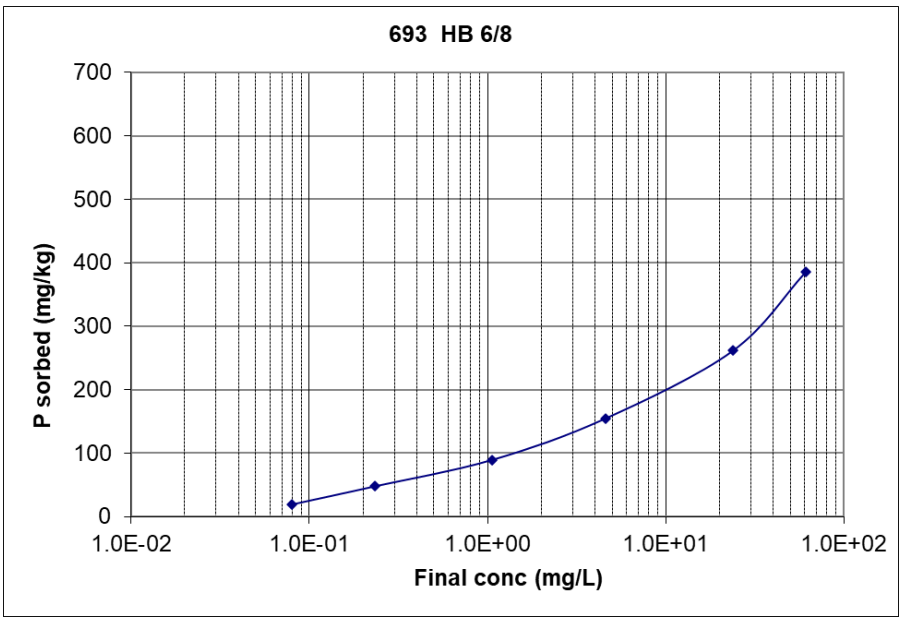

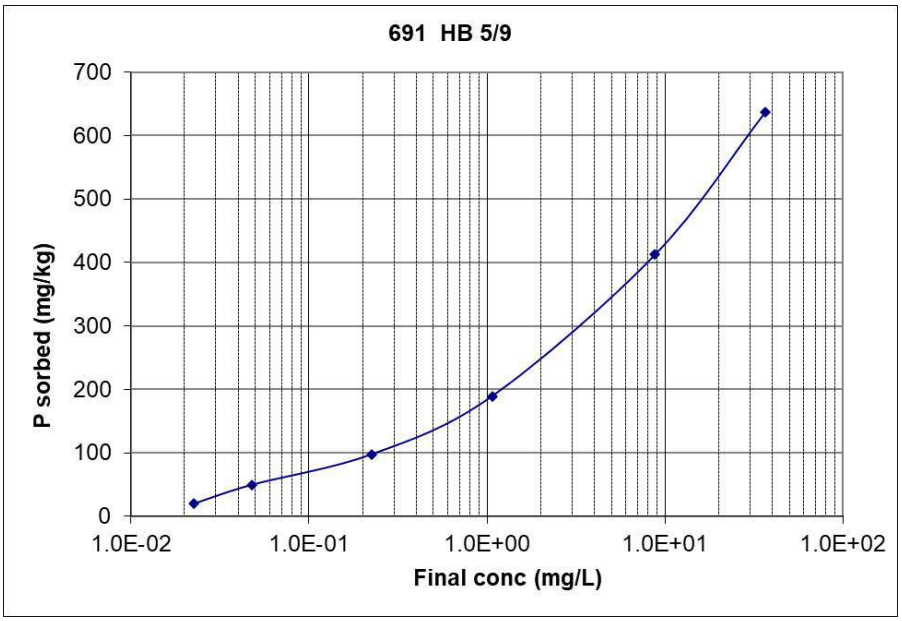

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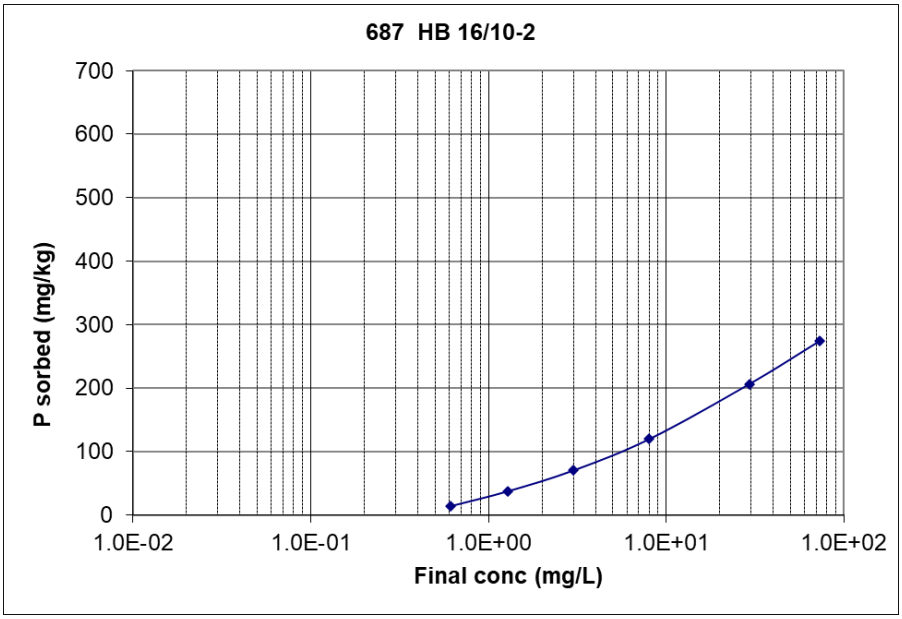

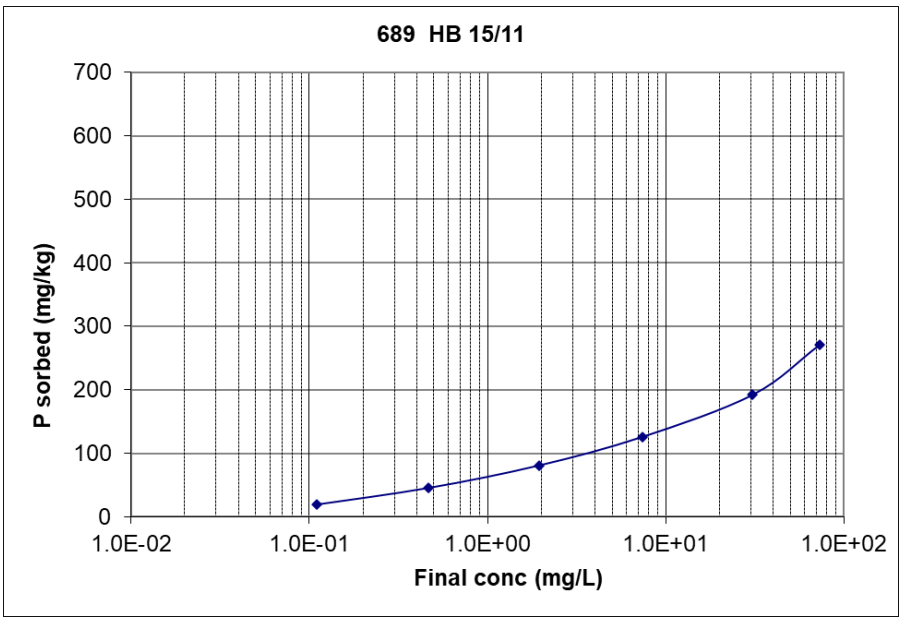

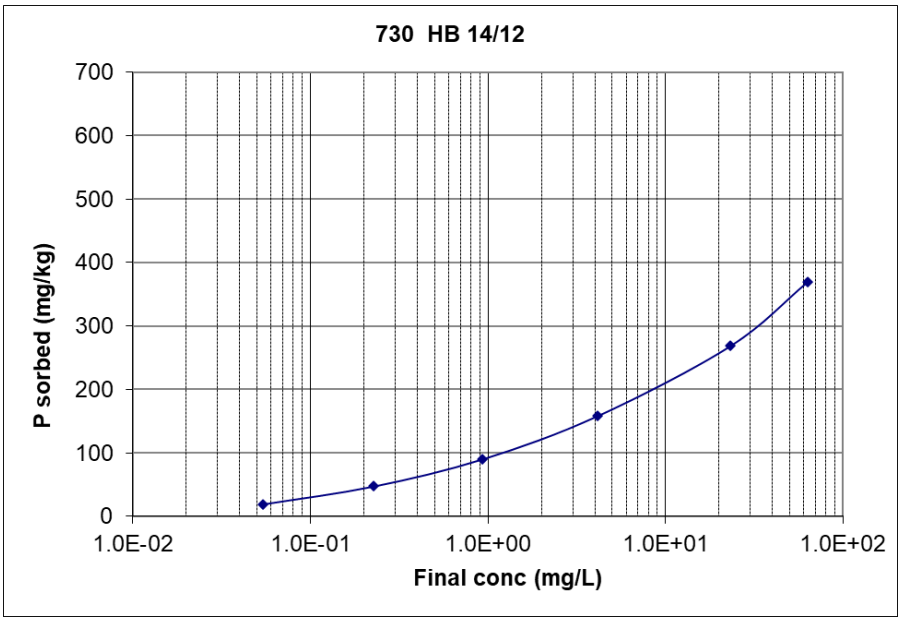

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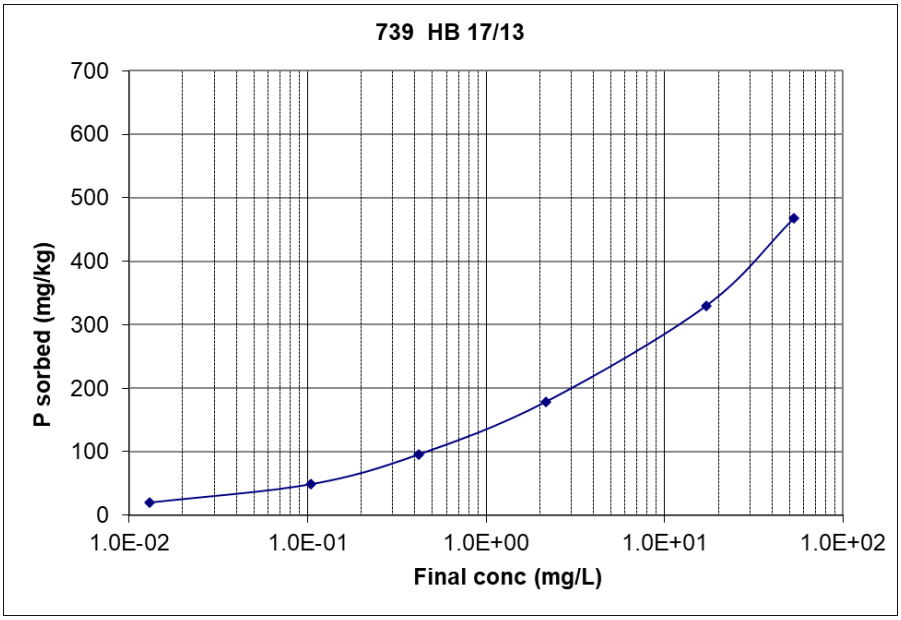

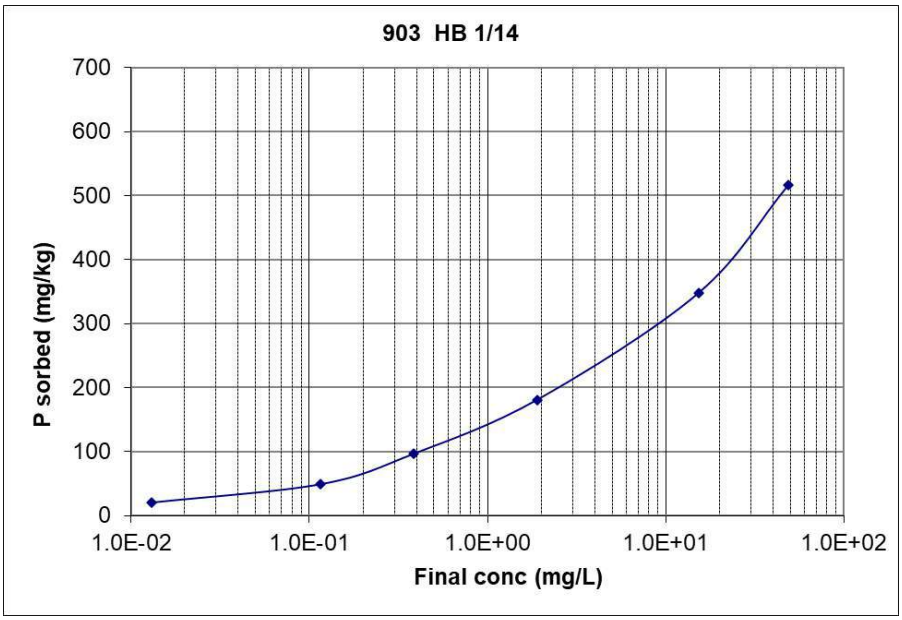

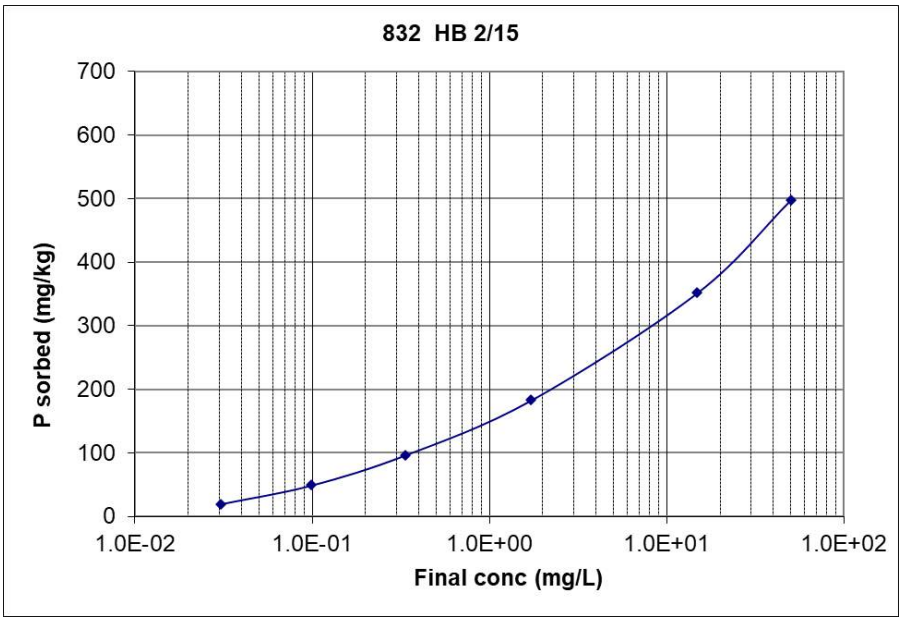

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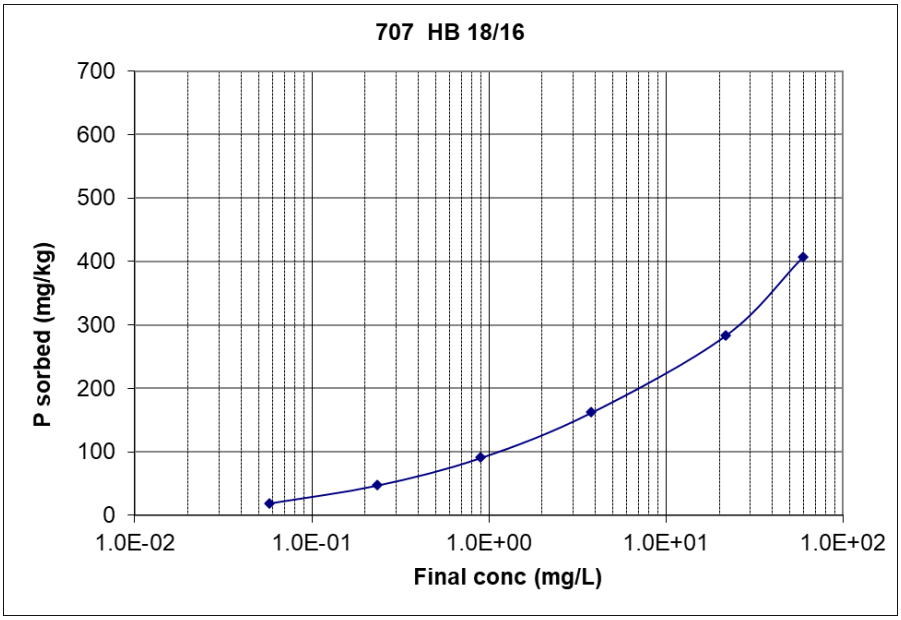

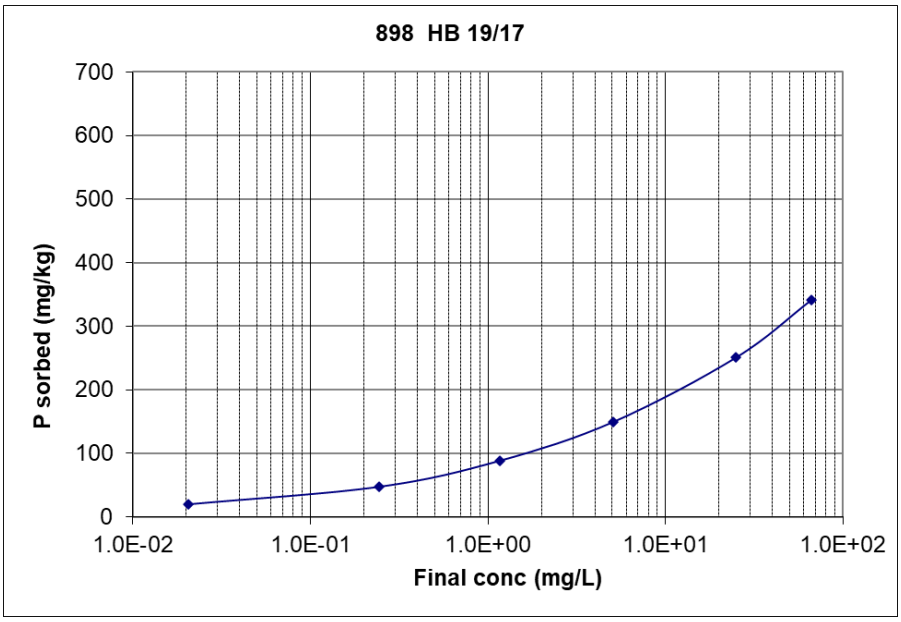

Soil Physics Laboratory
Analytical Report

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Manaaki Whenua
Landcare Research

Job number: PJ23052

Customer: Lowe Environmental Impact
Millie Taylor

Date received: 10 June 2024

Date Analysed: 8 July 2024 to 29 July 2024

Date reported: 13 August 2024

Homestead Bay

Sample name	Core number	ID number	Remarks	Particle density (g/cm^3)	Dry bulk density (g/cm^3)	Porosity (%)	Macro-Porosity (-5 kPa) (%)	Air Capacity (-10 kPa) (%)	Field capacity (%)	AWC (%)	K-40 (mm/hr)
HB 7/1	738	PP23-1730	1	2.72	1.60	41	13	15	27	15	4
HB 8/2	829	PP23-1731		2.72	1.28	53	16	20	33	26	-
HB 11/3	688	PP23-1732		2.79	1.49	47	13	16	30	21	14
HB 12/4	680	PP23-1733		2.75	1.43	48	11	14	34	29	-
HB 13/5	850	PP23-1734		2.80	1.34	52	10	16	37	27	14
HB 9/6	697	PP23-1735		2.82	1.33	53	8	12	41	37	-
HB 10/7	714	PP23-1736		2.78	1.44	48	10	13	35	31	13
HB 6/8	693	PP23-1737		2.67	1.43	47	15	17	29	24	32
HB 5/9	691	PP23-1738		2.68	1.32	51	15	18	33	24	-
HB 16/10-2	687	PP23-1740		2.76	1.33	52	15	18	34	26	-
HB 15/11	689	PP23-1741		2.80	1.36	52	13	16	36	31	20
HB 14/12	730	PP23-1742		2.82	1.45	49	9	10	38	26	3
HB 17/13	739	PP23-1743		2.77	1.27	54	12	14	40	29	-
HB 1/14	903	PP23-1744		2.65	1.30	51	11	16	35	24	-
HB 2/15	832	PP23-1745		2.69	1.34	50	14	19	31	23	15
HB 18/16	707	PP23-1746		2.77	1.33	52	14	17	35	23	26
HB 19/17	898	PP23-1747		2.79	1.41	50	13	15	34	24	-

Remarks: 1) Large stones removed from lower surface and backfilled

Sample name	Gravimetric water content (%w/w)					Volumetric water content (%w/w)				
	As received moisture	Saturation (calc.)	5 kPa	10 kPa	1500 kPa	As received moisture	Saturation (calc.)	5 kPa	10 kPa	1500 kPa
HB 7/1	12	26	18	17	7	20	41	28	27	12
HB 8/2	18	41	29	26	5	24	53	37	33	7
HB 11/3	11	31	23	20	6	17	47	34	30	9
HB 12/4	16	34	26	24	4	23	48	37	34	5
HB 13/5	12	39	32	27	7	16	52	43	37	10
HB 9/6	12	40	34	30	2	16	53	45	41	3
HB 10/7	13	33	26	24	3	19	48	38	35	4
HB 6/8	17	33	22	20	4	24	47	31	29	6
HB 5/9	16	39	27	25	7	22	51	36	33	9
HB 16/10-2	19	39	28	25	6	26	52	37	34	8
HB 15/11	17	38	28	26	4	23	52	39	36	5
HB 14/12	20	33	28	26	8	29	49	40	38	12
HB 17/13	28	43	34	32	9	36	54	43	40	11
HB 1/14	19	39	31	27	8	24	51	40	35	10
HB 2/15	17	38	27	23	7	22	50	36	31	9
HB 18/16	20	39	28	26	8	26	52	38	35	11
HB 19/17	18	35	26	24	8	26	50	37	34	11

Macro-porosity cited here is determined between total porosity and tension of -5 kPa, for consistency with the National Soils Database of New Zealand (NSD).
Air Capacity cited here is determined between total porosity and tension of -10 kPa. This may be referred to as Macro-porosity for specifications requiring this characteristic to be measured at -10 kPa. It is important to be aware what tension has been used, particularly with historical or NSD

References:
Gradwell, M.W. 1972: Methods for physical analysis of soils. *Scientific Report 10C.* Lower Hutt, N.Z. Soil Bureau.
Cook FJ, Lilley GP, Nunns RA 1993. Unsaturated hydraulic conductivity and sorptivity: Laboratory measurement. In: Carter MR ed. Soil sampling and methods of analysis. Boca Raton, FL, Lewis Publishers. Pp. 615–624.

Shane Cox
Laboratory Manager – Soil Physics

APPENDIX B
Overseer Modelling

MEMORANDUM Job 10934

To:	Brian Ellwood
From:	Jimena Rodriguez
Date:	17 December 2024
Subject:	OVERSEER Nutrient Modelling for Homestead Bay

This memo summarises the OverseerFM nutrient modelling outcomes for the baseline (current farm system) and two scenarios that modelled the discharge of wastewater from a 'residential and commercial development' at RCL's Homestead Bay.

The baseline data was provided by Matt Little, who is the farm manager for both properties. Attachment A is the farm map provided by Matt indicating the boundary of the farm. The properties are operated together and have been modelled as a single operating unit.

BASELINE NUTRIENT LOSS RATES

The baseline Overseer input Data used in the nutrient modelling is provided in the following tables.

Table 1: Overseer Blocks and Area

Block	Property	Area (ha)
Dryland flats	QEII	135
Hill	QEII	400
Irrigation	QEII	80
Lot 8	RCL	134
Lot 12	RCL	36
Lucerne	RCL	13.4
Young grass	QEII	18
Barley	RCL	16.7
Bush	QEII	25.5
Trees	QEII	43.4

Table 2: Baseline Fertiliser Inputs

Blocks	Area (ha)	Fertiliser and Application Rate
Young grass	18	- Cropzeal: 250 kg/ha in Spring - Lime: 1-3 tonnes in Spring - DAP sulphur super: 125 kg/ha in spring - Urea- rate assumed 55 kg N/ha in April
Swedes	10	- Cropzeal: 250 kg/ha in Spring - DAP sulphur super: 125 kg/ha in spring
Dryland flats	125	- DAP sulphur super: 125 kg/ha in spring Urea- rate assumed 55 kg N/ha in October and March
Hill	400	- Super 10: 125 kg/ha in late winter - Lime: 1-3 tonnes in Spring
Irrigation	80	- DAP sulphur super: 125 kg/ha in spring
Airstrip -Barely	16.7	- Cropzeal and some urea Rate assumed to 80 kg N/ha in September and November

Table 3: Baseline Stock

	Sheep			Beef					Deer
Month	Ewes	Hoggets	Lambs	Cows	Steer	Heifers	Rep Heifers	Bulls	Hinds
July	1,800	520		110	65	65	25	4	840
Aug	1,800	520		110	65	65	25	4	840
Sep	1,780	520	2,520	110	65	65	25	4	840
Oct	1,770	520	2,520	110	65	65	25	4	840
Nov	1,670	520	2200	110	65	65	25	4	840
Dec	1,650	520	1,800	110	65	65	25	4	840
Jan	1,500	520	1,500	110	65	65	25	4	840
Feb	1,375	450	1,100	110	65	65	25	4	840
Mar	1,350	-	400	110	65	65	25	4	840
Apr	1,800	520	150	110	65	65	25	4	840
May	1,800	520		110	65	65	25	4	840
Jun	1,800	520		110	65	65	25	4	840

Table 4: Baseline Supplements and Crops

Crop Type	Harvest Block		Destination	Amount Made (T)	Animals Fed
Barley	Airstrip		Most Blocks	120	Deer
Baleage	Irrigation		Most Blocks	650 bales	Most
Swedes	Cattle yards			110	Weaners

- Irrigation block:
  - 80 ha
  - Application depth 52 mm
  - Irrigation from November to March

SCENARIOS

1. RCL:
   - In this scenario, the Wastewater from the residential development is discharged to A1, A2, A3 and A4 at RCL property (see map in Appendix B for the identification and location of each area).
   - The number of animals is reduced proportional to the reduction in the total area available for grazing, keeping the stock unit per ha similar to the baseline. In this Scenario, Lot 8 (165 ha) is a house block (residential development); the rest of Lot 8 and 12 (8 ha) will be landscaped lawns mowed at least twice a year, with the grass will be collected.
   - The area (ha) and average annual discharge depth (mm/day) where the WW is discharged is summarised in Table 5 below:

Table 5: Areas of Discharge and Discharge Depth

Overseer Block Groups	Land Treatment **Area's**	Area (ha)	Average Discharge Depth (mm/d)	Design Flow Rate (m3/day)	Annual Flow Rate (m3/year)
Area 1	C3, C4, C5 and JP buffer-grazed	4.5	5.4	250	89,089
Area 2	C1, C2, A, D, E, F, G	11.6	7.1	820	299,554
Area 3	H,I,J,K,L	7.2	7.1	515	187,716
Area 4	JP Village	5.2	8.0	420	152,005
Total		28.5	7.0	2,005	728,364

- Table 6 summarises the N and P loading (kg/ha) per month that is discharged in Areas groups 1 to 4. The nutrient loading and discharge depth are the same for the four areas. Therefore, it is summarised as A1 to A4. The nitrogen is provided in the model as organic fertiliser.

Table 6: Total N and P Applied (kg/ha) in Irrigation Wastewater

Area 1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total/year
Application depth ADW (mm/ha)	167	151	167	162	167	162	167	167	162	167	162	167	1,971
Nitrogen Loading kg	57	51	57	55	57	55	57	57	55	57	55	57	668
N Loading kg/ ha	12.6	11.3	12.6	12.2	12.6	12.2	12.6	12.6	12.2	12.6	12.2	12.6	148
P Loading kg	19	17	19	18	19	18	19	19	18	19	18	19	223
P Loading kg/ ha	4	4	4	4	4	4	4	4	4	4	4	4	49

Area 2	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total/year
Application depth ADW (mm/ha)	220	199	220	213	220	213	220	220	213	220	213	220	2,592
Nitrogen Loading kg	191	172	191	185	191	185	191	191	185	191	185	191	2,247
N Loading kg/ ha	16.5	14.9	16.5	16.0	16.5	16.0	16.5	16.5	16.0	16.5	16.0	16.5	194
P Loading kg	64	57	64	62	64	62	64	64	62	64	62	64	749
P Loading kg/ ha	6	5	6	5	6	5	6	6	5	6	5	6	65

Area 3	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total/year
Application depth ADW (mm/ha)	220	199	220	213	220	213	220	220	213	220	213	220	2,592
Nitrogen Loading kg	120	108	120	116	120	116	120	120	116	120	116	120	1,408
N Loading kg/ ha	16.5	14.9	16.5	16.0	16.5	16.0	16.5	16.5	16.0	16.5	16.0	16.5	194
P Loading kg	40	36	40	39	40	39	40	40	39	40	39	40	469
P Loading kg/ ha	6	5	6	5	6	5	6	6	5	6	5	6	65

Area 4	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total/year
Application depth ADW (mm/ha)	248	224	248	240	248	240	248	248	240	248	240	248	2,920
Nitrogen Loading kg	97	87	97	94	97	94	97	97	94	97	94	97	1,140
N Loading kg/ ha	18.6	16.8	18.6	18.0	18.6	18.0	18.6	18.6	18.0	18.6	18.0	18.6	219
P Loading kg	32	29	32	31	32	31	32	32	31	32	31	32	380
P Loading kg/ ha	6	6	6	6	6	6	6	6	6	6	6	6	73

- Supplements:

  The management for the Area 1 group is grazed by sheep or planted in native forestry, while Area 2, 3 and 4 are operated as cut & carried; baleage will be harvested four times per year, removing approximately 10 t DM/ha/yr.

OVERSEER OUTCOMES

The nutrient loss for the baseline farmed area total, the RCL blocks of the current system and the proposed RCL total subdivision and Land treatment areas are presented in Table 7.

Table 7: Total Losses for Baseline and the Scenario

	Total losses				
Analyses	N (kg/y)	N (kg/ha/y)	P(kg/y)	P (kg/ha)	GHG (t)
Year 2023-2024 (Baseline)	8,039	9.0	128	0.1	3,121.7
RCL- baseline*	1,839	9.1			
RCL LTA	2,052	10.2	62	0.3	91.9

* refers to the total N losses/y from those located at RCL (Lot 8, lucerne, barley and Lot 12)

Table 8 illustrates the nutrient loss rates for the individual blocks, which comprise the RCL area during the current farming period as a baseline and the proposed housing development.

Table 8: Nitrogen Losses Per Block for the Baseline and RCL-LTA

	Blocks	Blocks area (ha)	Total N loss (kg/y)	N leaching (kg/ha/y)	Total P Loss (kg/y)	P Loss (kg/ha/yr)
Year 2023-2024 Baseline	Lot 8	134	1,188	9	4	0.1
	Lucerne	13.4	148	10.8	0	0.1
	Barley	16.7	284	16.9	1	0.1
	Lot 12	36	219	6.5	2	0.1
	N losses from lucerne, barley lot 8 and lot 12		*1,839*	9.1	7	0.1
RCL LTA	Area 1- C3, C4, C5, JP Buffer - grazed	4.5	411	91.6	16	3.4
	Area 2- C1, C2, A, D, E, F, G	11.6	582	50.1	14	1.2
	Area 3 - i, H, J, K, L	7.2	352	48.5	9	1.2
	Area 4 - JP Village	5.2	311	60	6	1.3
	Lot 8 and 12 other areas	8	24	3	0	
	Lot 8 housing	165	371	2	16	0.1
	N losses		2,052	10.2	61	0.3

COMMENTS

Year 2023-2024- Baseline (original farm system)

- In the baseline, there are 10 blocks: Dryland flat, Hill, Irrigation, Lot 8, Lot 12, Lucerne, Young grass, Barley, Swedes, Bush and Scrub.
- The N losses per ha for the baseline equals to 9.0 kg N/ha.
- The total N losses from the baseline is 8,039 kg N/y.
- Total N losses from RCL-specific Blocks, Lot 8, Lot 12, Lucerne, and Barley blocks equal 1,839 kg N /y. These blocks are the only blocks kept in the Scenario below (RCL- LTA) with WW applied.

RCL- LTA

- WW volume discharged per year equals to 728,364 m^3/yr or averaging 1,996 m^3/day.
- In the RCL development scenario, WW is discharged to four areas (A1 to A4) which are located in Lot 8 and 12.
- The N loss per ha for the full development area equals 10.2 kg N/ha.
- The total N losses for this scenario equals to 2,052 kg N/y (212 kg N/yr higher than the RCL baseline model), where WW will be discharged.
- A RCL housing development block was added to the model, which is the block where the houses will be built. N losses from this block are equal to 371 kg N/yr.

With WW applied to Areas 1, 2, 3 and 4, the total N losses increased by 212 kg N/yr (1,839 kg N/yr compared to 2,052 kg N/yr).

Table 9 compares the N losses permitted by the ORC Water Plan (RWP)[1] and the N losses obtained from OverseerFM. The N losses predicted by Overseer is 2,052 kg N/y, which is 986 kg N/y lower than the amount permitted without consent by the RWP (3,038 kg N/y).

Table 9: Permitted N Losses by the RWP and N losses Modelled by OverseerFM

Block	Property	Area (ha)	Permitted N Loss (15 kg N/ha/y)	Modelled loss (kg N/y)
Lot 8 and Lot 12	RCL	8	120	24
Lot 8 housing	RCL	165	2,475	371
A1 to A4	RCL	28.5	428	1,656
Total		200.1	3,038	2,052

*This is the total amount lost from A1, A2, A3, A4 and area from lot 12 modelled by Overseer

[1] ORC Regional Plan: Water for Otago (RPW) Plan

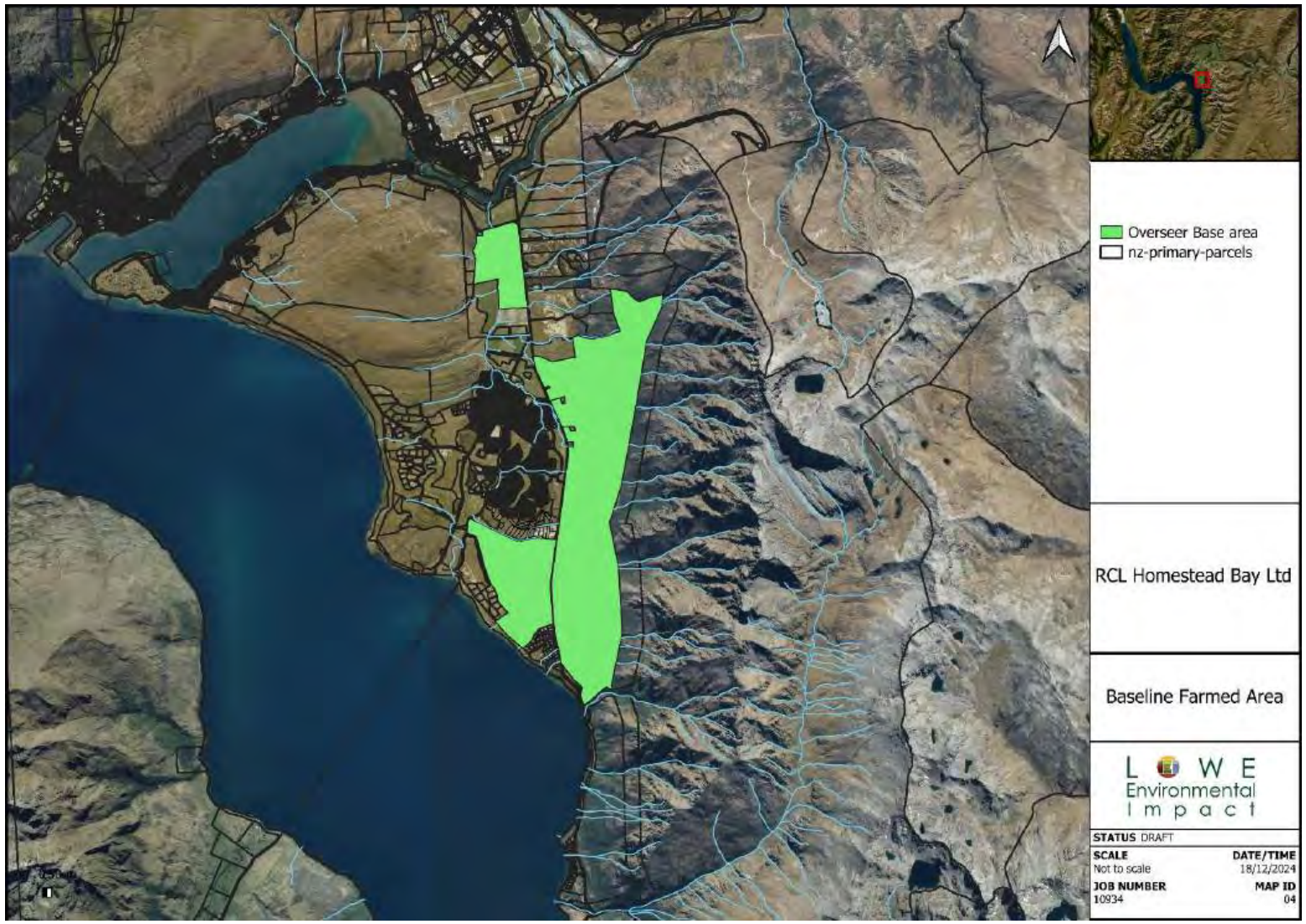
APPENDICES

Appendix A Farm Map

Appendix B Identification and Location of the LTA at RCL Property

APPENDIX A

Farmed Area Maps

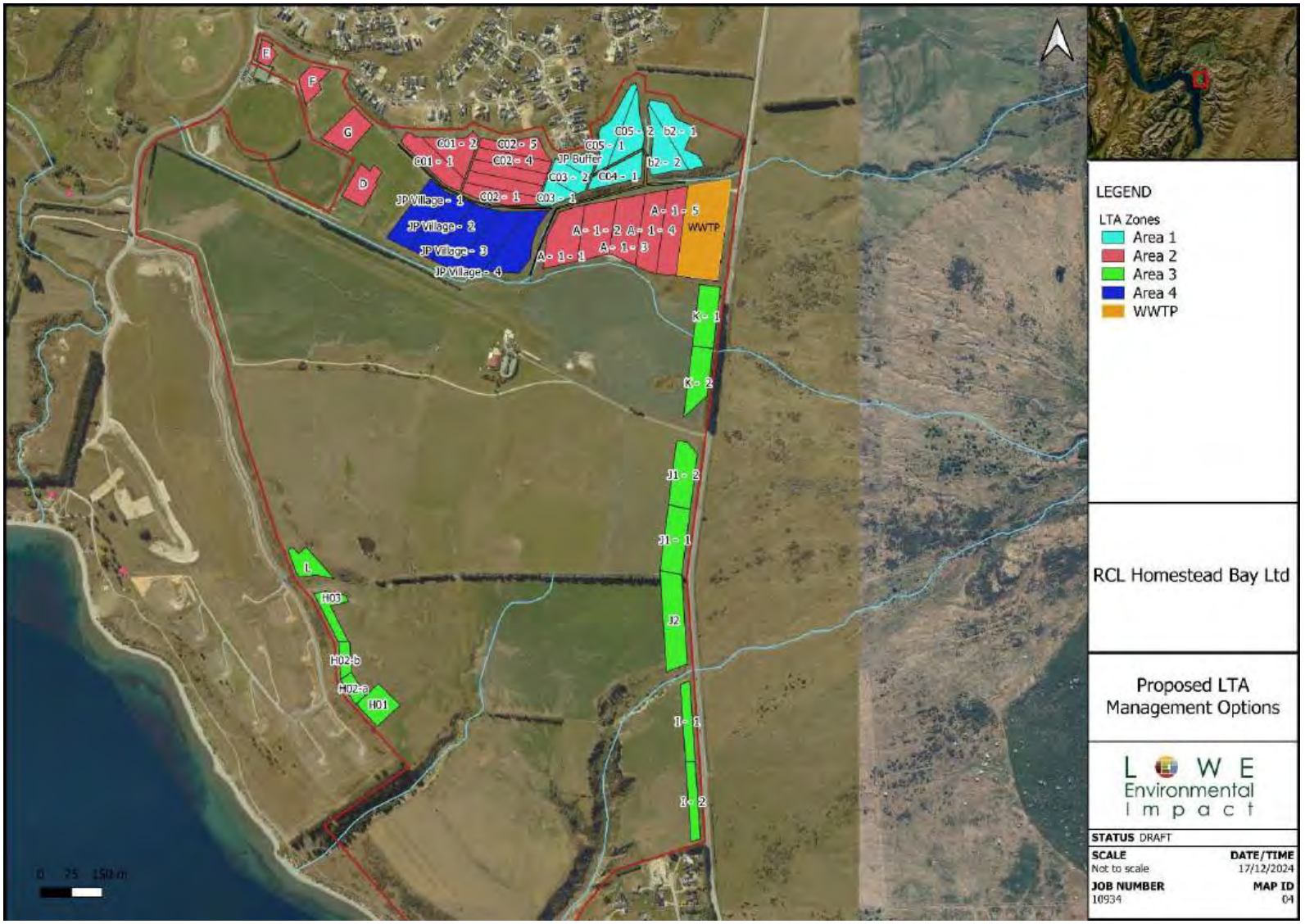


Appendix A: Baseline Farmed Area

Appendix A: Paddock Map

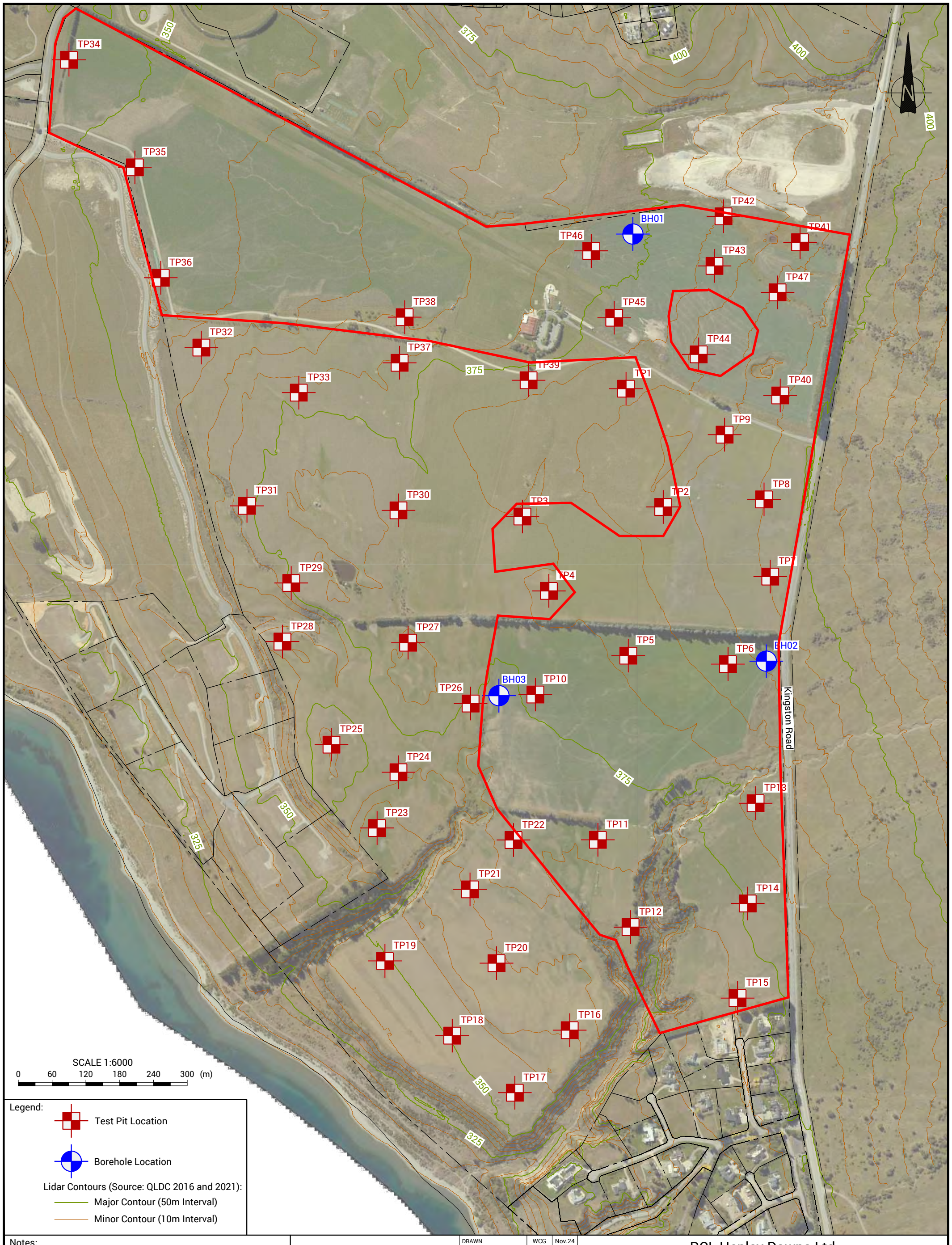
APPENDIX B

Identification and Location of the LTA at RCL



Appendix B: Proposed Land Treatment Areas

APPENDIX C
Geosolve Logs



Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Limited with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

GEOSOLVE
Level 1, 70 MacAndrew Road, South Dunedin
www.geosolve.co.nz

DRAWN	WCG	Nov.24
DRAFTING CHECKED		
APPROVED		
CADFILE: 220556.01-I.dwg		
SCALES (AT A3 SIZE): 1:6000		
PROJECT No: 220556.01		

RCL Henley Downs Ltd

Homestead Bay

Geotechnical Assessment (GI)

Investigation Site Plan

FIG No: Appendix A, Figure 1

Rev: 0

TEST PIT LOG

HOLE NO.: TP01

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371 | **CONTRACTOR:** Base Contracting | **START DATE:** 22/10/2024

COORDINATES: 1265689.0 mE, 4998600.0 mN (NZTM2000) | **EQUIPMENT:** 13T | **END DATE:** 22/10/2024

LOCATION METHOD: Handheld GPS | **ACCURACY:** ± 3 m | **LOGGED BY:** JMJ

ELEVATION: Existing ground level | **OPERATOR:** Jeremy | **CHECKED DATE:** 04/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic silty SAND, trace rootlets, brown. 0.20 m				2		
LOESS	Silty fine SAND, with rootlets and organic inclusions, brownish orange, massive. Loose, moist. 0.50 m				2, 1, 2		
WEATHERED GLACIAL TILL	Sandy fine to coarse GRAVEL, with minor to some silt and trace cobbles, orange, massive. Medium dense, moist, gravels are subrounded to rounded. Sand is fine to coarse. 0.70 m Fine SAND, with trace to minor gravel and trace silt. 500 mm diameter boulder at 1.20 m, orange and grey, massive. Loose to medium dense, moist to wet. 1.30 m		0.5 1.0		7, 7 2, 1 4 20 >>		
GLACIAL TILL	Fine to medium SAND, with minor gravel and trace cobbles and boulders up to 500 mm in diameter. Orange sand banding throughout, light grey, massive. Dry to moist, gravels are fine to coarse, subrounded to rounded. 3.80 m		1.5 2.0 2.5 3.0 3.5				Groundwater Not Encountered
	End Of Hole: 3.80 m		4.0 4.5				

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:07:01 am

TEST PIT LOG

HOLE NO.: TP02

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
COORDINATES: 1265764.0 mE, 4998393.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 22/10/2024
END DATE: 22/10/2024
LOGGED BY: JMJ
CHECKED DATE: 04/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)
TOPSOIL	Organic silty SAND, trace rootlets, brown. 0.30 m
LOESS	Silty fine SAND, with rootlets and organic inclusions, brownish orange, massive. Loose, moist. 0.60 m
WEATHERED GLACIAL TILL	Sandy fine to coarse GRAVEL, with minor silt and trace cobbles, orange and grey, massive. Loose to medium dense, moist , gravels are subrounded to rounded. Sand is fine to coarse. 0.80 m Fine SAND, with trace to minor gravel and trace silt and boulders up to 400 m in diameter, orange and grey, massive. Loose, moist, gravels are fine to medium, subrounded to rounded. 1.60 m
GLACIAL TILL	Fine to coarse SAND, with minor gravel, trace cobbles and boulders up to 300 mm in diameter, light grey, massive. Dense, dry to moist, gravels are fine to coarse, subrounded to rounded. 4.40 m
	End Of Hole: 4.40 m

SAMPLES | DEPTH / RL | LEGEND

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	Blows / 100 mm
0.0 – 0.3	1, 1
0.3 – 0.6	2, 2, 2, 3
0.6 – 0.8	2, 2
0.8 – 1.6	3, 2, 1, 2, 2, 2
1.6 – 4.4	6, 20 >>

SHEAR STRENGTH (kPa) Vane: 50, 100, 150, 200 | Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

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TEST PIT LOG

HOLE NO.: TP03

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
COORDINATES: 1265515.0 mE, 4998365.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 22/10/2024
END DATE: 22/10/2024
LOGGED BY: JMJ
CHECKED DATE: 04/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic silty SAND, trace rootlets, brown. 0.30 m		
ALLUVIAL FAN DEPOSITS	SILT, with trace organic inclusions, grey. Firm, moist. 0.70 m		
	Sandy, silty fine to coarse GRAVEL, brown and grey, chaotic. Medium dense, moist to wet, gradual top and bottom contacts, gravels are subrounded to rounded. Sand is coarse. 1.00 m		
	Sandy fine to coarse GRAVEL, orange, chaotic. Medium dense, moist, immediate contact at base, gravels are subrounded to rounded. Sand is coarse. 1.30 m		
GLACIAL TILL	Fine to coarse SAND, with minor gravel and trace cobbles and boulders, grey, massive, with orange banding decreasing with depth. Dense, moist, gravels are fine to coarse, subrounded to rounded. 3.80 m		
	End Of Hole: 3.80 m		

LEGEND

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	Blows
0.3	1
0.4	2
0.5	2
0.6	1
0.7	1
0.8	2
0.9	1
1.0	6
1.1	6
1.2	4
1.3	7
1.4	18 >>
1.5	20 >>

SHEAR STRENGTH (kPa) Vane: Values

WATER: Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:07:08 am

TEST PIT LOG

HOLE NO.: TP04

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 22/10/2024
COORDINATES: 1265567.0 mE, 4998235.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 04/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic silty SAND, trace rootlets, brown. 0.20 m			TS	3, 4		
UNCONTROLLED FILL	Silty, sandy fine to coarse GRAVEL, with Fragments of steel pipe, dark orange. Dry to moist, gravels are rounded, Sand is fine to medium . 0.60 m				6, 20 >>		
	Fine to coarse SAND, with minor gravel and trace silt, grey and orange, loosely bedded. Medium dense, moist, gravels are fine to coarse, rounded. 0.70 m		0.5				
	Coarse SAND, grey , bedded. Medium dense, moist.						
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL, trace cobbles, with some beds of gravel with trace sand, grey and orange, bedded. Medium dense, moist, dipping between 5-10° towards 222°, gravels are subrounded to rounded. Sand is fine to coarse.		1.0		6, 6, 9, 5, 4, 3, 5, 5, 4		Groundwater Not Encountered
	3.20 m		1.5				
	Gravelly fine to coarse SAND, with beds of coarse sand, grey, bedded. Medium dense, moist, dipping between 5-10° towards 222°, gravels are fine to coarse, subrounded to rounded.		2.0				
	4.20 m		2.5				
			3.0				
			3.5				
			4.0				
GLACIAL TILL	Sily SAND, with trace gravel, grey, minor laminations. Medium dense, moist to wet, horizontal contact, gravels are fine to medium, subrounded to rounded. 4.50 m		4.5				
	End Of Hole: 4.50 m						

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit collapsing in coarser gravels

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:07:12 am

TEST PIT LOG

HOLE NO.: TP05

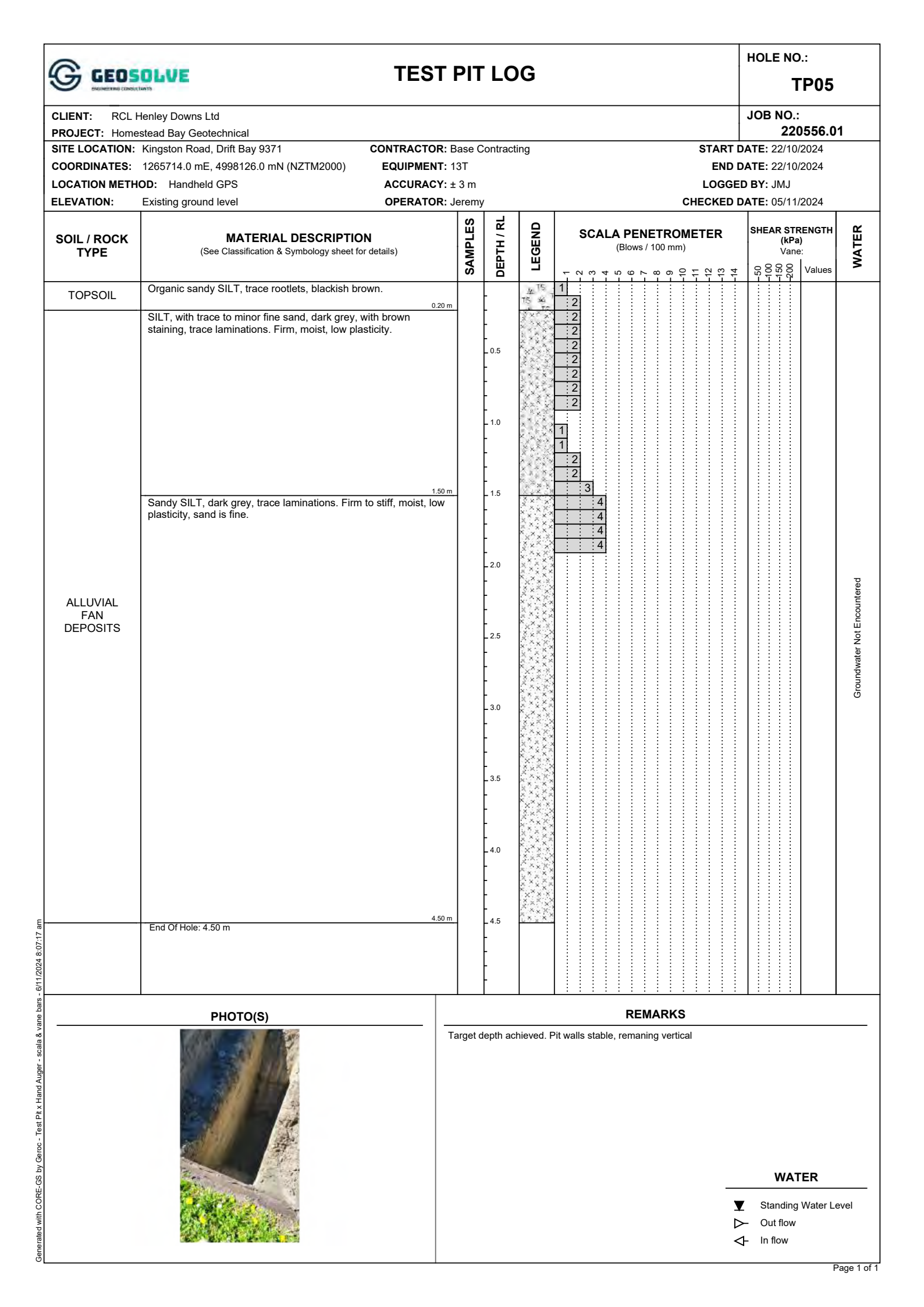
CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
COORDINATES: 1265714.0 mE, 4998126.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 22/10/2024
END DATE: 22/10/2024
LOGGED BY: JMJ
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic sandy SILT, trace rootlets, blackish brown. 0.20 m						
ALLUVIAL FAN DEPOSITS	SILT, with trace to minor fine sand, dark grey, with brown staining, trace laminations. Firm, moist, low plasticity. 1.50 m						
	Sandy SILT, dark grey, trace laminations. Firm to stiff, moist, low plasticity, sand is fine. 4.50 m						
	End Of Hole: 4.50 m						



Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaning vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:07:17 am

TEST PIT LOG

HOLE NO.: TP06

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 22/10/2024
COORDINATES: 1265891.0 mE, 4998119.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic sandy SILT, trace rootlets, blackish brown. 0.20 m						
ALLUVIAL FAN DEPOSITS	SILT, with trace gravel and fine sand, dark grey, laminated. Firm , moist, low plasticity. 0.60 m						
	Sandy fine to coarse GRAVEL, dark grey, discontinuous . Medium dense, moist, gravels are rounded. Sand is medium to coarse. 0.80 m						
	SILT, with trace gravel and fine sand, dark grey, with brown mottling, trace laminations. Loose to medium dense, moist. 2.80 m						
	Sandy fine to coarse GRAVEL, with trace cobbles and boulders up to 200 mm in diameter, dark grey. Moist, gravels are rounded. Sand is medium to coarse. 3.00 m						
	Sandy fine to coarse GRAVEL, dark grey, discontinuous . Medium dense, moist, gravels are rounded. Sand is medium to coarse. 3.50 m						
	Sandy SILT, grey, trace laminations. Firm to stiff, moist to wet, low plasticity, sand is fine. 4.60 m						
	End Of Hole: 4.60 m						

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaning vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:07:21 am

TEST PIT LOG

HOLE NO.: TP07

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371 | **CONTRACTOR:** Base Contracting | **START DATE:** 22/10/2024

COORDINATES: 1265959.0 mE, 4998281.0 mN (NZTM2000) | **EQUIPMENT:** 13T | **END DATE:** 22/10/2024

LOCATION METHOD: Handheld GPS | **ACCURACY:** ± 3 m | **LOGGED BY:** JMJ

ELEVATION: Existing ground level | **OPERATOR:** Jeremy | **CHECKED DATE:** 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic sandy SILT, trace rootlets, blackish brown. 0.20 m						
ALLUVIAL FAN DEPOSITS	SILT, with trace to minor fine sand, dark grey. Firm to stiff, moist, low plasticity. 0.40 m						
	Silty fine to coarse GRAVEL, trace sand, dark grey. Medium dense, moist, gravels are subrounded to rounded. 0.65 m						
	Sandy fine to coarse GRAVEL, with trace silt, dark grey. Medium dense, moist, gravels are subrounded to rounded. 0.70 m						
	SILT, with minor fine sand, dark grey. Firm to stiff, moist, low plasticity. 1.20 m						
	Sandy fine to coarse GRAVEL, trace silt, dark grey. Medium dense, moist, dipping at 5° towards 225°, gravels are subrounded to rounded. 1.60 m						
	Sandy fine to coarse GRAVEL, with trace silt, dark grey. Medium dense, moist, gravels are subrounded to rounded. 3.50 m						
	Sandy SILT, grey. Firm to stiff, moist to wet, low plasticity, sand is fine. 4.20 m						22/10/2024
	Sandy fine to coarse GRAVEL, trace silt, dark grey. Medium dense, saturated, dipping at 5° towards 225°, gravels are subrounded to rounded. 4.40 m						
	Sandy SILT, grey. Firm to stiff, saturated, low plasticity, sand is fine. 4.80 m						
	End Of Hole: 4.80 m						

PHOTO(S)

REMARKS

Target depth achieved. Pit walls collapsing below 4.2 m

WATER

- Standing Water Level
- Out flow
- In flow

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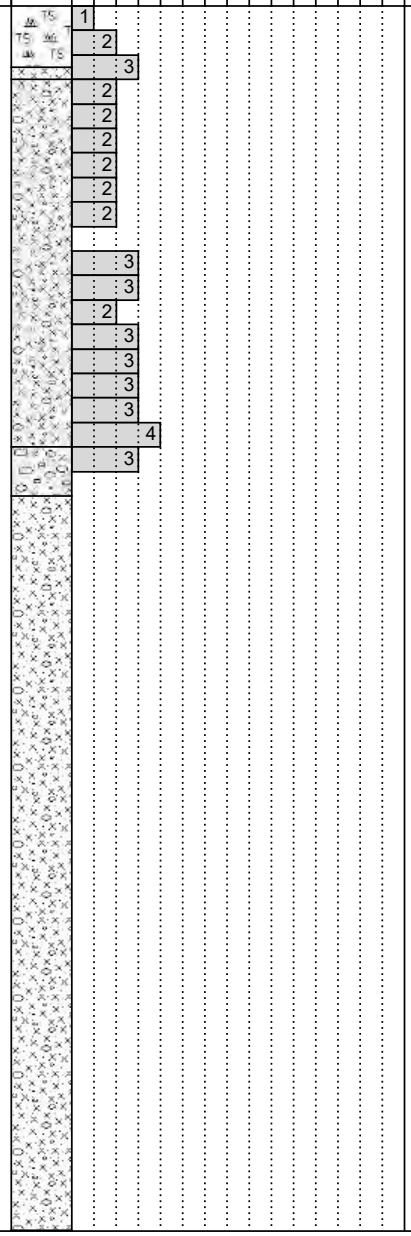
TEST PIT LOG

HOLE NO.: TP08

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 22/10/2024
COORDINATES: 1265942.0 mE, 4998418.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic sandy SILT, trace rootlets, blackish brown.		
	0.25 m Sandy SILT, with trace gravel, light grey. Stiff, moist. 0.30 m		
ALLUVIAL FAN DEPOSITS	SILT, with trace to minor sand, dark grey, discontinuous 100 mm sandy gravel layer at 1.50 m. Firm to stiff, moist, sand is fine.		
	1.80 m Sandy fine to coarse GRAVEL, with minor silt, dark grey. Medium dense, moist, gravels are subrounded to rounded. Sand is fine to coarse. 2.00 m		
	SILT, with some fine sand, grey with brown mottling, occasional discontinuous sandy gravel layers. Stiff, moist.		
	End Of Hole: 5.00 m 5.00 m		



PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaning vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:07:32 am

TEST PIT LOG

HOLE NO.: TP09

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371 | **CONTRACTOR:** Base Contracting | **START DATE:** 22/10/2024

COORDINATES: 1265867.0 mE, 4998529.0 mN (NZTM2000) | **EQUIPMENT:** 13T | **END DATE:** 22/10/2024

LOCATION METHOD: Handheld GPS | **ACCURACY:** ± 3 m | **LOGGED BY:** JMJ

ELEVATION: Existing ground level | **OPERATOR:** Jeremy | **CHECKED DATE:** 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic sandy SILT, trace rootlets, blackish brown. 0.20 m		
ALLUVIAL FAN DEPOSITS	SILT, with minor fine sand, dark grey. Firm, moist, low plasticity. 0.60 m		
	Sandy SILT, with trace gravel, light grey. Firm, moist, gravels are fine to medium, subrounded to rounded. Sand is fine. 0.80 m		
	SILT, with minor sand, dark grey, mottled orange. Firm, moist, low plasticity, sand is fine. 1.60 m		
	Sandy fine to coarse GRAVEL, with trace silt, cobbles and boulders, dark grey, mottled orange. Medium dense, saturated, gravels are subrounded to rounded. Sand is fine to coarse. 3.10 m		
WEATHERED GLACIAL TILL	SILT, with minor sand, grey. Firm, saturated, low plasticity, sand is fine. 3.60 m		
	Sandy fine to coarse GRAVEL, with trace silt, cobbles and boulders, dark grey, mottled orange. Medium dense, saturated, gravels are subrounded to rounded. Sand is fine to coarse. 4.00 m		
GLACIAL TILL	SILT, with trace to minor sand and gravel, light grey. Very stiff, moist, sand is fine to medium. Gravels are fine and subrounded. 4.50 m		
	End Of Hole: 4.50 m		

LEGEND

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.0		2												
0.2		2												
0.4		2												
0.6		2												
0.8		2												
1.0		2												
1.2		2												
1.4		2												
1.6		2												
1.8		2												
2.0				4										
2.2								8						
2.4								8						

SHEAR STRENGTH (kPa) Vane: 50 100 150 200 Values

WATER: 22/10/2024

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaning vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:07:37 am

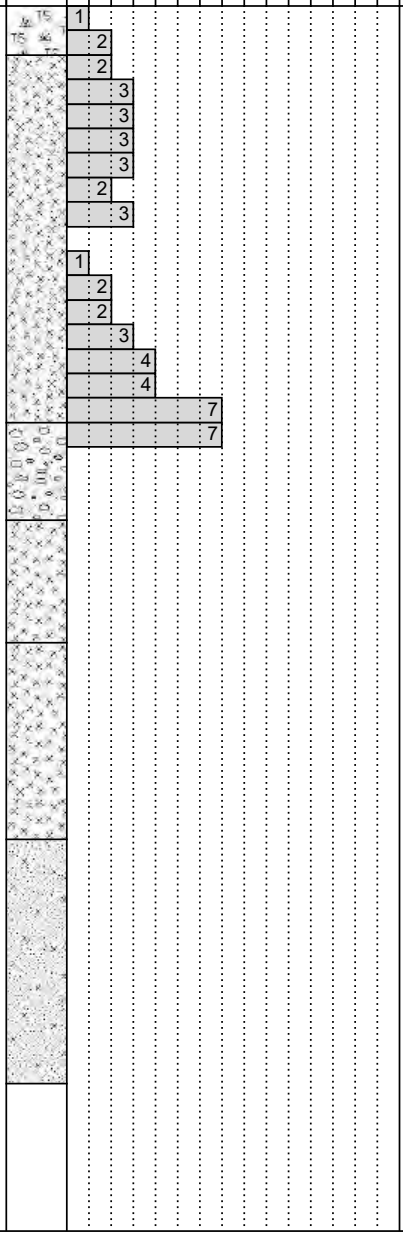
TEST PIT LOG

HOLE NO.: TP10

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 23/10/2024
COORDINATES: 1265552.0 mE, 4998050.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 23/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic sandy SILT, trace rootlets, blackish brown. 0.20 m		
ALLUVIAL FAN DEPOSITS	SILT, with minor sand, dark grey. Firm, dry to moist, low plasticity, sand is fine. 1.70 m		
	Sandy fine to coarse GRAVEL, with trace silt, dark brownish grey. Moist, gravels are subrounded. Sand is fine. 2.10 m		
GLACIAL POND SEDIMENT	SILT, with trace fine sand, grey. Stiff, dry, low plasticity, friable. 2.60 m		
	SILT, trace rootlets, grey, massive. Very stiff, dry, low plasticity, powdery. 3.40 m		
	Fine SAND, with minor silt and trace gravel, white and grey, massive. Hard, moist, gravels are medium to coarse, rounded. 4.40 m		
	End Of Hole: 4.40 m		



PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaning vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:07:41 am

TEST PIT LOG

HOLE NO.: TP11

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
COORDINATES: 1265674.0 mE, 4997797.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 23/10/2024
END DATE: 23/10/2024
LOGGED BY: JMJ
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND
TOPSOIL	Organic sandy SILT, trace rootlets, blackish brown. 0.20 m			
ALLUVIAL FAN DEPOSITS	SILT, with trace fine sand, brownish grey. Firm, dry to moist, low plasticity. 0.50 m			
	SILT, with trace fine sand, greyish brown. Firm, dry to moist, low plasticity. 1.60 m			
GLACIAL POND SEDIMENT	Fine SAND, with trace silt, light grey and orange banding, minor laminations, interbedded with 10-50 mm of silt bands. Medium dense, moist. 4.60 m			
	End Of Hole: 4.60 m			

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.0	1													
0.1	1													
0.2		2												
0.3		2												
0.4		2												
0.5			3											
0.6			3											
0.7			3											
0.8			3											
0.9		2												
1.0	1													
1.1		2												
1.2		2												
1.3		2												
1.4						6								
1.5						6								
1.6							7							
1.7							7							

SHEAR STRENGTH (kPa) Vane: 50, 100, 150, 200 — Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaning vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:07:47 am

TEST PIT LOG

HOLE NO.: TP12

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
COORDINATES: 1265739.0 mE, 4997644.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 23/10/2024
END DATE: 23/10/2024
LOGGED BY: JMJ
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND
TOPSOIL	Organic sandy SILT, trace rootlets, dark brown. 0.30 m			
ALLUVIAL FAN DEPOSITS	SILT, with trace fine sand, brownish grey. Firm, dry to moist, low plasticity. 0.60 m			
	SILT, with trace fine sand, grey. Firm, dry to moist, low plasticity. 0.70 m			
	SILT, with trace fine sand, with organic staining, brown. Firm, dry to moist, low plasticity. 0.75 m			
	SILT, with trace fine sand, grey. Firm, dry to moist, low plasticity. 1.40 m			
GLACIAL POND SEDIMENT	Sandy fine to medium GRAVEL, grey, bedded. Loose to medium dense , dry to moist, gravels are subrounded to rounded. Sand is medium to coarse. 1.60 m			
	Fine SAND, with trace silt, light grey, minor laminations within silt. Loose to medium dense , dry to moist, pockets of sandy gravel at base contact. 3.10 m			
	Sandy, fine to coarse GRAVEL, grey, bedded. Medium dense, dry to moist, gravels are subrounded to rounded. Sand is fine to coarse. 3.50 m			
	Silty, fine SAND, grey, bedded. Medium dense, dry to moist. 4.40 m			
	End Of Hole: 4.40 m			

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.0		2												
0.3			3											
0.4			3											
0.5			3											
0.6			3											
0.7		2												
0.8			3											
0.9			3											
1.0			3											
1.1		2												
1.2			3											
1.3			3											
1.4			3											
1.5			3											
1.6			3											
1.7			3											
1.8			3											
1.9			3											
2.0			3											

SHEAR STRENGTH (kPa) Vane: 50, 100, 150, 200 — Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaning vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:07:51 am

TEST PIT LOG

HOLE NO.: TP13

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371 | **CONTRACTOR:** Base Contracting | **START DATE:** 23/10/2024

COORDINATES: 1265951.0 mE, 4997874.0 mN (NZTM2000) | **EQUIPMENT:** 13T | **END DATE:** 23/10/2024

LOCATION METHOD: Handheld GPS | **ACCURACY:** ± 3 m | **LOGGED BY:** JMJ

ELEVATION: Existing ground level | **OPERATOR:** Jeremy | **CHECKED DATE:** 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Sandy organic SILT, trace rootlets, blackish brown. 0.40 m				1, 2		
ALLUVIAL FAN DEPOSITS	Fine to medium SAND, with trace silt and organic inclusions, greyish brown. Loose, moist. 0.55 m		0.5		1, 3, 3		
	Sandy GRAVEL, trace silt and rootlets, greyish brown. Loose, moist. 0.90 m				4, 4, 5		
	SILT, with trace to minor sand, greyish brown. Firm, moist to wet, low plasticity, sand is fine . 2.10 m		1.0, 1.5, 2.0		1, 1, 1, 1, 1, 1, 1		
	Sandy fine to coarse GRAVEL, trace silt and cobbles, greyish brown. Medium dense, moist, dipping gently to 261°, gravels are subrounded. Sand is fine to coarse. 3.10 m		2.5, 3.0				
	SILT, with trace to minor sand, greyish brown. Firm, moist to wet, low plasticity, sand is fine . 3.50 m		3.5				
	Sandy fine to coarse GRAVEL, trace silt and cobbles, greyish brown. Medium dense, moist, dipping gently to 261°, gravels are subrounded. Sand is fine to coarse. 4.40 m		4.0				
	End Of Hole: 4.40 m		4.5				Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls collapsing in coarser soils

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:07:55 am

TEST PIT LOG

HOLE NO.: TP14

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

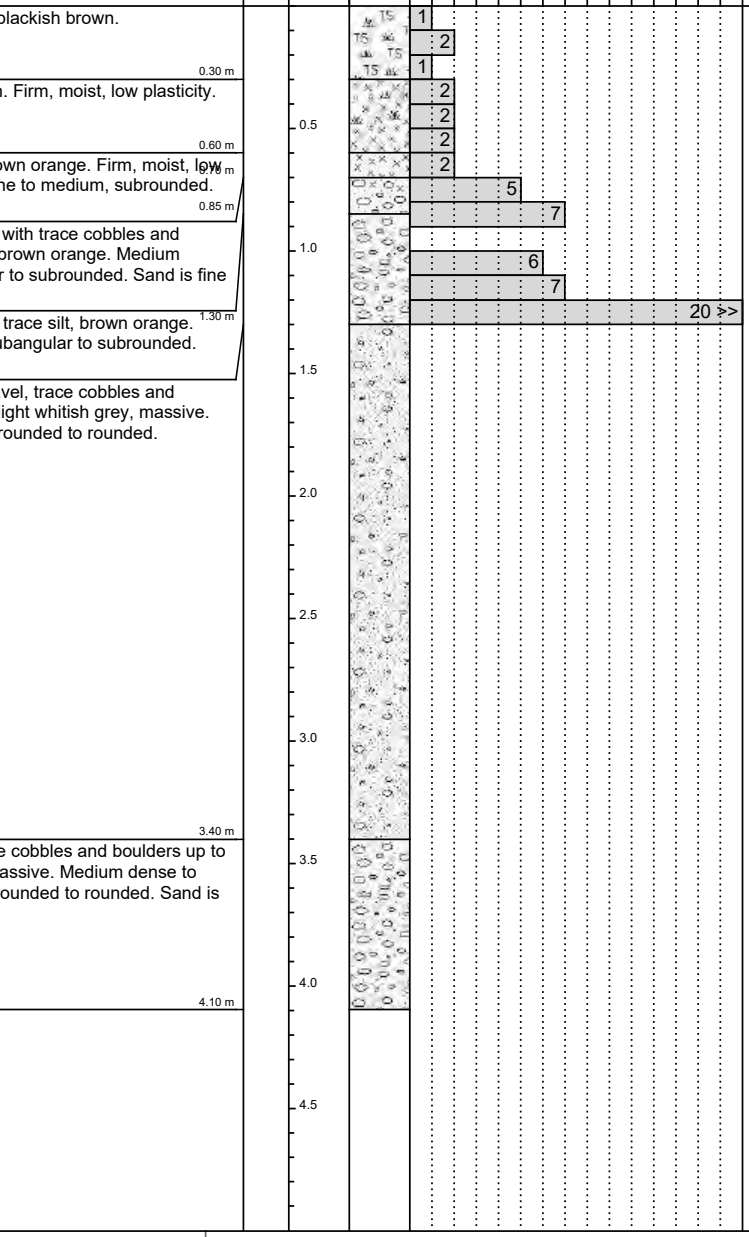
SITE LOCATION: Kingston Road, Drift Bay 9371 | **CONTRACTOR:** Base Contracting | **START DATE:** 23/10/2024

COORDINATES: 1265945.0 mE, 4997695.0 mN (NZTM2000) | **EQUIPMENT:** 13T | **END DATE:** 23/10/2024

LOCATION METHOD: Handheld GPS | **ACCURACY:** ± 3 m | **LOGGED BY:** JMJ

ELEVATION: Existing ground level | **OPERATOR:** Jeremy | **CHECKED DATE:** 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Sandy organic SILT, minor rootlets, blackish brown.		
	0.30 m		
ALLUVIAL FAN DEPOSITS	Slightly organic SILT, blackish brown. Firm, moist, low plasticity.		
	0.60 m		
	SILT, with trace sand and gravel, brown orange. Firm, moist, low plasticity, sand is fine. Gravels are fine to medium, subrounded.		
	0.85 m		
	Sandy, silty fine to coarse GRAVEL, with trace cobbles and boulders up to 400 mm in diameter, brown orange. Medium dense, moist, gravels are subangular to subrounded. Sand is fine to coarse.		
	1.30 m		
	Sandy, fine to coarse GRAVEL, with trace silt, brown orange. Medium dense, moist, gravels are subangular to subrounded. Sand is fine to coarse.		
GLACIAL TILL	Fine to coarse SAND, with minor gravel, trace cobbles and boulders up to 400 mm in diameter, light whitish grey, massive. Dense, dry to moist, gravels are subrounded to rounded.		
	3.40 m		
	Sandy, fine to coarse GRAVEL, trace cobbles and boulders up to 500 mm in diameter, orange grey, massive. Medium dense to dense, dry to moist, gravels are subrounded to rounded. Sand is fine to coarse.		
	4.10 m		
	End Of Hole: 4.10 m		



PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaning vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:08:00 am

TEST PIT LOG

HOLE NO.: TP15

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 23/10/2024
COORDINATES: 1265934.0 mE, 4997527.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 23/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Sandy organic SILT, minor rootlets, blackish brown. 0.30 m		
ALLUVIAL FAN DEPOSITS	SILT, trace sand and organic inclusions, greyish brown. Firm, moist, low plasticity, sand is fine. 0.50 m		
	Sandy, silty, fine GRAVEL, brownish grey. Medium dense, moist, gravels are subangular to subrounded. Sand is fine to medium. 0.70 m		
	Silty, fine SAND, grey. Medium dense, moist. 0.80 m		
	Sandy, silty, fine GRAVEL, brownish grey. Medium dense, moist, gravels are subangular to subrounded. Sand is fine to medium.		
	Fine SAND, with minor silt, grey. Loose, wet, sand is fine. 1.30 m		
	Silty, fine SAND, grey. Medium dense, wet. 1.70 m		
	Fine to medium SAND, grey, bedded. Loose, wet. 2.00 m		
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL, with trace cobbles and boulders up to 400 mm in diameter, brown, bedded. Medium dense, moist, gravels are subrounded to rounded. Sand is fine to coarse. 4.40 m		
GLACIAL TILL	Fine to medium SAND, with minor gravel, whitish grey, massive. Dense, dry to moist, gravels are fine to coarse, rounded. 4.80 m		
	End Of Hole: 4.80 m		

LEGEND

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.0	1	1												
0.5		2	2	2	4	2	4	2						
1.0	1		3	2										
1.5			3	3	3	3	3	3						
2.0														
2.5														
3.0														
3.5														
4.0														
4.5														

SHEAR STRENGTH (kPa) Vane: 50, 100, 150, 200 — Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaning vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:08:05 am

TEST PIT LOG

HOLE NO.: TP16

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
COORDINATES: 1265639.0 mE, 4997457.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 23/10/2024
END DATE: 23/10/2024
LOGGED BY: JMJ
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND
TOPSOIL	Sandy organic SILT, minor rootlets, brown. 0.25 m			
LOESS	Fine SAND, with trace silt, rootlets and organic inclusions, orange. Firm, moist. 0.40 m			
OUTWASH DEPOSITS	Sandy, fine to coarse GRAVEL, with trace cobbles and boulders up to 500 mm in diameter, orange, interbedded with sandy layers. Medium dense, moist, gravels are subrounded to rounded. Sand is fine to coarse. 4.00 m		0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5	
	End Of Hole: 4.00 m			

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.0	1	2	2	2										
0.5									9					20 >>
1.0				4		6								20 >>

SHEAR STRENGTH (kPa) Vane: 50, 100, 150, 200 — Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaning vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:08:11 am

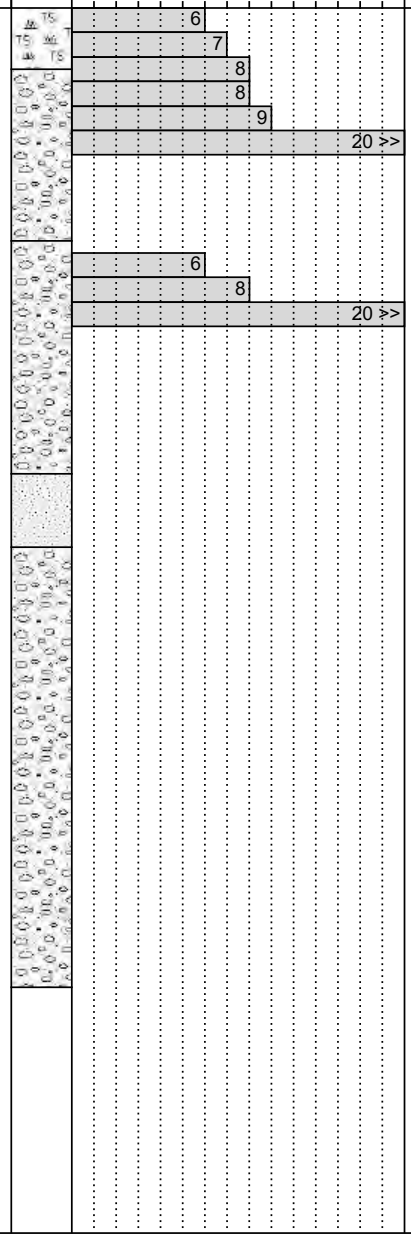
TEST PIT LOG

HOLE NO.: TP17

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 23/10/2024
COORDINATES: 1265503.0 mE, 4997339.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 23/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Gravelly organic SILT, with trace sand and rootlets, brown. Dry to moist, gravels are fine to medium.		
	0.25 m		
	Sandy, fine to coarse GRAVEL, trace rootlets, orange, bedded. Medium dense, dry to moist, gravels are subrounded. Sand is fine to coarse.		
	0.95 m		
	Sandy, fine to coarse GRAVEL, with trace cobbles and boulders up to 300 mm in diameter, grey and orange, bedded. Dense, dry to moist, gravels are subrounded. Sand is fine to coarse.		
	1.90 m		
OUTWASH DEPOSITS	Fine to medium SAND, grey, bedded. Medium dense, moist.		
	2.20 m		
	Sandy, fine to coarse GRAVEL, with trace cobbles and boulders up to 150 mm in diameter, grey, bedded. Moist, gravels are subrounded. Sand is fine to coarse.		
	4.00 m		
	End Of Hole: 4.00 m		



WATER: Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaning vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:08:17 am

TEST PIT LOG

HOLE NO.: TP18

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

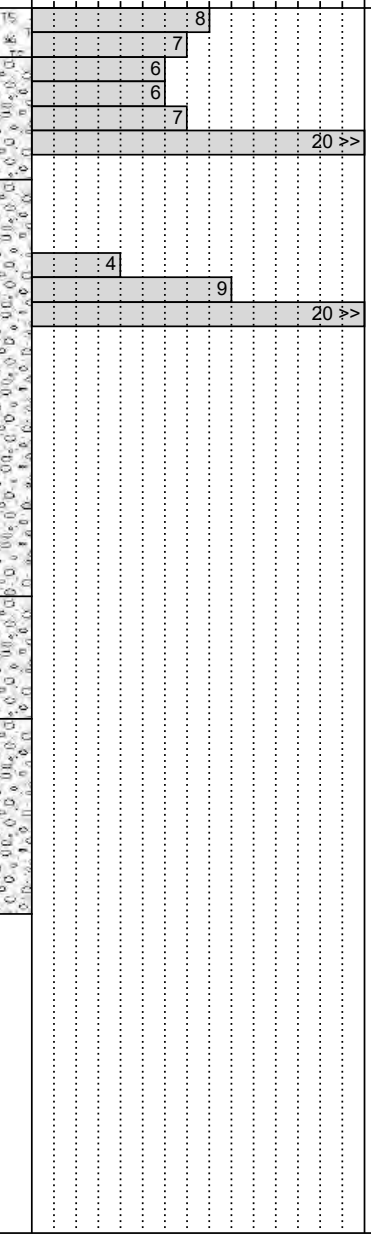
SITE LOCATION: Kingston Road, Drift Bay 9371 | **CONTRACTOR:** Base Contracting | **START DATE:** 23/10/2024

COORDINATES: 1265426.0 mE, 4997339.0 mN (NZTM2000) | **EQUIPMENT:** 13T | **END DATE:** 23/10/2024

LOCATION METHOD: GIS\Web map viewer | **ACCURACY:** ± 5 m | **LOGGED BY:** JMJ

ELEVATION: Existing ground level | **OPERATOR:** Jeremy | **CHECKED DATE:** 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Gravelly organic SILT, with trace sand and rootlets, brown. Dry to moist, gravels are fine to medium. 0.20 m		
OUTWASH DEPOSITS	Sandy, fine to coarse GRAVEL, trace rootlets, orange, bedded. Medium dense, dry to moist, gravels are subrounded. Sand is fine to coarse. 0.70 m		
	Sandy, fine to coarse GRAVEL, with trace cobbles and boulders up to 300 mm in diameter, grey and orange, bedded. Dense, dry to moist, gravels are subrounded. Sand is fine to coarse. 2.40 m		
	Sandy, fine to coarse GRAVEL, grey, bedded. Dense, dry to moist, sand is fine to coarse. 2.90 m		
	Sandy, fine to coarse GRAVEL, with trace cobbles and boulders up to 300 mm in diameter, grey and orange, bedded. Dense, dry to moist, gravels are subrounded. Sand is fine to coarse. 3.70 m		
	End Of Hole: 3.70 m		



SHEAR STRENGTH (kPa) Vane: 50 100 150 200 Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaning vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:08:22 am

TEST PIT LOG

HOLE NO.: TP19

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 24/10/2024
COORDINATES: 1265305.0 mE, 4997565.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 24/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Gravelly organic SILT, with trace rootlets, blackish brown. Moist. 0.30 m		
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL, trace rootlets within the top 200 mm, with trace cobbles and boulders up to 300 mm in diameter, orange, bedded. Medium dense, dry to moist, gravels are subangular to subrounded. Sand is fine to coarse. 0.90 m		0.5
	Sandy fine to coarse GRAVEL, interbedded with sand, with trace cobbles and boulders up to 200 mm in diameter, grey and orange, bedded. Medium dense, dry to moist, gravels are subangular to subrounded. Sand is fine to coarse. 3.60 m		1.0, 1.5, 2.0, 2.5, 3.0, 3.5
	End Of Hole: 3.60 m		4.0, 4.5

LEGEND

SCALA PENETROMETER (Blows / 100 mm)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			4		6						12		20 >>
						7							20 >>

SHEAR STRENGTH (kPa) Vane:

50	100	150	200	Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaning vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:08:26 am

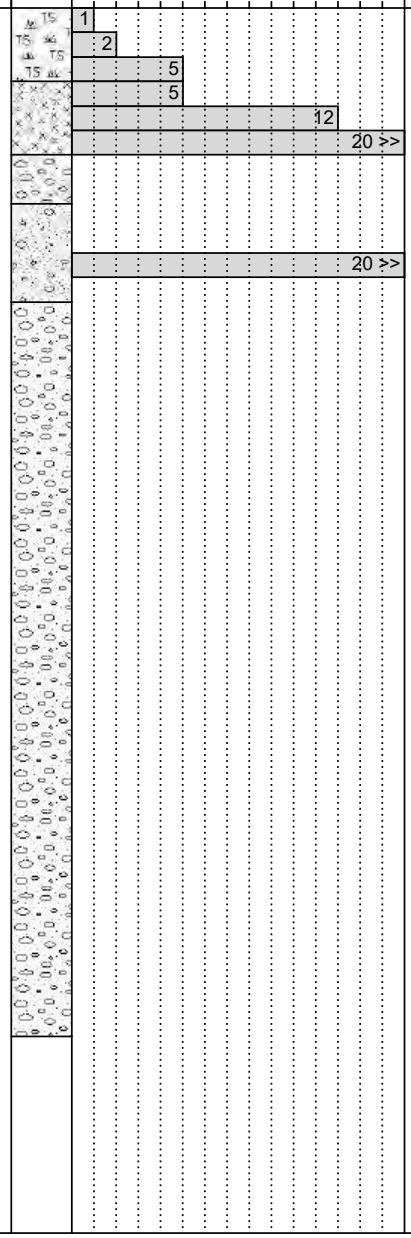
TEST PIT LOG

HOLE NO.: TP20

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 24/10/2024
COORDINATES: 1265503.0 mE, 4997570.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 24/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Gravelly organic SILT, with trace rootlets, blackish brown. Moist. 0.30 m		
LOESS	Sandy SILT with a trace of gravel and organics, brownish/orange. Low plasticity, moist, sand, fine; gravel, fine to medium, subrounded. 0.60 m		
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL with a trace of silt, brownish/orange. Medium dense, moist, Silt content decreasing with depth, gravel, surrounded; sand, fine to coarse. 0.80 m		
	Gravelly fine to coarse SAND with a trace of silt and cobbles, grey. Dense, moist, sand, mostly fine to medium; gravel, fine to coarse, rounded to subrounded. 1.20 m		
	Sandy fine to coarse GRAVEL with trace cobbles and boulders, grey, interbedded sandy layers. Medium dense, moist, bedded, gravel, subrounded; sand, fine to coarse. 4.20 m		
	End Of Hole: 4.20 m		



PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:08:31 am

TEST PIT LOG

HOLE NO.: TP21

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
COORDINATES: 1265451.0 mE, 4997699.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 24/10/2024
END DATE: 24/10/2024
LOGGED BY: JMJ
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Gravelly organic SILT, with trace rootlets, blackish brown. Moist. 0.20 m				1, 2		
LOESS	Sandy SILT with a trace of gravel and organics, brownish/orange. Low plasticity, moist, sand, fine; gravel, fine to medium, subrounded. 0.70 m		0.5		5, 4, 6, 12, 20 >>		
OUTWASH DEPOSITS	Gravelly fine to coarse SAND with a trace of silt and cobbles, grey. Dense, moist, sand, mostly fine to medium; gravel, fine to coarse, rounded to surrounded. Boulders up to 200 mm. 1.00 m		1.0		20 >>		
	Sandy fine to coarse GRAVEL with trace cobbles and boulders, grey, interbedded sandy layers. Medium dense, moist, bedded, gravel, subrounded; sand, fine to coarse.		1.5, 2.0, 2.5, 3.0, 3.5, 4.0				
	4.20 m						
	End Of Hole: 4.20 m		4.5				

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:08:37 am

TEST PIT LOG

HOLE NO.: TP22

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 24/10/2024
COORDINATES: 1265527.0 mE, 4994805.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 24/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Sandy organic SILT with a trace rootlets, dark brown. Moist. 0.30 m				1, 2, 3, 3		
COLLUVIUM	Sandy fine to coarse GRAVEL with minor silt and a trace of rootlets and organics, orange. Medium dense, moist, chaotic, gravel, subrounded; sand, fine to medium. 0.70 m		0.5				
OUTWASH DEPOSITS	Fine SAND, light orange, interbedded 200 mm with silty sand beds. Medium dense, moist to wet. 1.60 m		1.0		4, 4, 5, 4, 6, 20 >>		
	Fine to medium SAND with some gravel and a trace of silt, grey. Dense, moist, bedded, gravel, fine to medium, subrounded to rounded. 2.60 m		1.5 2.0 2.5				
	Sandy fine to coarse GRAVEL with a trace of cobbles, dark grey. Medium dense, moist, bedded, gravel, rounded to subrounded; sand, medium to coarse. 3.40 m		3.0				
	Gravelly coarse SAND, grey. Medium dense, wet, bedded, gravel, fine to coarse, rounded to subrounded. 4.40 m		3.5 4.0				
	End Of Hole: 4.40 m		4.5				Groundwater Not Encountered

Scala penetrometer axis: 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Shear strength (Vane) axis: 50 100 150 200

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:08:42 am

TEST PIT LOG

HOLE NO.: TP23

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 24/10/2024
COORDINATES: 1265281.0 mE, 4997801.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 24/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Sandy organic SILT with a trace rootlets, dark brown. Moist, strong organic smell. 0.35 m		0.0	TS	1, 2		
	Silty fine SAND with a trace of gravel, grey. Medium dense to dense, wet. Moist from 0.6 m, minor laminations, gravel, fine to medium, subrounded. 2.00 m		0.5		3, 3, 3, 12, 15, 15		
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL with a trace of silt, cobbles and boulders, orange/grey. Medium dense, moist, bedded, gravel, subrounded to rounded. Sand, fine to coarse; boulders up to 250 mm. 4.40 m		1.0		6, 11, 12, 20 >>		Groundwater Not Encountered
	End Of Hole: 4.40 m		1.5				
			2.0				
			2.5				
			3.0				
			3.5				
			4.0				
			4.5				

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:08:46 am

TEST PIT LOG

HOLE NO.: TP24

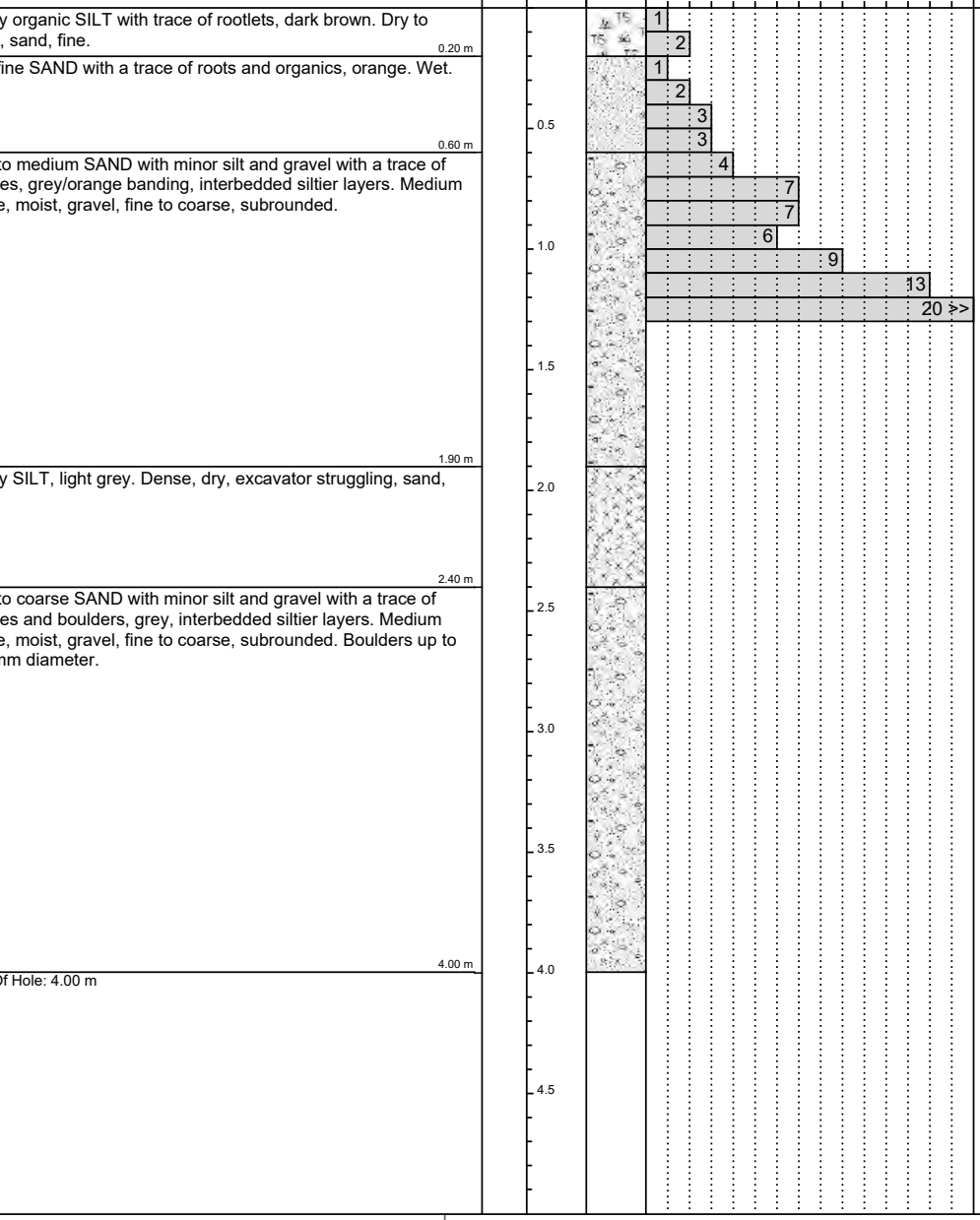
CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
COORDINATES: 1265315.0 mE, 4997901.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 25/10/2024
END DATE: 25/10/2024
LOGGED BY: JMJ
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND
TOPSOIL	Sandy organic SILT with trace of rootlets, dark brown. Dry to moist, sand, fine. 0.20 m			
LOESS	Silty fine SAND with a trace of roots and organics, orange. Wet. 0.60 m			
GLACIAL TILL	Fine to medium SAND with minor silt and gravel with a trace of cobbles, grey/orange banding, interbedded siltier layers. Medium dense, moist, gravel, fine to coarse, subrounded. 1.90 m			
	Sandy SILT, light grey. Dense, dry, excavator struggling, sand, fine. 2.40 m			
	Fine to coarse SAND with minor silt and gravel with a trace of cobbles and boulders, grey, interbedded siltier layers. Medium dense, moist, gravel, fine to coarse, subrounded. Boulders up to 750 mm diameter. 4.00 m			
	End Of Hole: 4.00 m			



PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:08:50 am

TEST PIT LOG

HOLE NO.: TP25

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 25/10/2024
COORDINATES: 1265193.0 mE, 4997945.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 25/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Sandy organic SILT with minor gravel and trace rootlets, brown. Wet, sand, fine; gravel, fine to coarse, subrounded to subangular. 0.20 m				2		
COLLUVIUM	Fine to coarse SAND with minor gravel and a trace of silt and organics, grey/orange. Medium dense, moist, chaotic, gravel, fine to coarse, surrounded. 0.6 m: two 20 mm thick brown beds near basal contact 0.70 m		0.5		3, 3, 4, 20 >>		
GLACIAL TILL	Fine to coarse SAND with minor gravel and a trace of cobbles and silt, grey with orange streaks. Medium dense, dry to moist, sand, mostly fine to medium; gravel, fine to coarse, subrounded to rounded. 1.80 m		1.0		4, 5, 7, 14, 20 >>		
	Gravelly fine to coarse SAND with a trace of silt, cobbles, grey/brown, interbedded siltier layers. Dense, dry to moist, gravel, fine to coarse, subrounded to rounded. Boulders up to 200 mm diameter. 4.20 m		1.5 2.0 2.5 3.0 3.5 4.0 4.5				Groundwater Not Encountered
	End Of Hole: 4.20 m						

SHEAR STRENGTH (kPa) Vane: 50, 100, 150, 200

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:08:54 am

TEST PIT LOG

HOLE NO.: TP26

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 25/10/2024
COORDINATES: 1265437.0 mE, 4998029.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 25/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Sandy organic SILT with trace rootlets, brown. Moist, sand, fine. 0.30 m			TS	2		
COLLUVIUM	Silty fine SAND with a trace of gravel and organics, orange . Loose to medium dense, moist, chaotic.			TS	2		
	Fine to coarse SAND with a trace of silt, gravel, cobbles and boulders, grey with orange banding. Medium dense, moist to wet, gravel, fine to coarse, rounded to subrounded. Boulders up to 400 mm diameter. 1.20 m		0.5	TS	3		
GLACIAL TILL	Fine to coarse SAND with a trace of silt, gravel, cobbles and boulders, light grey, interbedded siltier layers. Medium dense, moist to wet, gravel, fine to coarse, rounded to subrounded. Boulders up to 400 mm diameter. 2.40 m		1.0		4, 4, 6, 8, 9, 9		
	Gravelly fine to coarse SAND with a trace of silt, cobbles and boulders, grey. Dense, moist to wet, gravel, fine to coarse, rounded to subrounded. Boulders up to 400 mm diameter. 3.90 m		1.5		4, 9, 14, 20 >>		
	End Of Hole: 3.90 m		2.0				
			2.5				
			3.0				
			3.5				
			4.0				
			4.5				

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:08:57 am

TEST PIT LOG

HOLE NO.: TP27

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 25/10/2024
COORDINATES: 1265322.0 mE, 4998132.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 25/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Sandy organic SILT with trace of rootlets, dark brown. Dry to moist, sand, fine. 0.20 m				1, 2		
LOESS	Silty fine SAND with a trace of rootlets and organics, orange. Loose to medium dense, moist to wet. 0.40 m				2, 2		
COLLUVIUM	Sandy fine to coarse GRAVEL with minor silt and trace organics, orange/grey. Medium dense, moist to wet, chaotic, gravel, fine to coarse, subrounded; sand, fine to coarse. 0.60 m		0.5		6, 7, 7, 7		
OUTWASH DEPOSITS	Gravelly fine to coarse SAND with a trace of silt, cobbles and boulders, grey/orange, interbedded siltier layers. Medium dense to dense, moist to wet, gravel, fine to coarse, subrounded; boulders up to 250 mm diameter. 1.50 m		1.0		4, 3, 6		
	Gravelly fine to coarse SAND with a trace of silt, cobbles and boulders, orange/grey, interbedded siltier layers. Dense, moist, gravel, fine to coarse, subrounded; boulders up to 400 mm diameter. 2.40 m		1.5				
	Gravelly SAND with a trace of silt, cobbles of boulders, grey. Dense, moist to wet, gravel, fine to coarse, subrounded; boulders up to 400 mm diameter. 2.80 m		2.0				
	Sandy fine to coarse GRAVEL with a trace of cobbles and boulders, grey/brown. Medium dense, moist, bedded, gravel, fine to coarse, subrounded. Boulders up to 300 mm. 4.20 m		2.5				
	End Of Hole: 4.20 m		3.0				
			3.5				
			4.0				
			4.5				

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls collapsing from 2.8 m. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:09:01 am

TEST PIT LOG

HOLE NO.: TP28

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
COORDINATES: 1265098.0 mE, 4998124.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level
CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy
START DATE: 25/10/2024
END DATE: 25/10/2024
LOGGED BY: JMJ
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND
TOPSOIL	Sandy organic SILT with trace of rootlets, dark brown. Dry to moist, sand, fine. 0.20 m			
COLLUVIUM	Fine to coarse SAND with minor gravel and silt with a trace of organics, orange. Medium dense, moist to wet, chaotic, gravel, fine to coarse, subrounded. 0.50 m			
OUTWASH DEPOSITS	Fine to coarse SAND with minor gravel and a trace of silt, cobbles and boulders, orange/grey. Dense, moist, gravel, fine to coarse, subrounded. Boulders up to 400 mm. 2.40 m			
	Sandy fine to coarse GRAVEL with a trace of cobbles and boulders, grey. Medium dense, moist, bedded, sand, fine to coarse; gravel, subrounded. Boulders up to 250 mm. 2.70 m			
GLACIAL TILL	Fine SAND, grey. Medium dense, dry to moist. 3.30 m			
	Fine to coarse SAND with minor gravel and a trace of silt, cobbles and boulders, orange/grey. Dense, moist, gravel, fine to coarse, subrounded. Boulders up to 400 mm. 4.20 m			
	End Of Hole: 4.20 m			

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.0	1	1												
0.5			3	4	3								14	20 >>
1.0				4								12	20 >>	
1.5														
2.0														
2.5														
3.0														
3.5														
4.0														
4.5														

SHEAR STRENGTH (kPa) Vane: 50, 100, 150, 200 — Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:09:05 am

TEST PIT LOG

HOLE NO.: TP29

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371 | **CONTRACTOR:** Base Contracting | **START DATE:** 25/10/2024

COORDINATES: | **EQUIPMENT:** 13T | **END DATE:** 25/10/2024

LOCATION METHOD: Handheld GPS | **ACCURACY:** ± 3 m | **LOGGED BY:** JMJ

ELEVATION: Existing ground level | **OPERATOR:** Jeremy | **CHECKED DATE:** 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic SILT with a trace of rootlets, dark brown. Moist. 0.30 m				1, 1, 1		
LOESS	Silty fine SAND with a trace of organics, orange. Loose to medium dense, moist to wet. 0.50 m				2, 2		
COLLUVIUM	Gravelly fine to medium SAND with minor to trace silt and a trace of cobbles, orange. Loose to medium dense, moist, chaotic, gravel, fine to coarse, subrounded to rounded. 1.00 m		0.5		2, 3, 4, 5		
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL with trace cobbles, orange and grey, interbedded sandy gravels and fine sands. Medium dense, moist, bedded, gravel, subrounded to rounded; sand, fine to coarse.. 1.40 m		1.0		6		
	Gravelly fine to coarse SAND with trace cobbles, dark grey. Dense, moist, bedded, gravel, rounded to subrounded; sand, medium to coarse. 4.20 m		1.5, 2.0, 2.5, 3.0, 3.5, 4.0				Groundwater Not Encountered
	End Of Hole: 4.20 m		4.5				

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:09:10 am

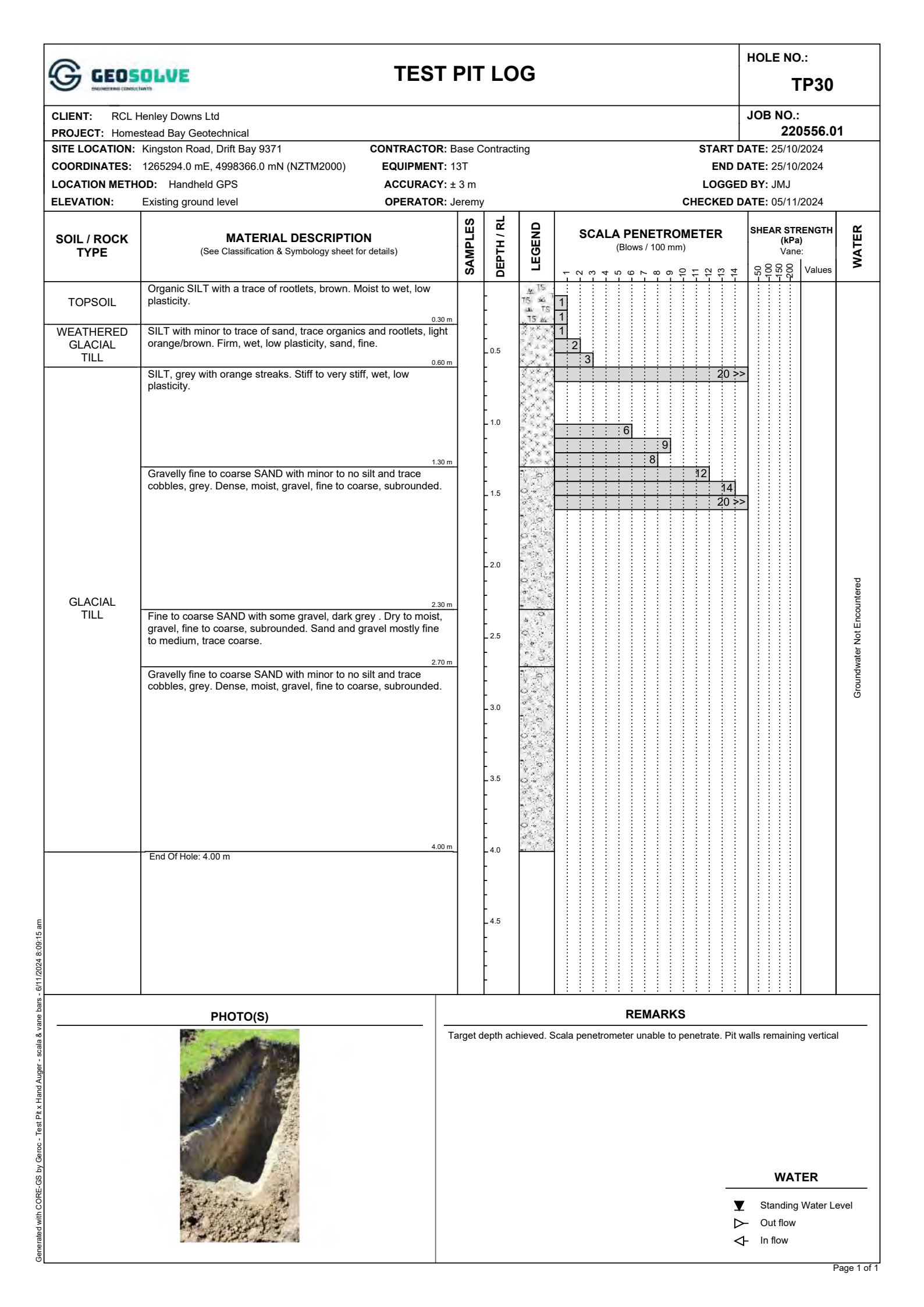
TEST PIT LOG

HOLE NO.: TP30

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 25/10/2024
COORDINATES: 1265294.0 mE, 4998366.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 25/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic SILT with a trace of rootlets, brown. Moist to wet, low plasticity. 0.30 m		
WEATHERED GLACIAL TILL	SILT with minor to trace of sand, trace organics and rootlets, light orange/brown. Firm, wet, low plasticity, sand, fine. 0.60 m		
GLACIAL TILL	SILT, grey with orange streaks. Stiff to very stiff, wet, low plasticity. 1.30 m		
	Gravelly fine to coarse SAND with minor to no silt and trace cobbles, grey. Dense, moist, gravel, fine to coarse, subrounded. 2.30 m		
	Fine to coarse SAND with some gravel, dark grey . Dry to moist, gravel, fine to coarse, subrounded. Sand and gravel mostly fine to medium, trace coarse. 2.70 m		
	Gravelly fine to coarse SAND with minor to no silt and trace cobbles, grey. Dense, moist, gravel, fine to coarse, subrounded. 4.00 m		
	End Of Hole: 4.00 m		



PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:09:15 am

TEST PIT LOG

HOLE NO.: TP31

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

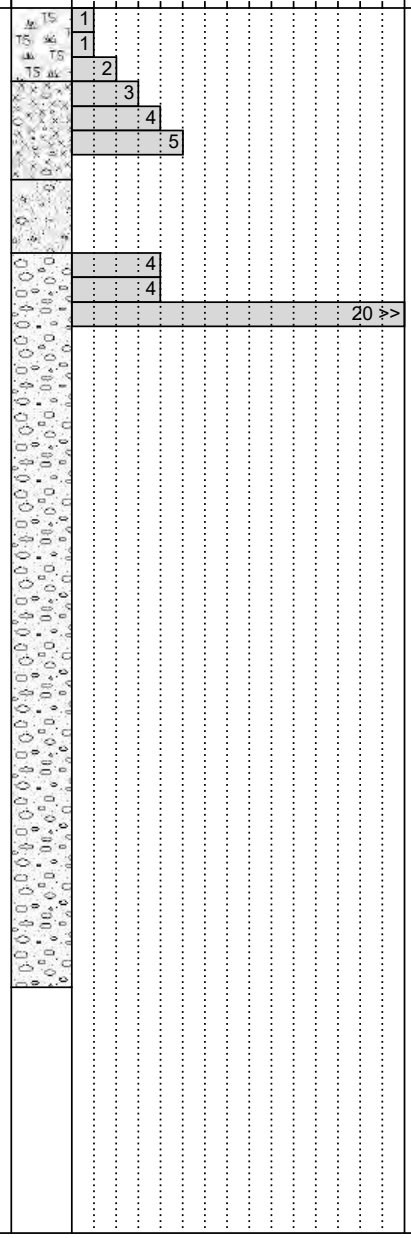
SITE LOCATION: Kingston Road, Drift Bay 9371 | **CONTRACTOR:** Base Contracting | **START DATE:** 25/10/2024

COORDINATES: 1265025.0 mE, 4998362.0 mN (NZTM2000) | **EQUIPMENT:** 13T | **END DATE:** 25/10/2024

LOCATION METHOD: Handheld GPS | **ACCURACY:** ± 3 m | **LOGGED BY:** JMJ

ELEVATION: Existing ground level | **OPERATOR:** Jeremy | **CHECKED DATE:** 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic SILT with trace rootlets, brown. Moist, low plasticity. 0.30 m		
COLLUVIUM	Sandy SILT with minor gravel and trace organics, orange. Firm, moist, low plasticity, sand, fine to coarse (mostly fine), gravel, fine to coarse, subrounded. 0.70 m		
OUTWASH DEPOSITS	Fine to coarse SAND with some gravel and a trace of silt and cobbles, grey. Dense, moist, gravel, fine to coarse, subrounded. Sand is mostly fine. 1.00 m		
	Sandy fine to coarse GRAVEL with a trace of cobbles and boulders, dark grey. Dense, moist, bedded, gravel, subrounded to rounded; sand, fine to coarse, mostly medium to coarse. Boulders up to 250 mm in diameter. 4.00 m		
	End Of Hole: 4.00 m		



PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:09:20 am

TEST PIT LOG

HOLE NO.: TP32

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
COORDINATES: 1264932.0 mE, 4998640.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 25/10/2024
END DATE: 25/10/2024
LOGGED BY: JMJ
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND
TOPSOIL	Organic SILT with trace rootlets, dark brown. Wet. 0.30 m			
LOESS	Silty fine SAND with trace organics, orange. Loose, wet. 0.50 m			
COLLUVIUM	Gravely fine SAND with minor silt and trace cobbles, orange/brown orange. Medium dense, wet, chaotic, gravel fine to coarse, subrounded to rounded. 0.90 m			
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL with trace cobbles and boulders, orange/grey becoming grey. Dense, moist, bedded, gravel, subrounded to rounded; sand, fine to coarse - mostly medium to coarse; boulders up to 250 mm diameter. 4.20 m			
	End Of Hole: 4.20 m			

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	Blows / 100 mm
0.0 – 0.3	1, 2, 1
0.3 – 0.5	2, 2
0.5 – 0.9	3, 4, 6, 4
0.9 – 1.0	7, 7
1.0 – 1.2	20 >>

SHEAR STRENGTH (kPa) Vane: Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:09:25 am

TEST PIT LOG

HOLE NO.: TP33

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
COORDINATES: 1265108.0 mE, 4998567.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 25/10/2024
END DATE: 25/10/2024
LOGGED BY: JMJ
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic SILT with trace rootlets, dark brown. Moist. 0.30 m				1, 2, 2, 2		
LOESS	Sandy SILT with a trace of gravel and organics, orange. Firm, moist, low plasticity, sand, fine; gravel, fine to coarse, subrounded. 0.40 m						
COLLUVIUM	Gravelly fine to carse SAND with minor silt, orange. Medium dense, moist, gravel, fine to coarse, subrounded to rounded. 0.70 m		0.5		5, 6, 12, 20 >>		
GLACIAL TILL	Gravelly fine to coarse SAND with trace silt and cobbles, orange/grey, beds of medium to coarse sand. Dense, moist, sand, rarely coarse; gravel, fine to coarse, subrounded to rounded. 4.20 m		1.0		6, 20 >>		Groundwater Not Encountered
	End Of Hole: 4.20 m		1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5				

Scala penetrometer: 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Shear strength (kPa) Vane: 50 100 150 200 Values

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:09:30 am

TEST PIT LOG

HOLE NO.: TP34

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371

CONTRACTOR: Base Contracting

START DATE: 29/10/2024

COORDINATES: 1264674.0 mE, 4999141.0 mN (NZTM2000)

EQUIPMENT: 13T

END DATE: 29/10/2024

LOCATION METHOD: GIS\Web map viewer

ACCURACY: ± 5 m

LOGGED BY: JMJ

ELEVATION: Existing ground level

OPERATOR: Jeremy

CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)
TOPSOIL	Organic SILT with minor sand and gravel with a trace of rootlets, dark brown. Wet, sand, fine to medium; gravel, fine to coarse, subrounded to rounded. 0.35 m
LOESS	Fine SAND with minor silt and a trace of gravel and organic inclusions, orange, unit dipping towards 094. Loose to medium dense, moist. 0.50 m
ALLUVIAL FAN DEPOSITS	Fine SAND with trace rootlets, grey/orange becoming grey. Loose, moist. 2.50 m
GLACIAL OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL with trace cobbles, grey/orange . Medium dense, moist, bedded, gravel, subrounded; sand, fine to coarse. 4.10 m
	End Of Hole: 4.10 m

SAMPLES | DEPTH / RL | LEGEND | SCALA PENETROMETER (Blows / 100 mm) | SHEAR STRENGTH (kPa) Vane: Values | WATER

Scala penetrometer blows (1 2 3 4 5 6 7 8 9 10 11 12 13 14): 1 1 1 1 | 2 | 3 3 | 4 4 | 1 2 | 4 4 | 3 | 2 2 2 2

Shear strength (kPa): 50 100 150 200

Depth / RL: 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:09:34 am

TEST PIT LOG

HOLE NO.: TP35

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371 | **CONTRACTOR:** Base Contracting | **START DATE:** 29/10/2024

COORDINATES: 1264800.0 mE, 4998955.0 mN (NZTM2000) | **EQUIPMENT:** 13T | **END DATE:** 29/10/2024

LOCATION METHOD: Handheld GPS | **ACCURACY:** ± 3 m | **LOGGED BY:** JMJ

ELEVATION: Existing ground level | **OPERATOR:** Jeremy | **CHECKED DATE:** 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic SILT with minor roots and rootlets, dark brown. Wet. 0.20 m		
ALLUVIAL FAN DEPOSITS	SILT with a trace rootlets in upper 400 mm, brownish grey. Firm, moist, low plasticity. 1.60 m		
GLACIAL OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL, brownish grey, slightly bedded. Medium dense, wet, pit walls collapsing, gravel, subrounded; sand, fine to coarse, mostly medium to coarse. 3.80 m		
	End Of Hole: 3.80 m		

LEGEND

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	Blows
0.0 – 0.2	1
0.2 – 0.4	2
0.4 – 0.6	2
0.6 – 0.8	1
0.8 – 1.0	2
1.0 – 1.2	2
1.2 – 1.4	1
1.4 – 1.6	1
1.6 – 1.8	1
1.8 – 2.0	1
2.0 – 2.2	2
2.2 – 2.4	2
2.4 – 2.6	2
2.6 – 2.8	2
2.8 – 3.0	9
3.0 – 3.2	20 >>

SHEAR STRENGTH (kPa) Vane: Values

WATER: Groundwater Not Encountered

PHOTO(S)

REMARKS

End of test, test pit walls collapsing. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:09:38 am

TEST PIT LOG

HOLE NO.: TP36

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371 | **CONTRACTOR:** Base Contracting | **START DATE:** 29/10/2024

COORDINATES: 1264854.0 mE, 4998761.0 mN (NZTM2000) | **EQUIPMENT:** 13T | **END DATE:** 29/10/2024

LOCATION METHOD: GIS\Web map viewer | **ACCURACY:** ± 5 m | **LOGGED BY:** JMJ

ELEVATION: Existing ground level | **OPERATOR:** Jeremy | **CHECKED DATE:** 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic SILT with minor rootlets, black. Wet. 0.35 m				1, 2		
UNCONTROLLED FILL	Sandy fine to medium GRAVEL with a trace of silt, brown/grey, rootlets in upper 300 mm. Medium dense, wet, uniform, gravel, subangular; sand, fine to coarse, mostly medium to coarse. 1.30 m		0.5, 1.0		1, 3, 4, 4, 4, 4, 4, 4, 5, 8		
GLACIAL POND SEDIMENT	Sandy fine to coarse GRAVEL, grey/orange, interbedded sandier layers increasing near basal contact. Dense, wet, bedded, gravel, subrounded; sand, fine to coarse. 2.20 m		1.5, 2.0		14, 20 >>		
OUTWASH DEPOSITS	Fine SAND with a trace of siltand rootlets, grey. Medium dense, moist. 4.40 m		2.5, 3.0, 3.5, 4.0				Groundwater Not Encountered
	End Of Hole: 4.40 m		4.5				

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:09:42 am

TEST PIT LOG

HOLE NO.: TP37

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371

CONTRACTOR: Base Contracting

START DATE: 29/10/2024

COORDINATES: 1265285.0 mE, 4998628.0 mN (NZTM2000)

EQUIPMENT: 13T

END DATE: 29/10/2024

LOCATION METHOD: Handheld GPS

ACCURACY: ± 3 m

LOGGED BY: JMJ

ELEVATION: Existing ground level

OPERATOR: Jeremy

CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic SILT with a trace of rootlets, dark brown. Wet. 0.30 m		
LOESS	Fine SAND with minor silt and a trace of organics, orange/brown. Loose, wet. 0.50 m		0.5
COLLUVIUM	Gravelly fine SAND with minor silt, orange/brown. Medium dense, wet, gravel, fine to medium, subrounded to subangular. 1.00 m		1.0
GLACIAL TILL	Fine to medium SAND with some gravel and a trace of silt, orange/grey. Medium dense, moist, gravel, fine to coarse (mostly fine to medium), subrounded. 2.00 m		1.5
	Fine to medium SAND with some gravel and a trace of silt and cobbles/boulders, orange/grey. Dense, moist, gravel, fine to coarse (mostly fine to medium), subrounded. Cobbles and boulders up to 300 mm diameter, subrounded. 4.00 m		2.0 2.5 3.0 3.5 4.0
	End Of Hole: 4.00 m		4.5

LEGEND: TS

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	Blows / 100 mm
0.00 – 0.10	1
0.10 – 0.20	1
0.20 – 0.30	1
0.30 – 0.40	2
0.40 – 0.50	3
0.50 – 0.60	4
0.60 – 0.70	4
0.70 – 0.80	4
0.80 – 0.90	5
0.90 – 1.00	3
1.00 – 1.10	5
1.10 – 1.20	7
1.20 – 1.30	13
1.30 – 1.40	15
1.40 – 1.50	20 >>

SHEAR STRENGTH (kPa) Vane: Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:09:47 am

TEST PIT LOG

HOLE NO.: TP38

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371

CONTRACTOR: Base Contracting

START DATE: 29/10/2024

COORDINATES: 1265290.0 mE, 4998710.0 mN (NZTM2000)

EQUIPMENT: 13T

END DATE: 29/10/2024

LOCATION METHOD: GIS\Web map viewer

ACCURACY: ± 5 m

LOGGED BY: JMJ

ELEVATION: Existing ground level

OPERATOR: Jeremy

CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic SILT with a trace of rootlets, dark brown. Wet. 0.35 m				1		
LOESS	Fine to medium SAND with a trace of silt and organics, light yellow/grey. Loose, wet, sand, mostly fine. Organic content decreases with depth. 1.50 m		0.5, 1.0		1, 2, 1, 2, 2, 3, 2, 2, 2, 2, 1, 2, 2		
GLACIAL TILL	Fine to medium SAND with minor silt and a trace of gravel, light yellow/grey. Medium dense, wet, gravel, fine to coarse, subrounded. 1.90 m		1.5		2, 5, 8, 20 >>		
	Gravelly fine to coarse SAND with trace cobbles and boulders, brownish grey. Medium dense to dense, wet, gravel, fine to coarse, subrounded; boulders up to 200 mm diameter. 2.20 m		2.0				
	Fine to coarse SAND with some gravel and trace cobbles and boulders, grey, zones of medium to coarse sand. Dense, moist, sand, mostly fine to medium; gravel, fine to coarse, mostly fine to medium. Boulders up to 250 mm. 3.50 m		2.5, 3.0, 3.5				
	End Of Hole: 3.50 m		4.0, 4.5				

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:09:52 am

TEST PIT LOG

HOLE NO.: TP39

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
COORDINATES: 1265515.0 mE, 4998607.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 29/10/2024
END DATE: 29/10/2024
LOGGED BY: JMJ
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic silty SAND with trace rootlets, brown. Moist. 0.25 m						
LOESS / COLLUVIUM	Fine SAND with a trace of silt and organics, orange. Loose to medium dense, moist to wet. 0.35 m						
	Gravelly fine to medium SAND with a trace of silt, orange. Medium dense, moist to wet, gravel, fine to coarse, subrounded. 0.55 m		0.5				
GLACIAL TILL	Fine to medium SAND with some gravel and a trace of silt, grey/brown. Medium dense to dense, moist to wet, gravel, fine to coarse, subrounded. 1.20 m		1.0				
	Fine to medium SAND with some gravel and trace cobbles and boulders, grey. Dense, moist, gravel fine to coarse, subrounded. 3.60 m		1.5 2.0 2.5 3.0 3.5				
	End Of Hole: 2.60 m		4.0 4.5				

Scala penetrometer blows: 1, 2, 2, 3, 4, 5, 9, 9, 9, 6, 11, 20 >>

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:09:57 am

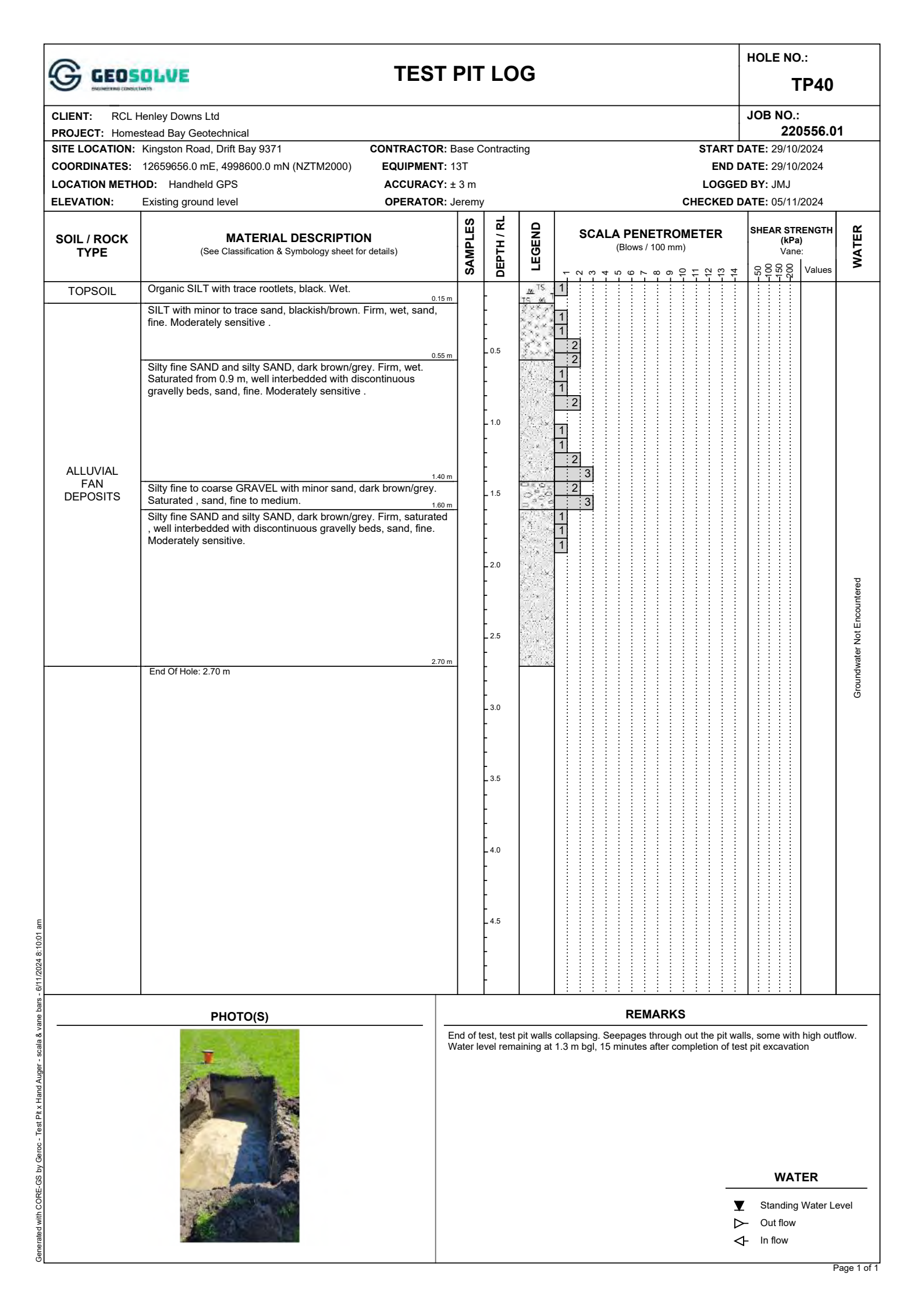
TEST PIT LOG

HOLE NO.: TP40

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 29/10/2024
COORDINATES: 12659656.0 mE, 4998600.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 29/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic SILT with trace rootlets, black. Wet. 0.15 m						
ALLUVIAL FAN DEPOSITS	SILT with minor to trace sand, blackish/brown. Firm, wet, sand, fine. Moderately sensitive . 0.55 m						
	Silty fine SAND and silty SAND, dark brown/grey. Firm, wet. Saturated from 0.9 m, well interbedded with discontinuous gravelly beds, sand, fine. Moderately sensitive . 1.40 m						
	Silty fine to coarse GRAVEL with minor sand, dark brown/grey. Saturated , sand, fine to medium. 1.60 m						
	Silty fine SAND and silty SAND, dark brown/grey. Firm, saturated , well interbedded with discontinuous gravelly beds, sand, fine. Moderately sensitive. 2.70 m						
	End Of Hole: 2.70 m						



PHOTO(S)

REMARKS

End of test, test pit walls collapsing. Seepages through out the pit walls, some with high outflow. Water level remaining at 1.3 m bgl, 15 minutes after completion of test pit excavation

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:10:01 am

TEST PIT LOG

HOLE NO.: TP41

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 29/10/2024
COORDINATES: 1265986.0 mE, 4998873.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 29/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic SILT with trace rootlets, black. Saturated . 0.10 m			TS	4		
UNCONTROLLED FILL	Medium to coarse GRAVEL with a trace of sand and silt, blackish grey. Medium dense, saturated, gravel, subrounded; sand, fine to medium. 0.40 m				9		
	SILT with minor sand, grey. Firm, wet , sand, fine. Moderately sensitive. 1.40 m		0.5		1 1 2 2		
	Gravelly fine to medium SAND with a trace of silt, grey. Medium dense, wet, gravel, fine to coarse, subrounded. 1.70 m		1.0 1.5				
	Boulders in gravelly SAND matrix, grey. Medium dense, wet, gravel, fine to coarse, subrounded; sand, fine to coarse. Boulders up to 600 mm diameter. 2.20 m		2.0				
ALLUVIAL FAN DEPOSITS	SILT with minor sand, grey. Firm, wet, sand, fine. Moderately sensitive. 2.60 m		2.5				29/10/2024
	Sandy fine to coarse GRAVEL with a trace of cobbles and boulders, grey. Medium dense, saturated, gravel, fine to coarse, subrounded; sand, fine to coarse. Boulders up to 600 mm diameter. 2.80 m						
	SILT with minor sand, grey. Firm, saturated, sand, fine. Moderately sensitive. 4.00 m		3.0 3.5				
	Sandy fine to coarse GRAVEL with a trace of cobbles and boulders, grey. Medium dense, saturated, gravel, fine to coarse, subrounded; sand, fine to coarse. Boulders up to 600 mm diameter. 4.20 m		4.0				
	End Of Hole: 4.20 m		4.5				

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:10:05 am

TEST PIT LOG

HOLE NO.: TP42

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

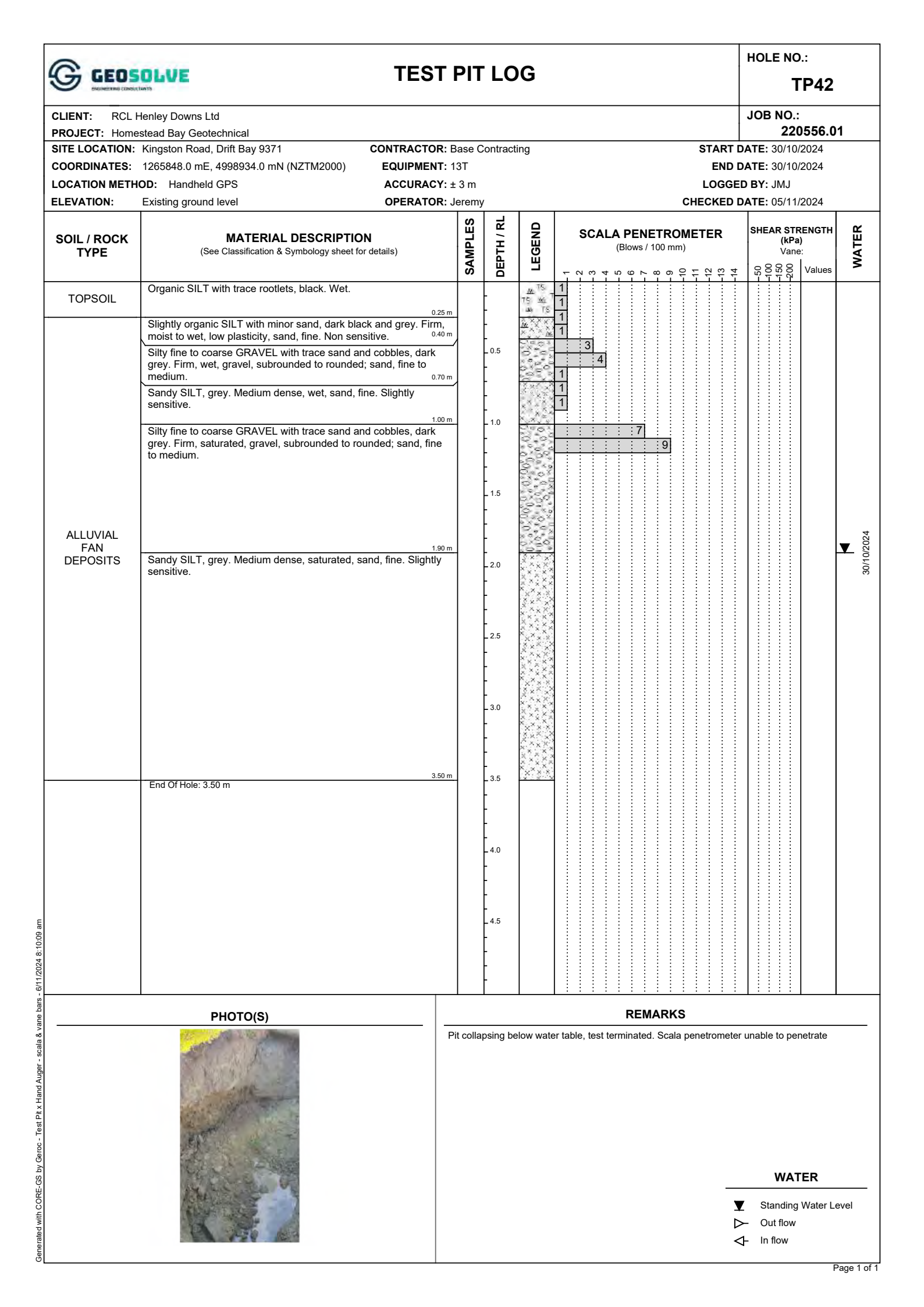
SITE LOCATION: Kingston Road, Drift Bay 9371 | **CONTRACTOR:** Base Contracting | **START DATE:** 30/10/2024

COORDINATES: 1265848.0 mE, 4998934.0 mN (NZTM2000) | **EQUIPMENT:** 13T | **END DATE:** 30/10/2024

LOCATION METHOD: Handheld GPS | **ACCURACY:** ± 3 m | **LOGGED BY:** JMJ

ELEVATION: Existing ground level | **OPERATOR:** Jeremy | **CHECKED DATE:** 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane:	WATER
TOPSOIL	Organic SILT with trace rootlets, black. Wet. 0.25 m						
ALLUVIAL FAN DEPOSITS	Slightly organic SILT with minor sand, dark black and grey. Firm, moist to wet, low plasticity, sand, fine. Non sensitive. 0.40 m						
	Silty fine to coarse GRAVEL with trace sand and cobbles, dark grey. Firm, wet, gravel, subrounded to rounded; sand, fine to medium. 0.70 m						
	Sandy SILT, grey. Medium dense, wet, sand, fine. Slightly sensitive. 1.00 m						
	Silty fine to coarse GRAVEL with trace sand and cobbles, dark grey. Firm, saturated, gravel, subrounded to rounded; sand, fine to medium. 1.90 m						
	Sandy SILT, grey. Medium dense, saturated, sand, fine. Slightly sensitive. 3.50 m						
	End Of Hole: 3.50 m						



PHOTO(S)

REMARKS

Pit collapsing below water table, test terminated. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:10:09 am

TEST PIT LOG

HOLE NO.: TP43

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
COORDINATES: 1265836.0 mE, 4998825.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 30/10/2024
END DATE: 30/10/2024
LOGGED BY: JMJ
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic SILT with trace rootlets, black. Wet. 0.20 m				1, 1		
ALLUVIAL FAN DEPOSITS	Slightly organic SILT with minor sand, dark black/grey. Firm, moist, low plasticity , sand, fine. Non-sensitive. 0.50 m				2, 2, 1		
	Silty fine to coarse GRAVEL with a trace of sand, dark grey. Medium dense, moist, gravel, subrounded to subangular; sand, fine to medium. 1.00 m		0.5		9, 20 >>		
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL with minor cobbles and trace boulders, dark grey. Medium dense, moist, gravel, subrounded to subangular; sand, fine to medium. Boulders up to 100 mm diameter. 2.20 m		1.0		9, 13, 20 >>		
	Fine SAND with a trace of gravel, grey. Medium dense, moist, gravel, fine to coarse, surrounded. 2.60 m		1.5				
	Silty fine to coarse GRAVEL with a trace of sand, dark grey. Medium dense, moist, gravel, subrounded to subangular; sand, fine to medium. 3.20 m		2.0				
GLACIAL TILL	Silty fine to medium SAND with a trace of gravel, light orange/grey. Medium dense, moist, gravel, fine to coarse (mostly fine to medium), rounded. 4.20 m		2.5				
	End Of Hole: 4.20 m		3.0				
			3.5				
			4.0				
			4.5				

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Ground water not encountered, pit walls vertical. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:10:13 am

TEST PIT LOG

HOLE NO.: TP44

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371 | **CONTRACTOR:** Base Contracting | **START DATE:** 30/10/2024

COORDINATES: 1265815.0 mE, 4998666.0 mN (NZTM2000) | **EQUIPMENT:** 13T | **END DATE:** 30/10/2024

LOCATION METHOD: Handheld GPS | **ACCURACY:** ± 3 m | **LOGGED BY:** JMJ

ELEVATION: Existing ground level | **OPERATOR:** Jeremy | **CHECKED DATE:** 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic silty fine SAND with trace of rootlets, dark brown. Moist. 0.25 m						
LOESS	Silty fine SAND with a trace of organics, orange. Loose to medium dense, moist, gravel, fine to coarse, rounded. 0.40 m						
WEATHERED GLACIAL TILL	Sandy silty fine to coarse GRAVEL, orange. Medium dense, wet to saturated, gravel, subrounded to subangular; sand, fine to medium. 0.70 m		0.5				
	Fine to coarse SAND with minor gravel and silt, light grey. Loose, wet, gravel, fine to coarse, subrounded; sand, mostly fine. 1.00 m		1.0				
	Gravelly fine to coarse SAND with a trace of silt and cobbles/boulders, light grey, excavator struggling. Dense, dry to moist, excavator struggling, gravel, fine to coarse (mostly fine to medium), subrounded. Boulders up to 300 mm diameter. 1.60 m		1.5				
GLACIAL TILL	Fine to coarse SAND with minor gravel and a trace of silt, cobbles and boulders, light grey, excavator struggling. Dense, dry to moist, excavator struggling, gravel, fine to coarse (mostly fine to medium), subrounded. Boulders up to 300 mm diameter. 3.70 m		2.0 2.5 3.0 3.5				Groundwater Not Encountered
	End Of Hole: 3.70 m		4.0 4.5				

PHOTO(S)

REMARKS

Target depth achieved. Ground water not encountered, pit walls vertical. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:10:18 am

TEST PIT LOG

HOLE NO.: TP45

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 30/10/2024
COORDINATES: 1265662.0 mE, 4998725.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 30/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic silty fine SAND with trace rootlets, blackish/brown. Moist. 0.30 m						
ALLUVIAL FAN DEPOSITS	Silty fine SAND with trace organics, dark grey. Loose, moist. 0.50 m Silty sandy GRAVEL with trace rootlets, dark grey, lenses out to 213 degrees. Medium dense, moist, sand, fine to medium. Gravel, fine to medium, subrounded. 0.80 m SILT with minor sand, grey. Firm, moist, low plasticity, sand, fine. 2.00 m		0.5 1.0 1.5 2.0	TS	1 1 2 2 2 3 2 1 1 1 2 2 2 3 2 3 2 2		
GLACIAL OUTWASH DEPOSITS	Sand fine to coarse GRAVEL with minor cobbles and trace boulders, grey, interbedded bands of fine sand. Medium dense, moist, bedded, gravel, rounded to subrounded; sand, fine to coarse. Boulders up to 300 mm diameter. 4.20 m		2.5 3.0 3.5 4.0				Groundwater Not Encountered
	End Of Hole: 4.20 m		4.5				

Scala penetrometer: 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Shear strength (kPa) Vane: 50 100 150 200 Values

PHOTO(S)

REMARKS

Target depth achieved. Ground water not encountered, pit walls vertical. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:10:21 am

TEST PIT LOG

HOLE NO.: TP46

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CONTRACTOR: Base Contracting
START DATE: 30/10/2024
COORDINATES: 1265622.0 mE, 49978884.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 30/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic silty fine SAND with trace rootlets, blackish/brown. Moist. 0.25 m						
LOESS	Fine SAND with a trace of rootlets, light grey. Loose, dry to moist. 0.50 m						
ALLUVIAL FAN DEPOSITS	Silty fine SAND with trace organics, dark grey. Loose, moist. 0.70 m						
	SILT with minor sand, brownish/grey. Firm, moist, low plasticity , sand, fine. 2.60 m						
	Fine SAND with minor silt, grey. Loose, moist. 3.20 m						
	Silty fine SAND with trace organics, dark grey. Loose, moist. 3.80 m						
GLACIAL TILL	Sandy SILT with minor gravel, grey/orange. Stiff, moist, sand, fine; gravel, fine, surrounded. 4.40 m						
	End Of Hole: 4.40 m						

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Ground water not encountered, pit walls vertical. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:10:25 am

TEST PIT LOG

HOLE NO.: TP47

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371 | **CONTRACTOR:** Base Contracting | **START DATE:** 30/10/2024

COORDINATES: 1265950.0 mE, 4998783.0 mN (NZTM2000) | **EQUIPMENT:** 13T | **END DATE:** 30/10/2024

LOCATION METHOD: Handheld GPS | **ACCURACY:** ± 3 m | **LOGGED BY:** JMJ

ELEVATION: Existing ground level | **OPERATOR:** Jeremy | **CHECKED DATE:** 05/11/2024

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic SILT with minor rootlets, dark brown. Soft, saturated. 0.30 m				1, 1		
ALLUVIAL FAN DEPOSITS	Silty fine to medium SAND, dark grey. Loose, wet. 0.40 m				3		
	Sandy fine to medium GRAVEL with trace rootlets, dark grey. Loose, wet, gravel, subrounded; sand, coarse. 0.50 m				6		
	SILT with a trace of sand, grey. Soft, wet, low plasticity, sand, fine. 0.60 m		0.5				
	Sandy fine to coarse GRAVEL with minor silt and trace of cobbles and boulders, grey. Loose, saturated, gravel, subrounded; sand, fine to coarse; boulders up to 300 mm. 0.80 m						
GLACIAL TILL	Fine to medium SAND with minor silt and gravel, with trace of cobbles and boulders, light orange/grey, dipping 224/10 . Dense, wet, gravel, fine to coarse, rounded to subrounded. Boulders up to 400 mm diameter.		1.0		4, 4		30/10/2024
			1.5		3		
			2.0		8		
			2.5				
			3.0				
	3.30 m		3.5				
	End Of Hole: 3.30 m		4.0				
			4.5				

PHOTO(S)

REMARKS

End of test, maximum excavator reach, hole collapsing. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 6/11/2024 8:10:32 am

SOIL LOG

HOLE NO.: BH01

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 21/10/2024
CO-ORDINATES: 1265689.0mE, 4998875.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
TOPSOIL	Organic SILT, with trace gravel and rootlets, dark brown . Gravels are fine to medium, angular to subrounded. 0.30 m									Cement 0.3m
ALLUVIAL FAN DEPOSITS	SILT, with trace gravel, with lenses of sand and organic inclusions, brownish grey. Soft, moist, low plasticity, gravels are fine, subangular to subrounded. Sand is fine to medium. 0.75 m			0.5						
	Silty, fine SAND, with trace gravel and organic inclusions , brownish grey. Loose, moist, non-plastic, gravels are fine to medium, subangular to rounded. 0.85 m									
	SILT, with trace gravel, with lenses of sand and organic inclusions, brownish grey. Soft, moist, low plasticity, gravels are fine to medium, subangular to subrounded. Sand is fine to medium. 1.10 m		51	1.0						
	Silty fine SAND, with some gravel, brownish grey. Loose, moist, gravels are fine to medium, subangular to subrounded. 1.30 m									
	Gravelly fine to medium SAND, with minor silt, light grey. Loose, moist, gravels are fine subangular to rounded. 1.55 m			1.5			SPT (S) 1.50m 1, 1 / 2, 2, 2, 2 375mm N=8			
	Silty fine SAND, with some gravel, brownish grey. Loose, moist, gravels are fine to medium, subangular to subrounded. 1.70 m									Bentonite
	SILT, with trace sand and gravel. With trace organic inclusions and rootlets, brownish grey, mottled orange and brown. Firm, moist , low plasticity, sand is fine. Gravels are fine and subrounded to rounded. 1.85 m									
	Silty fine SAND, with some gravel, brownish grey. Loose, moist, gravels are fine to medium, subangular to subrounded. 1.95 m			2.0						
	NO CORE RECOVERY. 2.30 m									
	SILT, with trace sand, light grey. Firm, dry, low plasticity, sand is fine. 2.50 m		103	2.5						
	Silty fine SAND, with some gravel, brownish grey. Loose, moist, gravels are fine to medium, subangular to subrounded. 2.75 m									
	Sandy fine to coarse GRAVEL, with minor silt, brownish grey. Loose, moist, gravels are subangular to subrounded. Sand is fine to medium. 3.00 m		81							

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:31 am

SOIL LOG

HOLE NO.: BH01

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 21/10/2024
CO-ORDINATES: 1265689.0mE, 4998875.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
ALLUVIAL FAN DEPOSITS	SILT, grey. Soft, moist, low plasticity.		81				SPT (S) 3.00m 2, 2 / 2, 2, 2, 1 375mm N=7			
	3.55 m			3.5						
	SILT, with some sand and minor gravel, brownish grey. Firm, moist , low plasticity, sand is fine. Gravels are fine, subrounded to rounded .									
	3.95 m									
	Sandy fine to coarse GRAVEL, with trace silt , brownish grey. Medium dense, moist , Gravels are angular to rounded. Sand is fine to coarse.		55	4.0						
	4.50 m			4.5			SPT (S) 4.50m 8, 10 / 8, 8, 10, 13 375mm N=39			
	Sandy, fine to coarse GRAVEL, with some silt, grey. Dense, moist, Gravels are angular to rounded. Sand is fine to coarse.			5.0						
			104						22/10/2024	Bentonite
	5.60 m			5.5						
	Silty fine SAND, with trace fine gravel, brownish grey, mottled orange. Medium dense, moist, gravels are subrounded to rounded.									
	5.85 m									
	SILT, with some sand and trace gravel, brownish grey, mottled orange. Firm, moist, low plasticity, sand is fine. Gravels are fine, subrounded to		71							
	6.65 m									

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:31 am

SOIL LOG

HOLE NO.: BH01

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 21/10/2024
CO-ORDINATES: 1265689.0mE, 4998875.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
	rounded .		71	6.5			SPT (S) 6.10m 3, 2 / 4, 4, 4, 4 375mm N=16			
	6.65 m Silty fine SAND, brownish grey. Medium dense, wet, low plasticity. 6.75 m									
	Sandy fine to medium GRAVEL, with some silt, grey. Medium dense, wet, gravels are subangular to rounded. Sand is fine to coarse. 7.10 m			7.0						
	SILT, with some sand and trace gravel, brownish grey, mottled orange. Firm, moist, low plasticity, sand is fine. Gravels are fine, subrounded to rounded . 7.25 m									
ALLUVIAL FAN DEPOSITS	Sandy fine to coarse GRAVEL, with trace silt , grey. Medium dense, moist, gravels are subangular to subrounded. 7.60 m		58	7.5						Bentonite
	Silty fine to coarse SAND, with trace fine gravel, brownish grey, with slight orange mottling. Medium dense, wet, sand is predominantly fine to medium. Gravels are subrounded.			8.0			SPT (S) 7.60m 3, 5 / 4, 3, 4, 4 375mm N=15			
	8.80 m		121	8.5						
ALLUVIAL FAN DEPOSITS	Sandy fine to coarse GRAVEL, with trace silt , grey. Medium dense, moist, gravels are subangular to subrounded. 8.95 m									
	9.10 m		83							

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:31 am

SOIL LOG

HOLE NO.: BH01

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 21/10/2024
CO-ORDINATES: 1265689.0mE, 4998875.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
ALLUVIAL FAN DEPOSITS	SILT, with minor sand, brownish grey, mottled orange. Firm , moist, low plasticity, sand is fine. 9.10 m Silty, gravelly fine to coarse SAND, brownish grey. Medium dense, moist, gravels are fine to medium subangular to subrounded. 9.55 m Sand is predominantly fine to medium. Gravels are subrounded, silty fine to coarse SAND, with trace fine gravel. Medium dense, moist, non-plastic. 9.80 m Silty, sandy fine to coarse GRAVEL, grey. Medium dense, moist, sand is fine to medium. 10.20 m		83	9.5 10.0			SPT (S) 9.10m 4, 3 / 4, 5, 5, 4 375mm N=18			Bentonite
GLACIAL TILL	Fine to medium SAND, with some silt and gravel, light brownish grey. Dense, moist, gravels are fine to coarse, subangular to subrounded. 10.70 m Sandy fine to medium GRAVEL, grey and brown. Very dense, moist, gravels are subangular to subrounded. Sand is medium to coarse. 11.65 m Gravelly fine to medium SAND, with minor silt, light greyish brown. Very dense, moist, gravels are fine to coarse, subangular to rounded. 12.60 m		63 90	10.5 11.0 11.5			SPT (S) 10.60m 14, 11 / 15, 17, 18 375mm N=50			

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:31 am

SOIL LOG

HOLE NO.: BH01

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 21/10/2024
CO-ORDINATES: 1265689.0mE, 4998875.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	[CONT] Gravelly fine to medium SAND, with minor silt, light greyish brown. Very dense, moist, gravels are fine to coarse, subangular to rounded.		83	12.5			SPT (S) 12.20m 17, 16 / 11, 9, 14, 16 375mm N=50			Bentonite
	12.60 m Sandy fine to medium GRAVEL, with trace silt, grey. Very dense, moist, gravels are subangular to subrounded. Sand is fine to coarse. With a fine to medium sand bed between 13.00 and 13.10 m .			13.0						
	13.30 m Gravelly fine to medium SAND, with trace silt, light grey. Very dense, moist, gravels are fine to medium subangular to rounded.		66	13.5			SPT (S) 13.70m 11, 17 / 24, 26 375mm N=50			
	14.00 m Sandy SILT, with some gravel, brownish grey, with slight orange mottling. Very stiff, moist, low plasticity, sand is fine. Gravels are fine to coarse subangular to rounded.		95	14.0 14.5						
	15.00 m									

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:31 am

SOIL LOG

HOLE NO.: BH01

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CO-ORDINATES: 1265689.0mE, 4998875.0mN (NZTM2000)
LOCATION METHOD: Handheld GPS
CONTRACTOR: Pro Drill **RIG:** FRASTE XL 170 DUO

ELEVATION: Ground
ACCURACY: ± 1m
DRILLER: Matty

START DATE: 21/10/2024
END DATE: 22/10/2024
LOGGED BY: WF
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%) 25 50 75	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected) 10 20 30 40	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	Sandy fine to coarse GRAVEL, with trace minor silt, grey and brown. Very dense, dry, gravels are subangular to rounded. Sand is fine to coarse.			15.5			SPT (S) 15.20m 17, 13 / 12, 12, 21, 5 375mm N=50			Bentonite
	15.65 m Sandy fine to coarse GRAVEL, with some silt, grey brown. Very dense, moist, gravels are subangular to rounded. Sand is fine to medium.			16.0						
	16.30 m Sandy fine to coarse GRAVEL, with minor silt, whitish grey. Very dense, dry, gravels are angular to rounded. Sand is fine to coarse.			16.5			SPT (S) 16.70m 20, 17 / 20, 22, 8 375mm N=50			16.8m Gravel
	19.90 m			17.0 17.5						

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:31 am

SOIL LOG

HOLE NO.: BH01

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 21/10/2024
CO-ORDINATES: 1265689.0mE, 4998875.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%) 25 50 75	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected) 10 20 30 40	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	[CONT] Sandy fine to coarse GRAVEL, with minor silt, whitish grey. Very dense, dry, gravels are angular to rounded. Sand is fine to coarse.			18.5			SPT (S) 18.30m 29, 21 375mm N=50			Gravel 19.8m
	19.90 m End Of Hole: 20.20m			19.0 19.5 20.0			SPT (S) 19.80m 26, 24 375mm N=50			
				20.5						

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:31 am

SOIL LOG

HOLE NO.: BH02

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 22/10/2024
CO-ORDINATES: 1265959.0mE, 4998127.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 23/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
TOPSOIL	Organic SILT, with trace gravel and rootlets, dark brown . Gravels are fine to medium, angular to subrounded. 0.30 m									Cement 0.3m
ALLUVIAL FAN DEPOSITS	Slightly organic gravelly, sandy SILT, dark brownish grey. Soft, wet, low plasticity, gravels are fine to coarse, angular to rounded. Sand is fine. 0.70 m			0.5						
	Slightly organic sandy SILT, with trace gravel, brownish grey. Soft, wet, low plasticity, sand is fine. Gravels are fine to medium, subangular to rounded. 1.15 m		42	1.0						
	Silty fine SAND, with some gravel, grey. Loose, wet, non-plastic, gravels are fine to medium subangular to rounded. 2.00 m			1.5			SPT (S) 1.50m 3, 2 / 2, 3, 3, 2 375mm N=10			Bentonite
	Sandy fine to coarse GRAVEL, with some silt, grey. Loose, moist to wet, gravels are angular to subrounded. Sand is fine to coarse. 2.30 m			2.0						
	Fine to medium SAND, with some silt and trace gravel, grey brown. Loose, moist, gravels are fine to medium, subangular. 3.80 m		33	2.5						

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:35 am

SOIL LOG

HOLE NO.: BH02

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 22/10/2024
CO-ORDINATES: 1265959.0mE, 4998127.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 23/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
ALLUVIAL FAN DEPOSITS	[CONT] Fine to medium SAND, with some silt and trace gravel, grey brown. Loose, moist, gravels are fine to medium, subangular.		33	3.5			SPT (S) 3.00m 2, 2 / 2, 2, 2, 3 375mm N=9			Bentonite
	3.80 m		245							
	SILT, with some sand and trace gravel, brownish grey, with slight orange mottling. Soft, moist, low plasticity, sand is fine to medium. Becoming sandy between 4.25 and 4.50 m. Gravels are fine to medium subangular to subrounded.		79	4.0						
	4.50 m			4.5			SPT (S) 4.50m 2, 1 / 2, 3, 2, 3 375mm N=10			
	Silty fine SAND, with trace coarse sand and fine gravel, brownish grey. Loose, moist, non-plastic.			5.0						
			48	5.5						
	6.00 m									

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:36 am

SOIL LOG

HOLE NO.: BH02

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 22/10/2024
CO-ORDINATES: 1265959.0mE, 4998127.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 23/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
ALLUVIAL FAN DEPOSITS	Sandy fine to coarse GRAVEL, with some silt, grey. Medium dense, moist, gravels are subangular to rounded. Sand is fine to coarse.		48	6.5			SPT (S) 6.10m 3, 3 / 4, 4, 6, 5 375mm N=19			
	6.90 m		285							
	Sandy SILT, grey, brown. Firm, moist, low plasticity, sand is fine.			7.0						
	7.35 m								23/10/2024	
GLACIAL OUTWASH	Silty, sandy fine to coarse GRAVEL, grey. Medium dense, moist, gravels are subangular to subrounded. 7.45 m		79	7.5						Bentonite
	Silty, gravelly fine to medium SAND, grey. Medium dense, wet, non-plastic, gravels are fine to medium subangular to subrounded. 7.60 m						SPT (S) 7.60m 3, 8 / 10, 8, 8, 15 375mm N=41			
	Sandy fine to coarse GRAVEL, with trace to some silt, grey. Medium dense to dense, moist to wet, gravels are angular to rounded. Sand is fine to coarse.			8.0						
			104	8.5						
	9.10 m									

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:36 am

SOIL LOG

HOLE NO.: BH02

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 22/10/2024
CO-ORDINATES: 1265959.0mE, 4998127.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 23/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL OUTWASH	[CONT] Sandy fine to coarse GRAVEL, with trace to some silt, grey. Medium dense to dense, moist to wet, gravels are angular to rounded. Sand is fine to coarse. 9.10 m NO SPT RECOVERY. 9.55 m		104 0	9.5			SPT (S) 9.10m 39, 11 375mm N=50			
	NO CORE RECOVERY. 10.60 m		0	10.0 10.5						Bentonite
	Sandy fine to coarse GRAVEL, with trace to some silt, grey. Very dense, moist to wet, gravels are angular to rounded. Sand is fine to coarse. 12.00 m		250 36	11.0 11.5			SPT (S) 10.60m 9, 11 / 12, 24, 12, 2 375mm N=50			

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:36 am

SOIL LOG

HOLE NO.: BH02

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 22/10/2024
CO-ORDINATES: 1265959.0mE, 4998127.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 23/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%) 25 50 75	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected) 10 20 30 40	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	Sandy fine to coarse GRAVEL, grey. Very dense, moist to wet, gravels are subangular to rounded. Sand is medium to coarse.		36	12.5			SPT (S) 12.20m 13, 18 / 16, 14, 13, 7 375mm N=50			Bentonite
	13.00 m			13.0						
	Sandy SILT, with trace gravel, light grey. Very stiff, wet, low plasticity, sand is fine. Gravels are fine to medium angular to subrounded.									
	13.30 m									
	Sandy fine to coarse GRAVEL, grey. Very dense, wet, gravels are subangular to rounded. Sand is medium to coarse.		62	13.5			SPT (S) 13.70m 18, 18 / 19, 18, 13 375mm N=50			
	14.20 m		100	14.0						
	Sandy fine to coarse GRAVEL, with minor to some silt, with trace cobbles and boulders, light brownish grey. Very dense , moist to wet, ravels are angular to rounded. Sand is fine to coarse.									
	16.85 m		50	14.5						

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:36 am

SOIL LOG

HOLE NO.: BH02

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 22/10/2024
CO-ORDINATES: 1265959.0mE, 4998127.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 23/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	[CONT] Sandy fine to coarse GRAVEL, with minor to some silt, with trace cobbles and boulders, light brownish grey. Very dense , moist to wet, ravels are angular to rounded. Sand is fine to coarse.		50	15.5			SPT (S) 15.20m 10, 14 / 15, 19, 16 375mm N=50			Bentonite
			80	16.0						16m
				16.5			SPT (S) 16.70m 10, 40 375mm N=50			Gravel
	16.85 m Silty, fine to coarse GRAVEL, with trace some sand and trace cobbles, bluish grey and brown. Very dense, wet, gravels are fine to coarse angular to subangular. Sand is medium to coarse .		137	17.0						
	17.50 m Gravelly SILT, with some sand and clay content, greyish brown. Stiff, wet, low plasticity, gravels are fine to coarse, subangular to rounded.			17.5						
SUB-GLACIAL SEDIMENT	17.70 m Sandy SILT, with minor gravel, greenish, greyish brown. Very stiff, moist , non-plastic, sand is fine. Gravels are fine to medium, subrounded.									
	18.00 m									

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:36 am

SOIL LOG

HOLE NO.: BH02

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 22/10/2024
CO-ORDINATES: 1265959.0mE, 4998127.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 23/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%) 25 50 75	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected) 10 20 30 40	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
SUB-GLACIAL SEDIMENT	SILT, with some sand and gravel. With iron oxidation staining and calcrete nodules, greenish brown, bluish grey, slightly laminated and fissured. Hard, dry, non-plastic, sand is fine. Gravels are fine to coarse subangular to rounded. 18.30 m Gravelly SILT, with minor sand, with iron oxidation staining and calcrete nodules, greenish brown, bluish grey, slightly laminated. Very stiff, moist to wet, low plasticity, gravels are fine to coarse. Sand is fine. 19.20 m		125	18.5 19.0			SPT (S) 18.30m 50 375mm N=50			Gravel 19m
	End Of Hole: 19.20m			19.5 20.0 20.5						

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:36 am

SOIL LOG

HOLE NO.: BH03

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 23/10/2024
CO-ORDINATES: 1265487.0mE, 4998045.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 24/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
TOPSOIL	Organic SILT, with trace gravel and rootlets, dark brown . Gravels are fine to medium, angular to subrounded.			0.5						Cement 0.3m
	0.70 m									
	SILT, with trace fine sand and gravel, and some organic inclusions, light greyish brown, with orange brown speckling. Soft, moist to wet, low plasticity.		57	1.0						
	1.50 m									
GLACIAL OUTWASH SILT	Gravelly SILT, with minor sand and trace rootlets, light greyish brown, with orange brown speckling . Stiff, wet, low plasticity, gravels are fine to medium, angular to subrounded. Sand is fine to medium.			1.5			SPT (S) 1.50m 2, 3 / 27, 23 375mm N=50			Bentonite
	1.90 m									
	Sandy, fine to coarse GRAVEL, with trace cobbles, grey. Dense, moist, gravels are subangular to rounded. Sand is fine to medium.			2.0						
	2.10 m									
	Silty, sandy fine to coarse GRAVEL, greyish brown. Dense, moist , gravels are subangular to rounded. Sand is medium.		133							
	2.30 m									
	Sandy fine to coarse GRAVEL, with minor silt, light greyish brown. Dense, moist , gravels are subangular to rounded. Sand is medium.			2.5						
	2.50 m									
	Silty, sandy fine to coarse GRAVEL, light grey and brown. Very dense, wet, Gravels are angular to rounded. Sand is fine to coarse.		83							
	3.70 m									

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:39 am

SOIL LOG

HOLE NO.: BH03

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 23/10/2024
CO-ORDINATES: 1265487.0mE, 4998045.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 24/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL OUTWASH SILT	[CONT] Silty, sandy fine to coarse GRAVEL, light grey and brown. Very dense, wet, Gravels are angular to rounded. Sand is fine to coarse.		83	3.5			SPT (S) 3.00m 7, 12 / 16, 13, 12, 9 450mm N=50			
	3.70 m Sandy fine to coarse GRAVEL, with some silt, grey. Very dense, wet, gravels are subangular to rounded. Sand is medium to coarse.									
	3.95 m Sandy fine to coarse GRAVEL, grey. Very dense, moist, gravels are subangular to rounded .		63	4.0						
	4.20 m Sandy fine to coarse GRAVEL, with some silt, grey, slightly brown. Very dense, wet, gravels are subangular to rounded. Sand is medium to coarse.			4.5			SPT (S) 4.50m 11, 17 / 26, 217, 17, 0 375mm N=50			
	4.60 m Sandy fine to medium GRAVEL, with minor silt, grey and brown. Very dense, moist, gravels are angular to subrounded.		222	5.0					24/10/2024	Bentonite
	5.30 m Sandy, fine to coarse GRAVEL, with trace to some silt, and trace cobbles, grey, brown and orange. Dense to very dense, moist, gravels are angular to rounded. Sand is fine to coarse.		51	5.5						
	6.60 m									

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:40 am

SOIL LOG

HOLE NO.: BH03

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 23/10/2024
CO-ORDINATES: 1265487.0mE, 4998045.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 24/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL OUTWASH SILT	[CONT] Sandy, fine to coarse GRAVEL, with trace to some silt, and trace cobbles, grey, brown and orange. Dense to very dense, moist, gravels are angular to rounded. Sand is fine to coarse.		51	6.5			SPT (S) 6.10m 8, 9 / 10, 10, 10, 9 375mm N=39			
	6.60 m Sandy, fine to coarse GRAVEL, with trace silt, grey brown. Very dense, moist, gravels are angular to rounded. Sand is fine to coarse.			7.0						
	7.00 m Sandy, fine to coarse GRAVEL, with minor to some silt, and trace cobbles, grey, brown and orange. Very dense, moist, gravels are angular to rounded. Sand is fine to coarse.		59	7.5			SPT (S) 7.60m 11, 15 / 16, 14, 16, 4 375mm N=50			Bentonite
GLACIAL TILL			131	8.0						
				8.5						
			147							
	8.90 m Sandy, fine to coarse GRAVEL, with some silt , grey, brown, bluish grey and orange . Very dense. 9.85 m									

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:40 am

GEOSOLVE

SOIL LOG

HOLE NO.: BH03

CLIENT: RCL Henley Downs Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371

START DATE: 23/10/2024

CO-ORDINATES: 1265487.0mE, 4998045.0mN (NZTM2000)

ELEVATION: Ground

END DATE: 24/10/2024

LOCATION METHOD: Handheld GPS

ACCURACY: ± 1m

LOGGED BY: WF

CONTRACTOR: Pro Drill

RIG: FRASTE XL 170 DUO

DRILLER: Matty

CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%) 25 50 75	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected) 10 20 30 40	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	moist, gravels are subangular to rounded. Sand is fine to coarse.		147	9.5			SPT (S) 9.10m 19, 23 / 22, 28 375mm N=50			Bentonite
	9.85 m Sandy, fine to coarse GRAVEL, with trace silt and cobbles, grey brown. Very dense, moist, gravels are angular to subrounded .			10.0						
	10.15 m Gravelly fine to medium SAND, with trace silt, brown. Very dense, moist, gravels are fine to coarse, predominantly fine to medium, and subangular to subrounded.		68	10.5						
	10.50 m Silt, gravelly fine to medium SAND, grey, brown and orange. Very dense, moist , gravels are fine to coarse subangular to subrounded .						SPT (S) 10.60m 23, 29 / 17, 18, 15 375mm N=50			
	10.60 m Sandy, fine to coarse GRAVEL, with minor silt, grey brown. Very dense, moist, gravels are angular to subrounded .		124	11.0						
	11.45 m Sandy fine to coarse GRAVEL, with minor to some silt, grey, brown, bluish grey and orange. Very dense, moist, gravels are fine to coarse angular to rounded. Sand is fine to coarse.		141	11.5						
	12.10 m									

REMARKS

Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:40 am

SOIL LOG

HOLE NO.: BH03

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 23/10/2024
CO-ORDINATES: 1265487.0mE, 4998045.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 24/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
	[CONT] Sandy fine to coarse GRAVEL, with minor to some silt, grey, brown, bluish grey and orange. Very dense, moist, gravels are fine to coarse angular to rounded. Sand is fine to coarse. 12.10 m		11							
	Silty, sandy fine to coarse GRAVEL, greenish grey and purplish brown. Very dense, moist, gravels are angular to subrounded. Sand is medium to coarse. 12.50 m			12.5			SPT (S) 12.20m 38, 12 375mm N=50			
	Silty, sandy fine to coarse GRAVEL, light greenish grey. Very dense, moist to wet, gravels are angular to rounded. Sand is medium to coarse. 13.00 m		7	13.0						
	Medium to coarse SAND, with some gravel, grey, brown. Very dense, moist to wet, gravels are fine to medium, subrounded. 13.10 m									
	Sandy fine to coarse GRAVEL, with some silt, grey, brown and orange. Very dense, moist to wet, gravels are subangular to rounded. Sand is fine to coarse. 13.40 m									
GLACIAL TILL	Medium to coarse SAND, with some gravel, grey, brown. Very dense, moist to wet, gravels are fine to medium, subrounded. Sand is predominantly coarse. 13.55 m			13.5						Bentonite
	Sandy fine to coarse GRAVEL, with some silt, grey, brown and orange. Very dense, moist to wet, gravels are subangular to rounded. Sand is fine to coarse. 13.70 m						SPT (S) 13.70m 22, 24 / 43, 7 375mm N=50			
	Silty, sandy fine to medium GRAVEL, light greenish grey and brown. Very dense, moist to wet, gravels are subangular to subrounded. Sand is fine to coarse . 14.05 m			14.0						
	Sandy fine to medium GRAVEL, with trace silt, light greenish grey and brown. Very dense, moist to wet, gravels are subangular to subrounded. Sand is medium to coarse. 14.20 m									
	Silty, sandy fine to coarse GRAVEL, greenish grey and purplish brown and orange. Very dense, moist, gravels are angular to rounded. Sand is medium to coarse.		55	14.5						
	15.50 m									

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:40 am

SOIL LOG

HOLE NO.: BH03

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
CO-ORDINATES: 1265487.0mE, 4998045.0mN (NZTM2000)
LOCATION METHOD: Handheld GPS
CONTRACTOR: Pro Drill **RIG:** FRASTE XL 170 DUO
ELEVATION: Ground
ACCURACY: ± 1m
DRILLER: Matty
START DATE: 23/10/2024
END DATE: 24/10/2024
LOGGED BY: WF
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	[CONT] Silty, sandy fine to coarse GRAVEL, greenish grey and purplish brown and orange. Very dense, moist, gravels are angular to rounded. Sand is medium to coarse.		55				SPT (S) 15.20m 19, 31 375mm N=50			Bentonite
	Silty, sandy, fine to medium GRAVEL, light greyish brown, with dark brown speckling . Very dense, wet, gravels are subangular to subrounded. 15.50 m			15.5						
	15.60 m									
	Silty, sandy fine to coarse GRAVEL, brownish grey. Very dense, wet, gravels are angular to subrounded. Sand is fine to medium. 15.75 m									
	Sandy fine to coarse GRAVEL, with some silt, grey and brown. Very dense, moist, gravels are subangular to subrounded. Sand is medium to coarse. 15.85 m		100							
	15.95 m									
	Gravelly medium to coarse SAND, with trace silt, grey and brown. Very dense, moist, gravels are fine to medium, subangular to subrounded. 16.05 m			16.0						
	Sandy fine to coarse GRAVEL, with some silt, grey and brown. Very dense, moist, gravels are subangular to subrounded. Sand is medium to coarse.									
	Gravelly fine to coarse SAND, with trace silt, orangish brown. Very dense, moist, gravels are fine to coarse, subangular to rounded. 16.45 m									
	Sandy fine to coarse GRAVEL, with minor to some silt. With trace decayed organic matter, greenish grey and orangish brown. Very dense, wet, gravels are angular to rounded. Sand is fine to coarse.			16.5						16.8m
GLACIAL TILL			165				SPT (S) 16.70m 24, 22 / 31, 19 375mm N=50			Gravel
				17.0						
			67	17.5						
	18.05 m									

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 4/11/2024 9:57:40 am

SOIL LOG

HOLE NO.: BH03

CLIENT: RCL Henley Downs Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 23/10/2024
CO-ORDINATES: 1265487.0mE, 4998045.0mN (NZTM2000)
ELEVATION: Ground
END DATE: 24/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matty
CHECKED DATE: 05/11/2024

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	[CONT] Sandy fine to coarse GRAVEL, with minor to some silt. With trace decayed organic matter, greenish grey and orangish brown. Very dense, wet, gravels are angular to rounded. Sand is fine to coarse. 18.20 m Gravelly medium to coarse SAND, with trace silt, greenish grey and brown. Very dense, wet, gravels are fine to medium, subangular to subrounded. Sandy fine to coarse GRAVEL, with minor to some silt, with trace cobbles, greenish grey and orangish brown. Very dense, wet, gravels are angular to rounded. Sand is fine to coarse. 18.90 m		67	18.5			SPT (S) 18.30m 25, 25 375mm N=50			
	Sandy, fine to medium GRAVEL, greenish grey. Very dense, wet, gravels are subangular to rounded. Sand is medium to coarse. 19.05 m Gravelly medium to coarse SAND, with trace silt, greenish grey and brown. Very dense, wet, gravels are fine to medium, subangular to subrounded. 19.30 m		85	19.0						
GLACIAL TILL	Gravelly, medium to coarse SAND, grey and brown. Very dense, moist , gravels are fine to medium, subangular to subrounded. 19.40 m Sandy fine to coarse GRAVEL, with some silt, grey and brown. Very dense, moist, gravels are subangular to rounded. 19.65 m Medium to coarse SAND, with some silt, grey and brown. Very dense, moist. 19.90 m Silty, sandy fine to coarse GRAVEL, greenish grey and purplish brown and orange. Very dense, moist to wet, gravels are angular to rounded. Sand is medium to coarse.		200	19.5			SPT (S) 19.80m 50 375mm N=50			Gravel 19.8m
	End Of Hole: 20.20m			20.0						
				20.5						

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

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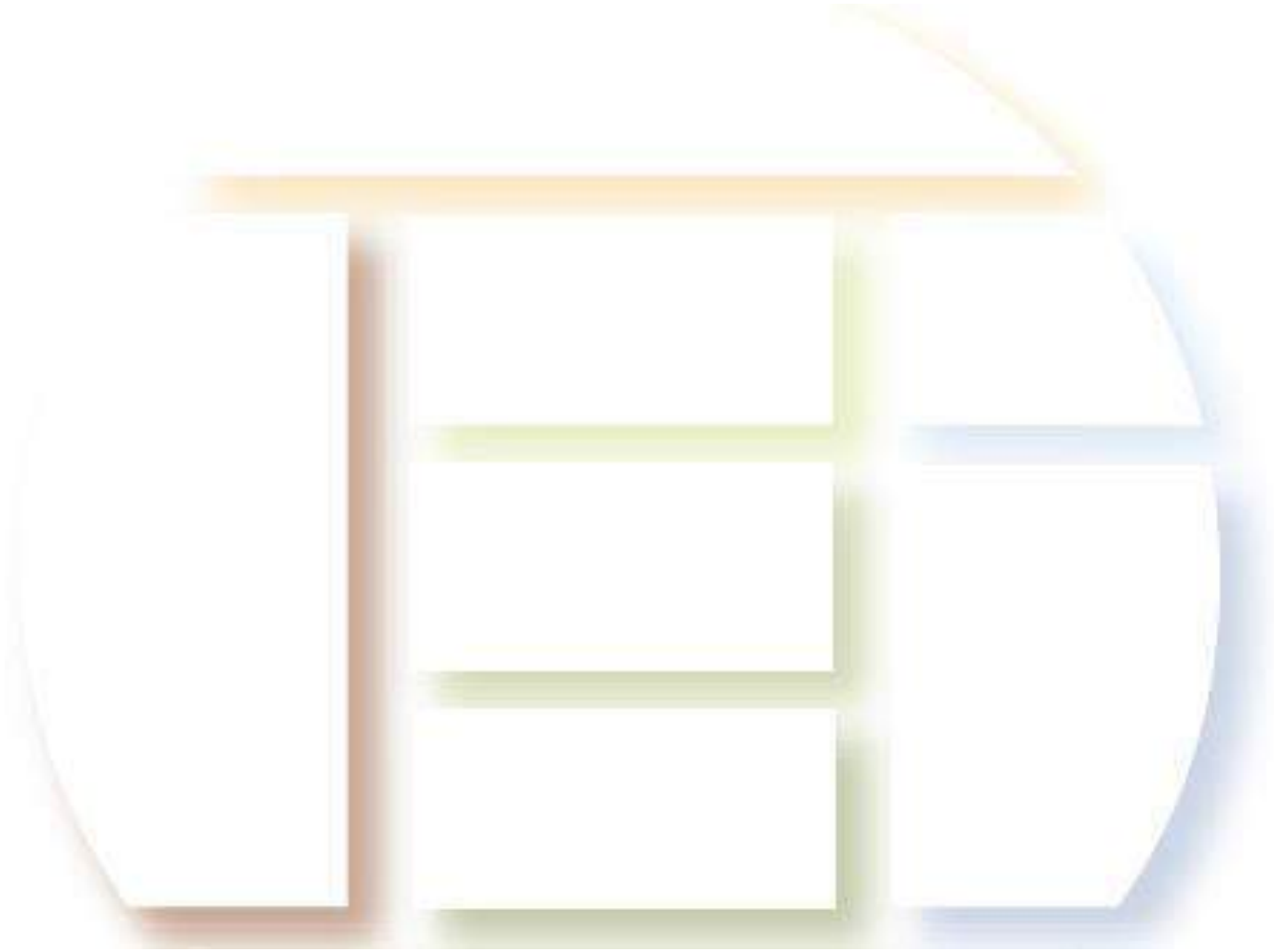

Appendix D Reeftide Environmental & Projects Peer Review

MEMORANDUM Job 10934

To:	Dan Wells, RCL Group
From:	Brian Ellwood, Lowe Environmental Impact (LEI)
Date:	17 March 2025
Subject:	Summary of Action Following Peer Review by Victor Mthamo (Reeftide Environmental & Projects) of Homestead Bay Consent Level Design Wastewater Land Application Prepared by LEI

The report "*Homestead Bay Consent Level Design for Wastewater Land Application*", dated 13 February 2025, was prepared by Lowe Environmental Impact (LEI) for RCL Group and outlines the consent-level design for the wastewater land treatment system associated with RCL's Homestead Bay development. The development is expected to include around 2,580 residential units, a commercial village, and potentially a school. The report describes the expected wastewater flows and designs, based on the soils and treatment technology and presents a land treatment system that aligns with the development plans while aiming to minimize environmental impacts.

Victor Mthamo from Reeftide Environmental & Projects provided a peer review of this report, and provided feedback in his letter dated February 25, 2025, "*Homestead Bay Wastewater Consent Application – Peer Review*" (Appendix A). LEI reviewed this feedback, which informed changes to the report. Brian Ellwood met with Victor Mthamo on March 11, 2025 to discuss the feedback and any outstanding matters in the report. Following this meeting, Victor Mthamo confirmed all items were addressed, with no outstanding issues in the report on March 13, 2025.

A summary table of each peer review item, LEI's response, Victor Mthamo's response and the status of each item is presented in Appendix B.

APPENDIX A

Homestead Bay Wastewater Consent Application – Peer Review

Reeftide Environmental
& Projects Ltd

e: victor.mthamo@reeftide.co.nz

☒ Project Specific - MemoReport

☐ For Information Only

☐ For Your Action

TO	RCL Group Level 1, 13 Camp St, Queenstown, New Zealand Attention: Dan Wells & Lower Environmental Impact Limited PO Box 29288, Christchurch 8440 Attention: Brian Ellwood
FROM	Victor Mthamo
DATE	25 February 2025
SUBJECT	Homestead Bay Wastewater Consent Application – Peer Review

1 Introduction

1.1 Purpose of this Memo

Reeftide Environmental Projects Limited (Reeftide) has been engaged to provide a peer review the Basis of Design (BoD) report "*Homestead Bay Consent Level Design Wastewater Land Application*"[1] prepared Lowe Environmental Impact (LEI) on behalf of RCL Group.

This review has been prepared by Reeftide's Victor Mthamo whose qualification and experience to provide the peer review is provided in Attachment 1 of this memo.

1.2 Context of the Report and the Peer Review

The purpose of the LEI report is "*….to present the consent-level design for the wastewater land treatment system for RCL's Homestead Bay development. The proposed development will include approximately 2,580 residential lots/units, a commercial village, and possibly a school*". The scope of the report excludes assessment of environmental effects. The peer review has been undertaken with these considerations in mind.

2 Minor Observations

The report is dated 13 February 2024. This should possibly be February 2025.

3 Section 2 - Introduction

3.1 Purpose

This section discusses the anticipated land use or zoning within the development. It is proposed to adopt the NZS4404:2010 recommended flow rate of 0.4 L/s/ha for light industrial and commercial and assuming a 12-hour operational period.

We agree with the assumed flow rates. However, we recommend that rather than reference NZS4404:2010 the report should reference the more relevant *Queenstown Lakes District*

[1] *Lowe Environmental Impact. 2025. Homestead Bay Consent Level Design Wastewater Land Application.*

Council Land Development and Subdivision Code of Practice (2020)[2]. The code of practice recommends the same flow rates in its Table 5.1 (Commercial and industrial flows) in Section 5.3.5.1. We appreciate that the code of practice is also partly based on NZS4404:2010.

3.2 Sections 3.2.1 and 3.2.2 Wastewater Quality

Provide references for the wastewater influent and effluent quality.

The N and P effluent concentrations provided are very low which makes it important to provide the basis for these values as they determine every aspect of the this BoD.

3.3 Section 3.2.3 – Wastewater Flows

Please refer to the earlier comment (Section 3.1) regarding the source reference.

Amend the first paragraph below Table 5.1 for readability. It states that *"The design flow rates have been modified and calculated using standards relevant to domestic wastewater management using NZS 4404:2010 Land Development and Subdivision Infrastructure for communal systems and NZS 1547:2012*".

We commend the use of Method 1 in the flow estimates to start with. This is because to adopt Method 2 would the typology and use (e.g. holiday homes vs permanent homes) of the dwellings at the proposed Homestead development to be the same as those at Hanley's Farm and/or Shotover Country. For example, if a development has a higher weighted average of apartments and terraced houses the wastewater generation would be considerably less than where the proportion of standalone dwellings is higher.

The proposal to adjust the design flows as the staging progresses enables a better understanding of the development's wastewater generation profile and to tailor the design accordingly.

The allowance per student and staff at the school used in Table 3.2 is 53 L/p/day. A reference for this rate is recommended. This is also highly conservative. An acceptable alternative would be 30 L/p/day suggested in NZS1457:2012. This will yield a Design Average Flow Rate of 19.8 m^3/day.

Normally we would expect the population estimates in the area to have seasonal variations. If historical data of the variations is/was available this could be used to estimate the monthly or seasonal flows. This approach is likely to give lower and more realistic volumes. However, we acknowledge that in the absence of such data the approach taken is conservative.

Table 3.3 – for the school ROW amend Column 4 (Peak Population). The 53 is, we assume, the same flow rate in Table 3.2. Furthermore, Table 3.3 is based on NZS4404:2010 and thus 30 L/p/day could be used for the school flow estimates.

The report states (above Table 3.2) that "*While also having the capacity to receive intermittently higher flows up to the Peak Wet Weather Flow (PWWF), which can occur during times of wet weather. It should be noted that the flow associated with diurnal variations will be stored and balanced as part of the WWTP"*. This is a significant assumption. We recommend strong justification for it be provided as this impacts the size of the LTA, nutrient and hydraulic loading rates etc. This also impacts the storage volume and without a detailed analysis (e.g. water balance) or justification it could be impossible to nominate a storage volume. While we appreciate the recommendation in the report that flows with be refined as development progresses and flows from the early stages are understood, for the purposes of this BoD we would recommend that the peak flows be used for:

- Sizing the LTA and for consenting purposes.
- The areas, the nutrient and hydraulic loading rates.

[2] https://www.qldc.govt.nz/media/s21al2gz/2020-qldc-land-development-and-subdivision-code-of-practice.pdf

Alternatively, the dry weather flows could still be adopted but this should be supported by a more detailed discussion on the likely or anticipated storage volumes.

3.4 Section 3.3 – Determinant Loading

No matters to comment on.

3.5 Section 3.3.1 – Land Treatment Area

Minor correction – Blocks H, I, J, K, L add up to 7.4 ha based on the areas in Table 5.1. Will make minimal difference as the flow rates assumed in previous sections are conservative.

Delete the 7.1 mm/day in the last ROWs of Tables 3.4, 3.5 and 5.1.

Below is an alternative to Table 3.4 generated using the areas and the DIRs in Table 3.4. Minor differences and could be due to rounding differences.

Block	Area (ha)	DIR (mm/day)	Flow (m^3/day)	Annual Flow Rate (m^3/year)
1	4.5	5.4	243	88,695
2	11.6	7.1	824	300,614
3	7.2	7.1	511	186,588
4	5.2	8	416	151,840
Total	28.5		1,994	727,737

We also note that the flows in alternative to Table 3.4 above are similar to those reported in the Overseer Report (i.e. on Page 7 of 10 under the RCL-LTA section). We have generated the table below from the application depths used in Table 6 (Total N and P Applied (kg/ha) in Irrigation Wastewater) in the Overseer Report.

Block	Annual Application Depth (mm)	Area (ha)	Annual Volume (m^3)	Daily Flow (m3/day)
Area 1	1,971	4.50	88,695	243
Area 2	2,592	11.60	300,672	824
Area 3	2,592	7.20	186,624	511
Area 4	2,920	5.20	151,840	416
Total	10,075	28.50	727,831	1,994

The areas and DIRs and flows in Table 3.4 are based on the average flow of 2,005 mm^3/day. Please note or refer to our comments on the use of PWWF in Section 3.3 above.

3.6 Section 3.4 Wastewater Treatment Plant

No matters to raises in Sections 3.4.1-3.4.5.

Comments on Table 3.7:

- There is a stage missing between Stages 2 and 3 or in Column 4.
- The total number of lots at Stage 6 should be 2,578.
- We agree with the proposal to assume high N concentrations in the early stages of the development.
- Add units to all components of the first column in the table.
- Add notes below the table to explain the basis for the "*Likely Area Development Scenario*".
- This comment should be taken in the context of comments in Section 3.3 relating to average vs peak flows. The table is based on the averages flows of up to 2,005 m^3/day in Stage 6. With the suggested LTA areas this yields a consent N limit of 220 kg N/ha/year. However, when the peak flows are considered the 220 kg N/ha could be exceeded. For example;
    - If say Stage 5 had a flow of 3,000 m^3/year the N loading rate would be 288 kg N/ha.

- If at Stage 6 the full peak flow of 3,974 m^3/day was delivered this N loading would be 382 kg N/ha/year.

4 Section 4 – Discharge Environments

No specific comments for this section. Will be most relevant to consider as part of any future assessment of environmental effects which are excluded from the report scope.

5 Section 5 – Discharge System

5.1 Section 5.1 – Discharge within the LTA

Minor comments shown on the report using callout boxes.

Comments on Table 5.2:

- System Application Rate should be Average System Application Rate if this is based on the 2005 m^3/day and the 28.4 ha.
- The Average System Application Rate should be 2.94 m^3/day if based on the above or alternatively used a range e.g. 2.6-2.95 m^3/day.
- Duration of Operation also use a range as this may be up to 2.99 hrs if we assume 8 mm is to be applied at the estimated average application rate. Therefore, for the purposes of this report we suggest reporting these a range for the soil types.

Comments on Table 5.3:

- It is not clear what is meant by Number of Operations and how this has been estimated – is this the number runs (each with a cluster of zones) per day? If so, it's also not clear why the number is only 4 using the peak flows. It should be the same with the main difference being the number of operational hours per run and the depth of application.
- In the table below we have run parallel estimates for some of the parameters shown in Table 5.3.

Parameter	DWF	PWWF
Area (ha)	28.4	28.4
Target Discharge (m^3/day)	2,005	3,973
Average Application Rate (mm/day)	7.1	14.0
Dispersal Rate (mm/hr)	2.9	5.8
Estimated Discharge Required (m^3/hr)	83.5	165.6
Estimated Discharge Required (L/s)	23.2	46.0

- To work around some of the matters noted above for Tables 5.2 and 5.3 we suggest range of values be provided as the actual parameters will be defined at the detailed design stage.

5.2 Section 5.2 – Nutrient Loading Rates

No comments relating to Section 5.2.

5.3 Sections 5.3 and 5.4 – LTA N and P Loading Rates

The BoD states that "*Considering the information in the Table 5.4, it is assumed that the proposed average loading rate of 193 kg N/ha/yr is a sustainable loading rate in the aforementioned LTA's.* "

A point or two relating to the N and P loading rates when peak flows are considered would be good.

It would also be good to note that the 193 kg N/ha/yr is for the fully developed state. During the early stages this loading rate is up to 217 kg/ha/yr as shown in Table 3.7.

5.4 Section 5.5 - Current Land Use and Permitted Baseline Loss

The assumptions around N application are clear. These are also supported by the Overseer Modelling report. Please refer to Section 8 below on comment relating to the Overseer memo.

5.5 Section 5.6 – Overseer Outcomes

The 3rd paragraph states that "*In the proposed LTA system, OverseerFM modelling applied the wastewater as irrigation in the form of drip irrigation. The total application depth modelled varied evenly across the year from 2,064 mm to 3,060 mm. There is no seasonal variability in the modelled irrigation depth*".

The second table in Section 3.5 above provides the range of application depths across Areas 1-4.

This 3rd paragraph assumes no seasonal variation. We appreciate this provides a conservative outcome as regards flows and volumes. However, as discussed in Section 3.3 above we would expect a development in this area to have significant seasonal variations as many of the properties will function as holiday homes. Therefore, there is an opportunity to refine the flows when the developed stages start showing seasonal flow trends.

The paragraph above Table 5.5 states that "*The OverseerFM nutrient budget shows a total leaching value for the 4 different LTA areas to range from 68 to 86 kg N/ha/yr*". Please refer to Table 8 (Nitrogen Losses Per Block for the Baseline and RCL-LTA) in the Overseer Memo which shows that the range is 60-91.1 kg N/ha/year.

Regarding the areas in Tables 5.5, 5.6 etc please refer to the comment in Section 8 below were we comment on Tables 7 and 8 of the Overseer memo.

5.6 Section 5.7 – Simple Nitrogen Mass Balance

No nitrogen mass balance is presented. A mass balance could be developed along the lines shown in the snip below. However, we don't think there is much value is doing one for this site.

Date	Nitrogen Loading (kg N/ha)	Denitrification/volatilisation/soil storage- Kg N/ha)	Atmospheric/Fixation Inputs	Plant Removal/Rebates (kg N/ha)	Net Nitrates in the Soil (Kg N/ha)	Cummulative N in the Soil (kg N/ha)
1/01/2022	0.81	0.33	0.00	0.00	0.49	0.49
2/01/2022	0.81	0.33	0.00	0.00	0.49	0.98
3/01/2022	0.81	0.33	0.00	0.00	0.49	1.47
4/01/2022	0.81	0.33	0.00	0.00	0.49	1.95

An appropriate title for this section could be "*Comparison of Modelled Nitrogen Losses Against Reported Literature*".

5.7 Section 5.8 – Phosphorus

We have no specific comments regarding Section 5.8.

5.8 Section 5.9 – Service Structure

We have no specific comments regarding Section 5.9.

6 Section 6 – Operation Regime

6.1 Section 6.1 – Daily Operation

Section 6.1 states that "*The maximum daily discharge at the site will be the wet weather flow volume, as discussed in Section. Error! Reference source not found*".

The design appears to be based primarily on dry weather flows and not wet weather flows as discussed in the preceding sections. Thus, in assuming that up to the peak flows will be accommodated it is important to check the loading rates (nutrient and hydraulic rates) to confirm that the 220 kg N/ha/year limit will be achieved, the leaching rates in Overseer etc.

Please also check the report as the 2,005 m^3/day is referred to both average dry weather flows and peak dry weather flows.

7 Appendix A – Field Investigation Soil Profile Descriptions

We have no specific comments regarding Appendix A.

8 Appendix B - OVERSEER Nutrient Modelling for Homestead Bay

The Overseer input data in Tables 1-4 has been reviewed and noted. There are no comments.

Comments on Table 5:

- Comments in previous sections regarding the use of the average dry weather flow apply.

Comments on Table 6:

- We have checked these and we have no specific comments.
- The assumptions regarding Area 1 being gazed to mimic the use of native vegetation is noted.

Comments on Table 7 and 8:

- The RCL-LTA and RCL-Baseline areas are slightly different i.e. 201.5 ha vs 200.1 ha. It's a marginal difference and will have inconsequential effects on the outcomes.

Conclusions on Page 7 of 10:

- We have reviewed the conclusions on Page 7 of 10 of the Overseer memo and we agree with the assumptions and conclusions.

9 Appendix C – Geosolve Logs

We have no specific comments regarding Appendix C.

ATTACHMENT 1 – VICTOR MTHAMO'S QUALIFICATION AND EXPERIENCE

Victor report holds:

- A Bachelor of Agricultural Engineering (Honours) with a major in Soil Science and Water Resources (University of Zimbabwe).
- Master of Engineering Science in Water Resources (University of Melbourne in Victoria, Australia).
- Master of Business Administration (University of Zimbabwe).
- An Advanced Certificate in Overseer Nutrient Management modelling qualification.

I am a member of Engineering New Zealand (MEngNZ) and am a Chartered Professional Engineer (CPEng) and an International Professional Engineer (IntPE). I am a past National Technical Committee Member of (i) Water New Zealand and (ii) New Zealand Land Treatment Collective (NZLTC).

Below is a sample of Victor Mthamo's past projects:

Turley Farms Limited – Consenting Expert – (2024)
Prepared and lodge resource consent for wastewater discharges to land for a 21-person accommodation facility in Temuka, Canterbury. The consent addressed many complex site-specific issues that included – high groundwater, high nutrient area, proximity to waterways.

Southern Parallel Campus (SPEC) – Engineer and Consenting Expert – (2023-2024)
I was engaged by SPEC to carry out assessment of the various infrastructure required to enable the development to be progressed. This included (i) water supply requirements and options assessment (ii) wastewater investigations and assessments (iii) assessment of the soils and (iv) various other activities that required to enable the development to be progressed against the various statutory instruments e.g. Canterbury Land and Water Regional Plan (CLWRP), the National Environmental Standards for Freshwater, the Canterbury Regional Policy Statement etc. From this assessment I concluded that there were a number of Environment Canterbury consents that were required before the works could be started on site. On behalf of SPEC I applied for the following resource consents (i) to discharge contaminants to land from an onsite wastewater system, (ii) to install a culvert and construct bridges across Lagmhor Creek (iv) to take and use groundwater for dewatering purposes, (v) to discharge dewatering water and (vi) to use land for earthworks. All consents were granted within 3 months of lodgement.

Gibbston Valley Wastewater Irrigation - Lowe Environmental Impact (2022)
Engaged by LEI to design the micro and sprinkler irrigation systems for the wastewater discharges in compliance with the regional council consent and site-specific constraints and requirements. Prepare a schedule and specification for the design.

Karaka North Wastewater Discharge Consent – Apex Environmental – (2021)
Prepare the Assessment of Environmental Effects and Application for the proposed 1,250 lot Karaka North Subdivision Community Wastewater discharge to land and water. Consents applied for included a discharge permit to discharge domestic sewage effluent and wastewater contaminants to land and to water, a discharge permit to discharge odour and contaminants to air, a discharge permit to discharge sediment (contaminants) to water during the construction phase, a discharge permit to dewater for construction works, a land use consent to undertake works in, on or under the beds and/or margins of waterways, including disturbance.

Wainui Community Wastewater Discharge Consent (2021)
Prepared and lodged the Wainui Community wastewater discharge consent. The treated wastewater from the community scheme was to be discharge to land. The assessment of effects included modelling the soil hydraulic and nutrient loadings to determine the best application rates to ensure compliance with load limits. Carried out the irrigation design using IrriCAD. The preliminary works included Overseer modelling of the nutrient discharges and to use this as a basis for the design.

Foxton Wastewater Irrigation Design – Peer Review – Lowe Environmental Impact (2020)
Provided a peer review of the design of the Foxton Wastewater treated wastewater irrigation system. The design had been done by Irrigation Services and needed to be peer reviewed prior to construction. A detailed peer review was carried out with recommendations made to the pump size, pipe sizes, filtration system and operation and management of the system. The review also included running Overseer modelling scenarios to confirm the basis of the proposed irrigation rates to ensure that the discharges was matched to the soils and potential leaching limits on the consent.

Waitarere Beach WW Irrigation Design – Peer Review – Lowe Environmental Impact (2019)
Provided a peer review of the design of the treated wastewater irrigation system. The design had been done by Irrigation Services and needed to be peer reviewed prior to construction. A detailed peer review was carried out with recommendations made to the pump size, pipe sizes, filtration system and operation and management of the system.

The Pot Wastewater Irrigation System, Horowhenua District Council, Levin – (2017 - 2020)
Subcontracted by Lowe Environmental Impact to do the detailed design, specification and tender documents for the proposed upgrade to the Pot wastewater discharge system. Carried out the irrigation design using IrriCAD. The preliminary works included Overseer modelling of the nutrient discharges and to use this as a basis for the design.

Leeston Wastewater Treatment Plant Compliance Report – Selwyn District Council (2016-2023)
Prepared the Annual Compliance Monitoring report for the Leeston Wastewater Treatment Plant in Leeston. This is included a detailed analysis of the consent conditions including calculating the hydraulic and nitrogen loading rates, irrigation rates and discharge rates to ascertain the degree of compliance with the consent conditions. Proposed mitigation measures for the Council to deal with area of non-compliance observed.

Winery Wastewater Discharge Consenting – Hillersden Winery Limited, Marlborough (2018)
Prepared and submitted a resource consent application for wastewater discharges from winery processing. The consent was processed by MDC and granted. The application included charactering the discharges an assessment of the effects arising from the winery wastewater to ground.

Winery Wastewater Discharge Consenting – Te Awa Winery c/o Villa Maria Estates (2017)
Engaged to prepare and lodge a winery wastewater resource consent for Villa Maria's Te Awa Winery. A new wastewater treatment system using a Membrane Bioreactor was developed at Te Awa Winery. The proposal was for the treatment and discharge of the wastewater to land over the sensitive Heretaunga Aquifer system. Reeftide was engaged to assess, review and use the available groundwater, soil and effluent data to determine the best wastewater application method and rates. A resource consent complete with an assessment of environmental effects was prepared and lodged with the Hawkes Bay Regional Council.

Effluent Discharge Consenting – NNNZ Casings (2016)
Subcontracted by Apex Environmental Limited to prepare and lodged a resource consent to discharge 50-100 m^3/day of wastewater from the production of casings. The wastewater is treated via a Membrane Bio Reactor and pumped to a private farm where it is discharge to a pond. The wastewater is mixed with dairyshed and yard effluent, race effluent, silage leachate, dairyshed and yard washdown water, effluent and feed solids, stone trap sludge, vat wash and contaminated stormwater, from a milking herd of up to 700 cows. A full assessment of environmental effects was carried out taking into account the soils, the effluent quality and determining the discharge rates and the management of the irrigation system. The consent was prepared complete with the environmental effects and lodged with Horizons Regional Council.

Wastewater Discharge Consenting – Darfield High School (2016)
Darfield High School commissioned Reeftide to provide an assessment of environmental effects and prepare the necessary resource consent application for the discharge of wastewater to land. Estimated the capacity of the system. Carried out the site soil assessments and characterised the soils to determine the soil categories, application rates for the 4.5 m^3/day system, reviewed the various treatment systems on the market and made recommendations to the school as to the best option for them given the variable loads. Prepare and lodged a resource consent to discharge wastewater to ground with Environmental Canterbury.

Landuse Consent and Effluent Discharge Consent – Temuka Co-Operative Saleyards Company Limited (TESSCO) (2016)
Subcontracted by Apex Environmental Limited to prepare several resource consents. Prepared the applications and accompanying assessment of environmental effects for the landuse consent for a 3,000 m^3 wastewater storage pond and the air discharge consent from the pond into air to the regional council (Ecan) and a landuse consent to the district council.

Overseer Nitrogen Baseline Establishment, Central Plains Water Irrigation Scheme (2014)
Was engaged by The Agribusiness Group as a subcontractor to carry out 16 farm visits to collect data for Overseer Modelling. Farming systems ranged from cropping, dairy and sheep and beef. Carried out modelling for the 16 farms to establish the nutrient baseline.

Porter Heights Ski field, Infrastructure Consenting, Environmental Engineer (2009 – 2010):
Project engineer responsible for the design of the water supply component which included assessing the water demand and firefighting requirements, storage and conceptual design layout of the water supply network, on-site wastewater assessments, conceptual design, and assessment of environmental effects and consenting.

Buxton Gore Bay Subdivision, Infrastructure Consenting, Project Manager, Environmental Engineer (2009 – 2010):
Environmental Engineer on the proposed 83 lot subdivision that is proposed on 143 ha of pristine rural coastal land in Gore Bay near Cheviot. Conceptual design of stormwater, water supply and wastewater infrastructure. The water supply component involved assessing the water demand and firefighting requirements, storage and conceptual design layout of the water supply network. The wastewater component involved assessing wastewater generation, routing the conveyance network, comparison of pressure sewer versus STEP/STEG systems and costing the various options and finally recommending appropriate systems.

Queenstown Lakes District Council (2008-2009):
Environmental engineer for the Water, Stormwater and Wastewater Assessment studies for the town of Glenorchy. The studies' terms of reference were to assess the existing water, stormwater and wastewater capacities and make recommendation on the best options to meet the town's growing infrastructural requirements up to 2026.

Queenstown Lakes District Council: Glendhu Bay Wastewater Discharge (2010):
Options assessment, assessment of effects and consenting of decentralised sewage treatment and land treatment for the Glendhu Bay Camping Grounds.

APPENDIX B

Summary Table of Peer Review Items and Actions

Homestead Bay Consent Level Design Wastewater Land Application – Peer Review Table 10 March 2025

(Review by Victor Mthamo reeftide@gmail.com)

Comments Provided in Memo: Homestead Bay Wastewater Consent Application – Peer Review

Section	Comment	LEI Response 10 March 2025	VM Comments – 12/3/2025	Status
3.1 Purpose	We agree with the assumed flow rates. However, we recommend that rather than reference NZS4404:2010 the report should reference the more relevant *Queenstown Lakes District Council Land Development and Subdivision Code of Practice (2020).* The code of practice recommends the same flow rates in its Table 5.1 (Commercial and industrial flows) in Section 5.3.5.1. We appreciate that the code of practice is also partly based on NZS4404:2010.	Reference added	Issue addressed – Can be closed out.	**Closed**
3.2.1 & 3.2.2 Waste-water Quality	Provide references for the wastewater influent and effluent quality. The N and P effluent concentrations provided are very low which makes it important to provide the basis for these values as they determine every aspect of the this BoD.	Influent reference to be added and range removed – Metcalf and Eddy Effluent strength has been agreed upon in consultation with Apex Water and Stantec. We note that the nitrogen standards are similar to the Pines. Reference designer discussions that these numbers can be met. Consent on the basis of nitrogen loading kg N/ha/yr will allow for variable discharge quality at times. The average concentration will be low to meet the loading rates proposed.	Our understanding is that Apex and Stantec are confident that the treatment system will be able to achieve these target concentrations. More importantly the suggested approach to base consent compliance requirements on average or median loading rates will mitigate the diurnal or short-term fluctuations. Therefore, the item has been addressed and can be closed out. Therefore, our concerns have been addressed.	**Closed**
3.2.3 Waste-water Flows	Please refer to the earlier comment (Section 3.1) regarding the source reference. Amend the first paragraph below Table 5.1 for readability. It states that "The design flow rates have been modified and calculated using standards relevant to domestic wastewater management using NZS 4404:2010 Land Development and Subdivision Infrastructure for communal systems and NZS 1547:2012". We commend the use of Method 1 in the flow estimates to start with. This is because to adopt Method 2 would the typology and use (e.g. holiday homes vs permanent homes) of the dwellings at the proposed Homestead development to be the same as those at Hanley's Farm and/or Shotover Country. For example, if a development has a higher weighted average of apartments and terraced houses the wastewater generation would be considerably less than where the proportion of standalone dwellings is higher. The proposal to adjust the design flows as the staging progresses enables a better understanding of the development's wastewater generation profile and to tailor the design accordingly. The allowance per student and staff at the school used in Table 3.2 is 53 L/p/day. A reference for this rate is recommended. This is also highly conservative. An acceptable alternative would be 30 L/p/day suggested in NZS1457:2012. This will yield a Design Average Flow Rate of 19.8 m3 /day. Normally we would expect the population estimates in the area to have seasonal variations. If historical data of the variations is/was available this could be used to estimate the monthly or seasonal flows. This approach is likely to give lower and more realistic volumes. However, we acknowledge that in the absence of such data the approach taken is conservative. Table 3.3 – for the school ROW amend Column 4 (Peak Population). The 53 is, we assume, the same flow rate in Table 3.2. Furthermore, Table 3.3 is based on NZS4404:2010 and thus 30 L/p/day could be used for the school flow estimates. The report states (above Table 3.2) that "While also having the capacity to receive intermittently higher flows up to the Peak Wet Weather Flow (PWWF), which can occur during times of wet weather. It should be noted that the flow associated with diurnal variations will be stored and balanced as part of the WWTP". This is a significant assumption. We recommend strong justification for it be provided as this impacts the size of the LTA, nutrient and hydraulic loading rates etc. This also impacts the storage volume and without a detailed analysis (e.g. water balance) or justification it could be impossible to nominate a storage volume. While we appreciate the recommendation in the report that	Full design is based on Method 1. Amended to reference COP Method 2 presented to support that these flows are conservative Agree – consent on the basis of flow and nutrient load not dwellings Stantec MOE reference to be added (Stantec). Noted this is conservative and managed with the flow and load. Overall commercial and school will be a small % of the total flow and load Ensure consistency on numbers and reference added. Stantec have looked at the 2 x daily volume and 2.5 x flow rates. We see this as a design issue.	Amendments to the report noted. We also under from our discussion on 11/3/2025 that: - The allowance made for some activities e.g. the school are based on verifiable sources e.g. the study by Stantec. - The school may not be part of the proposal. However, even this changes there is more than ample allowance in the estimated daily volumes. - While a discussion on storage is outside the scope of this BoD consideration has been given to it by Apex and Stantec. The various response and based on our discussion we can confirm that this issue has been addressed satisfactorily and can be closed out.	**Closed**

<table>
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<tr><td></td><td>flows with be refined as development progresses and flows from the early stages are understood, for the purposes of this BoD we would recommend that the peak flows be used for:
Sizing the LTA and for consenting purposes.
The areas, the nutrient and hydraulic loading rates.
Alternatively, the dry weather flows could still be adopted but this should be supported by a more detailed discussion on the likely or anticipated storage volumes.</td><td>The LTA is designed for normal operation of[10]hr with the operation duration increasing to accommodate peak wet weather flows.

The LTA can receive and treat 2 x Daily flow to help management peak storage.

Stantec will address in their report. But for clarification we are not storing the wet weather flows but discharging at higher rate</td><td></td><td></td></tr>
<tr><td>3.3.1 Land Treatment Area</td><td>Minor correction – Blocks H, I, J, K, L add up to 7.4 ha based on the areas in Table 5.1. Will make minimal difference as the flow rates assumed in previous sections are conservative.

Delete the 7.1 mm/day in the last ROWs of Tables 3.4, 3.5 and 5.1.

Below is an alternative to Table 3.4 generated using the areas and the DIRs in Table 3.4. Minor differences and could be due to rounding differences.
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<tr><td>Area 4</td><td>2,920</td><td>5.20</td><td>151,840</td><td>416</td></tr>
<tr><td>Total</td><td>10,075</td><td>28.50</td><td>727,831</td><td>1,994</td></tr>
</table>
The areas and DIRs and flows in Table 3.4 are based on the average flow of 2,005 m3 /day. Please note or refer to our comments on the use of PWWF in Section 3.3 above.</td><td>Area H to be corrected to 1.4. Total area is 28.5
The total was missing 0.27 ha associated with area C03

Deleted in 3.4 but retained in 3.5, actual figure is based on daily volume and area.

Differences are rounding.</td><td>The changes made are noted and accepted. This item can be closed out.

Regarding the calculation shown in what we call the Alternative Table 3.4 we understand from our discussion that the available land has been set.
Any other differences between the tables are due to the rounding as you note.

As noted above this item can be closed out.</td><td>Closed</td></tr>
<tr><td>3.4 Waste-Water Treatment Plant</td><td>Comments on Table 3.7:
There is a stage missing between Stages 2 and 3 or in Column 4.
The total number of lots at Stage 6 should be 2,578.
We agree with the proposal to assume high N concentrations in the early stages of the development.
Add units to all components of the first column in the table.
Add notes below the table to explain the basis for the “Likely Area Development Scenario”.
This comment should be taken in the context of comments in Section 3.3 relating to average vs peak flows. The table is based on the averages flows of up to 2,005 m3 /day in Stage 6. With the suggested LTA areas this yields a consent N limit of 220 kg N/ha/year. However, when the peak flows are considered the 220 kg N/ha could be exceeded. For example;
If say Stage 5 had a flow of 3,000 m3 /year the N loading rate would be 288 kg N/ha.</td><td>Table 3.7 has been updated to incorporate feedback

Agree

Added

Added area’s but we are seeking flexibility and this table is only an example of the development. The actual investment sequence will be informed by a number of factors.

Peak flows are wet weather only; proposed consent conditions will require that the average on a 30-day period does not exceed 2,005 m3/day. 3,000 m3/day is not a design flow that can be sustained.</td><td>The changes made for bullet points 1-5 noted and accepted.

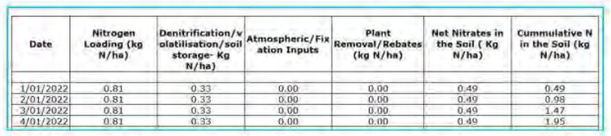
Regarding our assumed Stage 5 flow of 3,000 m³/year. This was an error on our part and can be ignored. The 2,005 m³/day will be the maximum possible for the development. We also agree with your suggested approach to seek 7-day average or monthly daily average flow.

Therefore, this Item has been discussed ad consensus reached. The item can be closed out.</td><td>Closed</td></tr>
<tr><td>4 Discharge Environments</td><td>No specific comments for this section. Will be most relevant to consider as part of any future assessment of environmental effects which are excluded from the report scope.</td><td>Do you have any comment on the methodology of deriving the DIR</td><td>Our no comment comment was because we agreed with the approach. We formally confirm that methodologies, analysis, inferences and conclusions made in the soils report are sound and based on best practices.

We further confirm that the DIR estimates are conservative and also what we would expect.</td><td>Closed</td></tr>
</table>

Section	Comment	LEI Response 10 March 2025	VM Comments – 12/3/2025	Status
5.1 Discharge with the LTA	Minor comments shown on the report using callout boxes. Comments on Table 5.2: • System Application Rate should be Average System Application Rate if this is based on the 2005 m3 /day and the 28.4 ha. • The Average System Application Rate should be 2.94 m3 /day if based on the above or alternatively used a range e.g. 2.6-2.95 m3 /day. • Duration of Operation also use a range as this may be up to 2.99 hrs if we assume 8 mm is to be applied at the estimated average application rate. Therefore, for the purposes of this report we suggest reporting these a range for the soil types. Comments on Table 5.3: • It is not clear what is meant by Number of Operations and how this has been estimated – is this the number runs (each with a cluster of zones) per day? If so, it's also not clear why the number is only 4 using the peak flows. It should be the same with the main difference being the number of operational hours per run and the depth of application. • In the table below we have run parallel estimates for some of the parameters shown in Table 5.3. • To work around some of the matters noted above for Tables 5.2 and 5.3 we suggest range of values be provided as the actual parameters will be defined at the detailed design stage.	Deleted Zone volume Added operation daily duration range The operation is the combinations of zones needed to irrigate the full daily volume. It is 21.05 hr / 2.63 hr per operation. Number of operations row is deleted Similar table no changes required Range of values added	We agree with the changes made. This item can be closed out.	**Closed**
5.3 & 5.4 LTA N and P Loading Rates	The BoD states that "Considering the information in the Table 5.4, it is assumed that the proposed average loading rate of 193 kg N/ha/yr is a sustainable loading rate in the aforementioned LTA's. " A point or two relating to the N and P loading rates when peak flows are considered would be good. It would also be good to note that the 193 kg N/ha/yr is for the fully developed state. During the early stages this loading rate is up to 217 kg/ha/yr as shown in Table 3.7.	The N and P mass at peak flow does not increase the mass of nitrogen generated in the catchment that we have based the design. We are comfortable with the annual average load. During the early stages of the development, it is expected the property will have a reduced stocking rate, effectively reducing the overall contribution of nutrients that the property will be making to the lake so that a higher intermediate load is for only a portion of the LTA area. We note the table is only referencing the LTA loading rates.	The additions made to Section 5.3 noted. The request to comment on the N and P loading was addressed during our discussion. We also note that the original draft of the report already addressed these issues. Fron the foregoing this item can be closed off.	**Closed**
5.5 Current Land Use and Permitted Baseline Loss	The assumptions around N application are clear. These are also supported by the Overseer Modelling report. Please refer to Section 8 below on comment relating to the Overseer memo.	Agree	Here we were commending you on your approach.	**Closed**
5.6 Overseer Outcomes	The 3rd paragraph states that *"In the proposed LTA system, OverseerFM modelling applied the wastewater as irrigation in the form of drip irrigation. The total application depth modelled varied evenly across the year from 2,064 mm to 3,060 mm. There is no seasonal variability in the modelled irrigation depth".* The second table in Section 3.5 above provides the range of application depths across Areas 1-4. This 3rd paragraph assumes no seasonal variation. We appreciate this provides a conservative outcome as regards flows and volumes. However, as discussed in Section 3.3 above we would expect a development in this area to have significant seasonal variations as many of the properties will function as holiday homes. Therefore, there is an opportunity to refine the flows when the developed stages start showing seasonal flow trends.	For the consent and LTA area sizing we have average daily dry weather flow based on the QLDC COP. This sets the LTA area when also considering nitrogen loading and landuse. If actual average dry weather flows are lower, the staged implementation of the LTA and WWTP can be altered to reflect the actual system. The proposed consent conditions seek to enable this staged implementation of capacity with maximum annual nutrient loading rates. The season occupation will further contribute to the staging. We do not consider that the design needs to be changed as the COP does not allow for seasonal variations.	We can put the differences between what we have estimated in Section 3.5 of our report and what's presented in BoD to rounding. The differences are inconsequential. The comments in response to the RFI are also noted. The conservative approach is noted and so is the need to adhere to the CoP. We suggest if any opportunities to refine the wastewater generation assumptions through gathering site specific flow data as the various stages of the development comes online this should be used to improve the flow design assumptions. This will offer an opportunity to deviate from the CoP as supported by Section 1.8.3.2 (Alternative Designs) of the CoP.	**Closed** **Closed**

Parameter	DWF	PWWF
Area (ha)	28.4	28.4
Target Discharge (m^3/day)	2,005	3,973
Average Application Rate (mm/day)	7.1	14.0
Dispersal Rate (mm/hr)	2.9	5.8
Estimated Discharge Required (m^3/hr)	83.5	165.6
Estimated Discharge Required (L/s)	23.2	46.0

Section	Comment	LEI Response 10 March 2025	VM Comments – 12/3/2025	Status
5.6 Overseer Outcomes	The paragraph above Table 5.5 states that "The OverseerFM nutrient budget shows a total leaching value for the 4 different LTA areas to range from 68 to 86 kg N/ha/yr". Please refer to Table 8 (Nitrogen Losses Per Block for the Baseline and RCL-LTA) in the Overseer Memo which shows that the range is 60-91.1 kg N/ha/year. Regarding the areas in Tables 5.5, 5.6 etc please refer to the comment in Section 8 below were we comment on Tables 7 and 8 of the Overseer memo.	The report has been updated	The update to the report is noted. From the foregoing this item can e closed out.	
5.7 Simple Nitrogen Mass Balance	No nitrogen mass balance is presented. A mass balance could be developed along the lines shown in the snip below. However, we don't think there is much value is doing one for this site.  An appropriate title for this section could be "Comparison of Modelled Nitrogen Losses Against Reported Literature".	We agree a daily water and nutrient balance could be prepared. Agree that the alternative assessment is not a mass balance but a literature method. Reference to literature assessment added	Changes noted. The item can be closed out.	**Closed**
6.1 Daily Operation	Section 6.1 states that *"The maximum daily discharge at the site will be the wet weather flow volume, as discussed in Section. Error! Reference source not found".* The design appears to be based primarily on dry weather flows and not wet weather flows as discussed in the preceding sections. Thus, in assuming that up to the peak flows will be accommodated it is important to check the loading rates (nutrient and hydraulic rates) to confirm that the 220 kg N/ha/year limit will be achieved, the leaching rates in Overseer etc. Please also check the report as the 2,005 m3 /day is referred to both average dry weather flows and peak dry weather flows.	Reference updated The system we considered is conservatively designed to receive average dry weather flows for 365 days per year. There will be times of lower flow when nutrient loading is less and days during higher flows when the load will be higher. By having a peak loading rate in kg N/ha/yr, the impact of wet weather is accounted for. The loading rate will be calculated based on the sum of daily flow x concentration (monthly) / LTA area.	The changes noted. Thank you for this clarification. Item can be closed out.	**Closed**
Appendix B OVERSEER Nutrient Modelling for Homestead Bay	Comments on Table 5: • Comments in previous sections regarding the use of the average dry weather flow apply. Comments on Table 6: • We have checked these and we have no specific comments. • The assumptions regarding Area 1 being gazed to mimic the use of native vegetation is noted. Comments on Table 7 and 8: • The RCL-LTA and RCL-Baseline areas are slightly different i.e. 201.5 ha vs 200.1 ha. It's a marginal difference and will have inconsequential effects on the outcomes. Conclusions on Page 7 of 10: • We have reviewed the conclusions on Page 7 of 10 of the Overseer memo and we agree with the assumptions and conclusions.	Agree it average daily flow To be corrected	The changes noted. Item can be closed out.	**Closed**

Date	Nitrogen Loading (kg N/ha)	Denitrification/volatilisation/soil storage- Kg N/ha)	Atmospheric/Fixation Inputs	Plant Removal/Rebates (kg N/ha)	Net Nitrates in the Soil (Kg N/ha)	Cummulative N in the Soil (kg N/ha)
1/01/2022	0.81	0.33	0.00	0.00	0.49	0.49
2/01/2022	0.81	0.33	0.00	0.00	0.49	0.98
3/01/2022	0.81	0.33	0.00	0.00	0.49	1.47
4/01/2022	0.81	0.33	0.00	0.00	0.49	1.95

Comments on Report

Page	Comment	LEI Response	Comments from VM – 12/3/2025	Status
2	Incorrect date (2024, should be 2025)	Updated	Change noted.	Closed
5	Grammar fix (change ids to is, delete full stop)	Noted	Change noted.	Closed
8	Grammar fix (add full stop)	Noted	Change noted.	Closed
9	Table 3.4 change – delete 7.1 as the total number of average discharge application	agreed	Change noted.	Closed
11	Table 3.5 – for average loading rate, can use a weighted average otherwise 7.1 should be deleted	Retained	Retention noted and accepted.	Closed
26	"submains from the treated water mainline" should be "submains from the treated wastewater mainline"	updated	Retention noted and accepted.	Closed
26	Table 5.1 – Total modelled DIR of 7 can be deleted from table	Deleted	Change noted.	Closed
26	Grammar error, delete second "will" from "will be grouped to will allow"	updated	Change noted.	Closed
27	Change "addition zones" to "additional zones"	updated	Change noted.	Closed
31	Change "different LTA areas to range from 68 to 86 kg" to "different LTA areas to range from 60 to 91.1 kg N/ha/yr"	Updated to align to overseer modelling	Change noted.	Closed
31	Table 5.5 – change total land area summary to 201.5ha	updated	Change noted.	Closed
34	Table 5.8 – missing footnote or comment from table (after Bulk Density)	Deleted not needed	Change noted.	Closed
Appendix B page 3	Fix: "with the grass will be collected" to "with the grass collected"	Updated	Change noted.	Closed
Appendix B page 4	Table 6 title crossed out (title might be incorrect?)	No change needed	This was our error. It should not have been crossed out.	Closed

From: Victor Mthamo <reeftide@gmail.com>
Sent: Thursday, 13 March 2025 06:09
To: 'Brian Ellwood'
Cc: Dan Wells
Subject: RE: peer review meeting
Attachments: 10934-Peer_Review_of_AEE_Status_Table- Updated with VM's Comments - 13 March 2025.docx

Hiu Brian,

Thanks again for sending the table through.

I have converted it to A3 and added a column (in blue) wherein I have put my response comments.

Essentially, we are in agreement. The matters previously raised in the peer review have been resolved.

Kind Regards,
Victor

From: Brian Ellwood <brian@lei.co.nz>
Sent: Tuesday, 11 March 2025 6:16 pm
To: Victor Mthamo <reeftide@gmail.com>
Cc: 'Dan Wells' <dan.wells@rclgroup.com.au>
Subject: RE: peer review meeting

Hi Victor,

Thank you for your time today to discuss the peer review and associated changes to the report.

I have attached the table with the peer review comments for you to confirm our discussion. I have also attached the main report with track changes showing the amendments. Once you have confirmed the changes are acceptable. I will accept the changes, forming the Basis of Design for inclusion as an appendix to the consent application.

If you have any questions, please let me know.

Kind regards

Brian

Brian Ellwood
Lowe Environmental Impact

| T | [+64] 3 359 3059**| M |** [+64] 21 676 052 **| E |** brian@lei.co.nz **| W |** www.lei.co.nz

---

From: Victor Mthamo <reeftide@gmail.com>
Sent: Monday, 10 March 2025 1:18 pm
To: Brian Ellwood <brian@lei.co.nz>
Cc: 'Dan Wells' <dan.wells@rclgroup.com.au>
Subject: RE: peer review meeting

Hi Brian,

Email received and invite accepted. Thanks.

I will read through the response comments in prep for tomorrow. I will try and get this done by mid morning so that I can advise on the items which can be closed out. That way we can just focus on any remaining ones.

Kind Regards,
Victor

From: Brian Ellwood <brian@lei.co.nz>
Sent: Monday, 10 March 2025 12:22 pm
To: Victor Mthamo <reeftide@gmail.com>
Cc: Dan Wells <dan.wells@rclgroup.com.au>
Subject: RE: peer review meeting

Hi Victor,

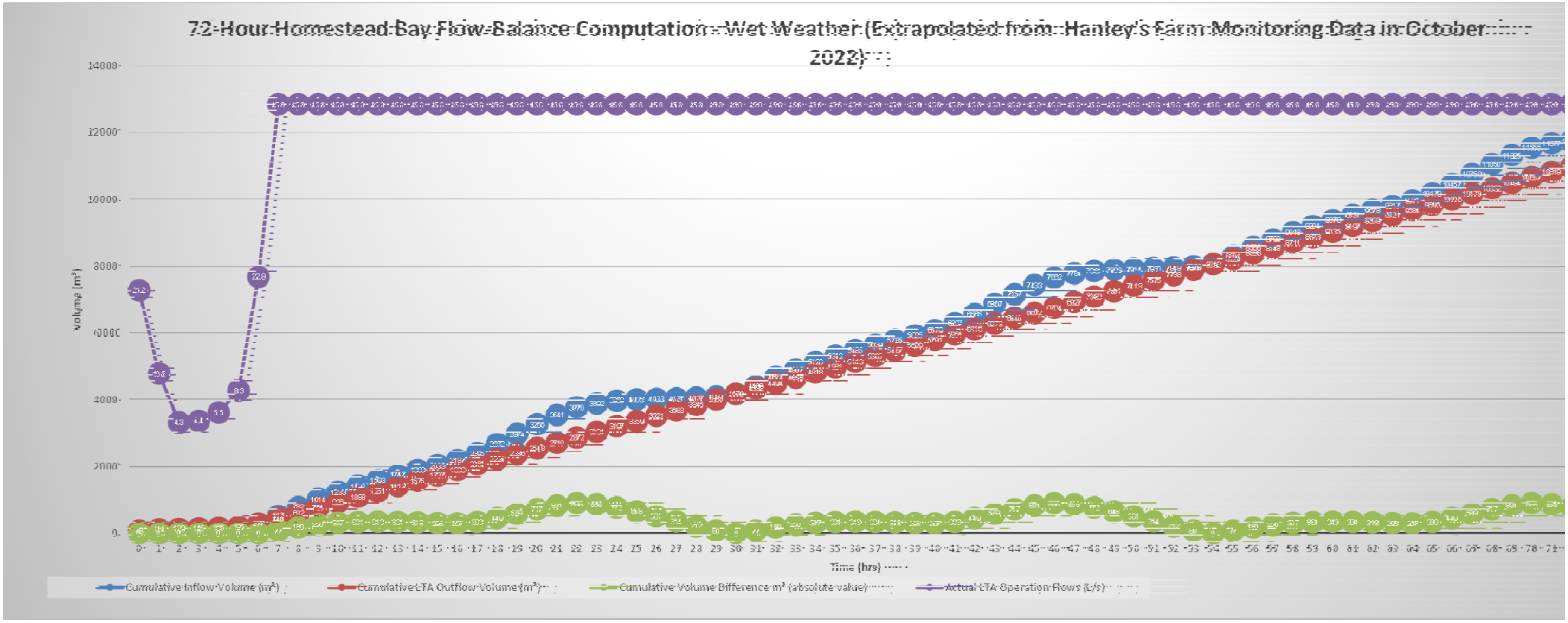
Please see the attached:

- Peer review comments table with my comments that we can discuss tomorrow at 2:30.
- Updated report in track changes - no appendices

Below is feedback from Stantec on the storage volumes:

With respect to the peer review comment 3.3 which relates to the storing and balancing of flows associated with diurnal variations, we comment as follows:

To optimize the WWTP size, a balance tank has been included to attenuate all wastewater flows above ADWF (22.7 L/s) during dry weather conditions and AWWF (45 L/s) during wet weather conditions. A spreadsheet model was built to demonstrate that a 1,000m3 balance tank provides sufficient storage to buffer the design peak diurnal and peak wet weather flows. The output of the wet weather flow modelling (worst case) is included below.



I look forward to discussing further.

Best regards

Brian

Brian Ellwood
Lowe Environmental Impact

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From: Victor Mthamo <reeftide@gmail.com>
Sent: Friday, 7 March 2025 3:55 am
To: Brian Ellwood <brian@lei.co.nz>
Subject: RE: peer review meeting

Hi Brian,

Monday or Tuesday would be ideal for me. I have a couple of commitments today.

Kind Regards,
Victor

From: Brian Ellwood <brian@lei.co.nz>
Sent: Thursday, 6 March 2025 1:17 pm
To: Victor Mthamo <reeftide@gmail.com>
Subject: peer review meeting

Hi Victor,

Would you have time tomorrow morning or around 2 to discuss your peer review?

I will send you my comments later today.

Thanks
Brian

Brian Ellwood

L W E Environmental Impact

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| E | brian@lei.co.nz **| W |** www.lei.co.nz

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Appendix E Geosolve Limited (GeoSolve) Natural Hazards Assessment of Homestead Bay

GEOSOLVE

GEOTECHNICAL

WATER RESOURCES

PAVEMENTS

Natural Hazard Assessment

Homestead Bay, Queenstown

Report prepared for:

RCL Limited

Report prepared by:

GeoSolve Limited

Distribution:

RCL Limited

GeoSolve Limited (File)

March 2025

GeoSolve Ref: 220556.02

Revision	Issue Date	Purpose	Author	Reviewed
0	17/1/2025	Draft for project team comment & peer review	HDW/JMJ	HS/PF
1	24/2/2025	Final draft following peer review comments	HDW/JMJ	NW
2	19/3/2025	Client Issue	HDW/JMJ	NW

GEOTECHNICAL WATER RESOURCES PAVEMENTS

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1 Executive Summary

This report describes the findings of a natural hazard assessment conducted by GeoSolve Ltd to support a resource consent application for a mixed-use subdivision at Homestead Bay, Queenstown. The natural hazards evaluated in this report include flooding, debris flow, lake seiche, rockfall, and cliff collapse. Additional hazards such as active faulting, slope stability, and liquefaction within the site are addressed in GeoSolve's separate geotechnical report[1].

A qualitative risk analysis was performed for each hazard following the framework provided in Appendix 6 (APP6) of the proposed 2021 Otago Regional Council (ORC) Regional Policy Statement. The risk analysis is also considered to satisfy the objectives of the operative QLDC district plan.

The risk of flooding was assessed as Acceptable, on the basis of standard proposed mitigation measures being put in place. These measures include the construction of diversion channels to redirect floodwaters around the proposed development areas. The diversion channels are considered to have negligible impact on downstream stormwater and floodwater discharges at the site boundary. Additionally, they are not anticipated to increase flooding risk for adjacent roads or neighbouring properties.

The risk from debris flow was found to be Acceptable without the need for mitigation measures. Analysis indicates the maximum credible event from the Northern alpine catchment lacks the run-out distance necessary to reach the site by a significant margin. The maximum credible event from the Middle and Southern alpine catchments were calculated to run-out to the site boundary only when very conservative flow mobility parameters are used in modelling, and in these conservative modelling results the flow depth and velocity that reaches the site would result in Insignificant consequence. Site observations do not indicate that a debris flow event of this magnitude has ever occurred in the geological history of the site. If such an event were to reach the site in the future, then the flood hazard mitigation measures proposed are considered to provide sufficient protection. It is noted that if transported debris were to reach the site, it is considered that it would be in transition from debris flow to debris flood, such as hyper-concentrated (muddy) flow.

The risk from rockfall and rock avalanche was assessed to be Acceptable without the need for any mitigation measures. Empirical assessments methods and 3D rockfall modelling both show that any debris originating from rockfall and rock avalanche events do not reach the site.

The risk from lake seiche was assessed as Acceptable due to the site's significant elevation above Lake Wakatipu and inferred high return period for such an event.

The assessment concludes that the risks posed by natural hazards to the proposed mixed-use development are Acceptable as per APP6 of the ORC Regional Policy Statement, provided that the proposed flooding mitigation measures and recommendations in this report are implemented. GeoSolve understands that these measures are being designed

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and constructed by others and are to be coordinated with the internal drainage of the proposed subdivision.

2 Introduction

2.1 General

This report presents the results of a natural hazards assessment undertaken by GeoSolve Limited (GeoSolve) in order to assess the risk posed to the proposed development site from flooding, debris flow, lake seiche, rock fall and rock avalanche. This reporting provides adequate detail to support a resource consent application.

Geotechnical issues internal to the site e.g. liquefaction and slope stability are assessed separately in GeoSolve's geotechnical reporting[1] for the site. Drainage and flood hazard mitigation within the proposed subdivision itself (from rainfall falling directly onto the site) have been assessed by Stantec in their reporting - partially informed by GeoSolve's assessment of the upstream catchments as described in this report.

This assessment has been undertaken for RCL Ltd in accordance with GeoSolve proposal, reference 220556.02 dated 9th October 2024, which outlines the scope of work and conditions of engagement.

2.2 Development

We understand the proposed development is a mixed-use subdivision. The subdivision is primarily residential, however commercial, educational and infrastructure land use is also proposed. The current draft subdivision layout (by others) is shown below in Figure 2.1.

Figure 2.1: Draft proposed development plan by others, understood to be current at the timing of writing.

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3 Site Description

The site is located at Homestead Bay, approximately 6 km south of Frankton, Queenstown, between Homestead Bay Road, Chief Reko Road and Kingston Highway (SH6). The site forms part of an existing farm, as shown in Figure 3.1 below. The site is legally described as Lot 8 DP 443832 & Lot 12 DP 364700 and is approximately 204 hectares in size.

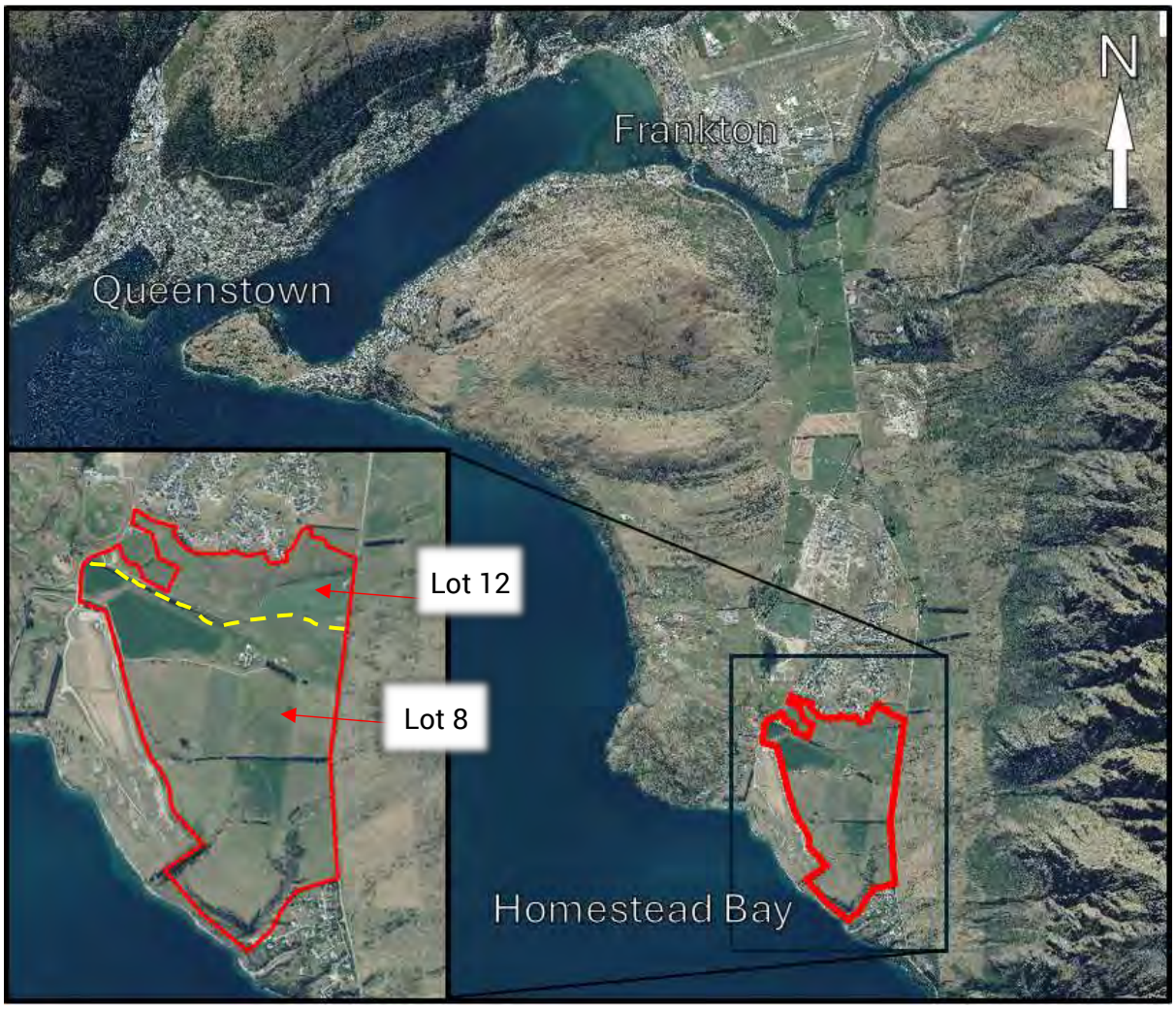

Figure 3.1: Site location plan showing the proposed development area is outlined in red. Aerial Image retrieved from QLDC GIS. Image not to scale.

The site area mainly comprises pastural farmland with farm tracks and associated farming infrastructure, as well as a grassed airstrip that runs east to west along the northern boundary of the site. The NZONE Skydive operational buildings and parking area are located in the northern area of Lot 8 adjacent to the airstrip. Vegetation cover comprises grass, feed crop paddocks, tree shelter belts and scattered bushes. A mixture of native and exotic scrub is found in the deeply incised creek channels towards the southern area of the site.

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3.1 Topography and Surface Drainage

The site is located in the Homestead Bay area at the western foot of the Remarkables Range. Wakatipu Waimāori (Lake Wakatipu) is approximately 45 m west of the south-western corner of the site and 800 m to the south of the north-western corner of the site.

Internally the site slopes from 400 m RL at the eastern boundary to 320 m RL in the lower southwestern corner. Development is proposed in areas of the site which are above 345 m RL. Lower areas of the site typically comprise incised drainage channels and lake margin areas in the southern area of the site.

Three significant surface drainage channels are present upstream of and across the site, named Northern, Middle, and Southern Creeks respectively for the purposes of this reporting. A smaller and ephemeral Southwestern Creek drains southwest from the central area of the site (see Figure 3.2 below). Numerous other paleochannels can be observed within and upstream of the site. The Southern Creek flows across the site towards the south-west and Lake Wakatipu. The Middle and Northern Creeks flow to the west in modified stream channels close to the northern boundary of Lot 8. Hydrology and flooding flow paths are discussed further in Section 0 & 5.

Figure 3.2: The Northern, Middle and Southern Creeks in relation the site boundary (red) on 20 m interval contour mapping. Image retrieved from wams.org.nz.

3.2 Alpine Catchments

The alpine catchments east of the site are all located on the western flanks of the Remarkables. The alpine catchments have been named as the Northern, Middle and Southern Catchments in accordance with their corresponding creeks described in Section 4.1. The catchments are separated by east to west trending ridgelines which run from the peak of the Remarkables. Alpine catchment boundaries are delineated in Section 0.

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Vegetation over the lower elevation of the three catchments typically comprises sparse small trees, bushes and alpine tussock. Some areas of bare soil and rock outcrops are present. The small trees and bushes typically extend to a maximum elevation of 1000 m, with some areas at higher elevation within gully features. Generally above 1000 m the vegetation is limited to alpine tussock grass. Areas of bare soil and rock outcrops generally increase with elevation. Assessments of the alpine catchment geology is provided in Section 6.3 & Section 7.2.

Several areas of collected rockfall, avalanche debris and talus are present on the catchment flanks in all three catchments. These are not on the proposed development area. A plan showing these areas is provided in Figure 1a, Appendix A.

An assessment of the observed alluvial fan geology and geomorphology is provided in Section 6.4. A plan showing the fan extent in context with the site is provided in Figure 1a, Appendix A.

3.3 Mapped Natural Hazards

A review of the Queenstown Lakes District Council (QLDC) register hazard maps has been conducted for the site. The QLDC mapped hazards are shown in Figure 3.3. QLDC mapping was compared to Otago Regional Council mapping and was found to agree.

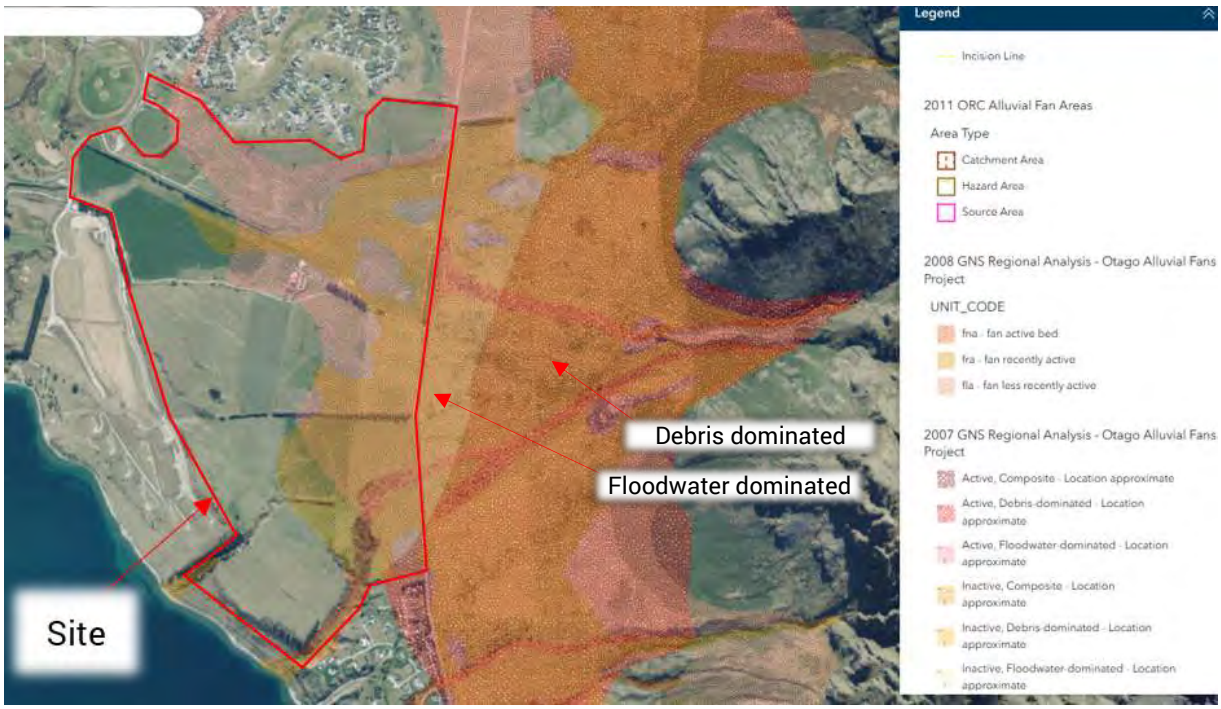

Figure 3.3: QLDC hazard mapping

The development site is situated on an alluvial fan, which is identified as being both 'active' and 'recently active' by differing layers on the QLDC natural hazards database, see Figure 3.3 above. Mapping shows the upper portion of the fan to be debris dominated and lower areas to be flooding dominated. The site specific analysis presented in this reporting is considerd to supercede the genralised mapping for this site. The site is located on the

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lower portion of the alluvial fan as shown below. This report assesses the risk posed to the proposed development site from flooding, debris flow, rock fall, debris avalanche and lake seiche. These hazards are discussed in detail in Sections 5, 6, 7, 8, & 9 respectively.

Liquefaction, slope stability and strong ground motion associated with a seismic event are assessed in GeoSolve's geotechnical reporting for the site[1]

The natural hazards assessment has considered the acceptability of natural hazard risks in accordance with the operative QLDC district plan and proposed Otago regional Council Regional Policy Statement2 (Objective 4.1 and Appendix 6 (APP6)). GeoSolve's risk assessment methodology and APP6 are appended in Appendix D. Risk assessments, as per this methodology, are presented separately for each hazard in the relevant section of this report.

[1] Geosolve (2025) Geotechnical Assessment for Resource Consent – Homestead Bay Queenstown (ref:220556.01)
[2] Otago Regional Council (2021) Proposed Otago Regional Policy Statement. Integrating the management of Otago's natural and physical resources. Published June 2021

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4 Alpine Catchment & Alluvial Fan Hydrological Assessment

4.1 Upstream catchment boundaries and characteristics

A hydrological model for the catchments upstream of Kingston Road/SH6 (including the alpine basins and alluvial fans), was set up in the Hydrologic Engineering Centre's Hydrologic Modelling System computer program (HEC-HMS) to determine anticipated runoff from the contributing catchments upstream of the development site. The catchments and outlets identified are shown below in Figure 4.1. Details on the input parameters used for this modelling are provided in the following sections.

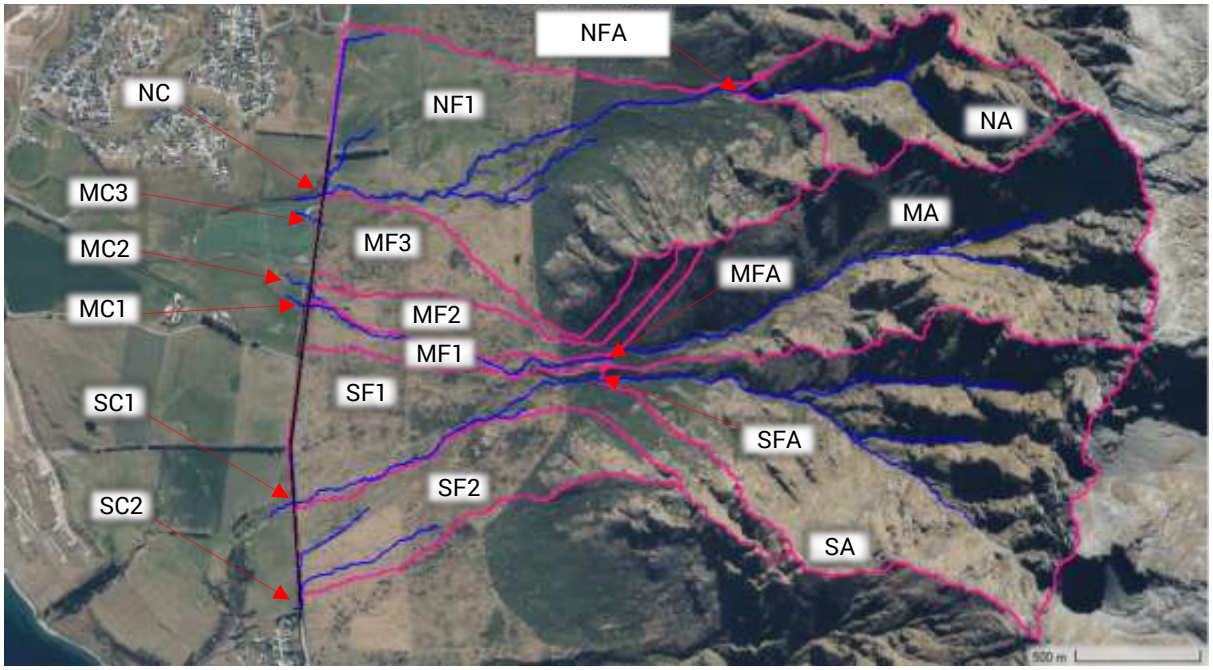

Figure 4.1: Schematic of upstream sub catchments. Sub catchments outlined in pink, flow paths resulting from a catchments area of >0.1 ha in blue.

The catchment boundaries and characteristics were determined from 1m resolution LINZ LiDAR Digital Elevation Model (DEM) by the GIS tool within HEC-HMS. 2021 LiDAR was used primarily, supplemented by 2016 LiDAR where required, due to the 2021 survey extent not fully covering the upper catchments. The topography of the upper catchment areas where 2016 LiDAR was used was assessed to not have changed significantly since the 2016 survey.

Catchments and outlets are designated as shown in Table 4.1. As the catchments do not converge before reaching the site and have differing properties, a relatively large number of sub-catchments was required to represent flow entering the site. Combined catchment outlets are discussed in Section 4.9.

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Table 4.1: Hydrological feature naming format

Label	Description
NA, MA, SA	Northern Alpine, Middle Alpine & Southern Alpine catchments
NFA, MFA, SFA	Northern Fan Apex, Middle Fan Apex & Southern Fan Apex
NF, MF, SF	Northern Fan, Middle Fan & Southern Fan catchments
NC, MC, SC	Northern Culvert, Middle Culvert & Southern Road Culvert (catchment outlets)

The catchment characteristics are provided below in Table 4.2. A site photo of the catchments is shown below in Figure 4.2.

Figure 4.2: Upstream catchment (approximate boundary in red, sub catchments not delineated).

Table 4.2: Catchment characteristics

Catchment	Area (km^2)	Flow path slope (10-85 average[3]) (m/m)	Flow path length (longest) (km)	Time of concentration (Bransby-Williams) (mins)
NA	0.47	0.77	1.64	27
NF	1.38	0.26	2.75	51
MA	1.27	0.53	2.62	42
MF1	0.11	0.14	1.51	41
MF2	0.18	0.23	2.02	47
MF3	0.27	0.12	1.41	36
SA	1.43	0.54	2.46	39
SF1	0.55	0.33	2.62	51
SF2	0.45	0.18	2.17	48

The flow path slope (10-85 average, as recommended by the HEC-HMS manual) above was found to be within 5% of the slope defined by the equal-area method. The 10-85 slope was used for calculations and is the more conservative value.

[3] https://www.hec.usace.army.mil/confluence/hmsdocs/hmsum/4.8/geographic-information/basin-characteristics

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Flow path length is taken as the distance travelled by runoff from the most hydraulically distant point of the catchment to the outlet.

Different time of concentration/lag time calculation methods were evaluated for the catchments as part of a sensitivity analysis. These included:

- HEC-HMS reference method (time of concentration)
- Bransby-Williams method (time of concentration)
- Friends Equation with Horton's roughness (time of concentration)
- 2D Hydraulic modelling of rain on grid in HEC-RAS (Lag time)
- Direct measurement of stream flow in response to rainfall using a water level data logger (Lag time)

The Bransby-William's method was selected due to its widespread use and acceptance in New Zealand, including being used by the National Institute of Water and Atmospheric Research (NIWA) for automation of flood flow calculations on their NZ River Flood Statistics page[4]. It also provided a more conservative estimate for time of concentration than the other method above and direct flow gauging.

4.2 Storm Duration

A 24-hour duration nested storm hyetograph was modelled as per the QLDC LDSC. This method simulates a design rainfall event where all 100-year ARI rainfall intensities ranging from 10 minutes to 24 hours occur within a single 24-hour storm. This method ensures the critical storm duration is assessed in terms of both peak flow and storm volume. This is considered to be a conservative approach.

The contributing catchments in this area have relatively short times of concentration, each of which are captured by the 24-hr nested hyetograph.

4.3 Rainfall

Rainfall data was obtained from the NIWA High Intensity Rainfall Design System (HIRDS). Rainfall intensity increase for the 2081-2100 RCP8.5 climate change scenario was used, which is the most conservative climate change prediction pathway. This is considered an appropriately conservative method to account for potential future unknowns. HIRDS rainfall predictions may also have a conservative estimate of orographic rainfall increase for the Remarkables range due the presence of significant surrounding mountain ranges and its distance from the main divide. However, the values provided by HIRDS have been used without adjustment.

The 2081-2100 RCP8.5 climate change scenario rainfall is significantly higher than historical rainfall in this area. Historical rainfall data was not considered in this reporting, as lower flows resulting from historical rainfall events are not appropriate for assessing potential alluvial fan hazards. Historical flows have been considered by Stantec for the internal stormwater design of the development.

[4] https://niwa.maps.arcgis.com/apps/webappviewer/index.html?id=933e8f24fe9140f99dfb57173087f27d

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Rainfall for the alpine catchments has been determined from HIRDS for the centroid of the middle alpine catchment. Rainfall for the fan catchments has also been taken from HIRDS for the centroid of the middle/southern alluvial fan. The maximum rainfall intensity was found to be similar for both elevations as shown below in Figure 4.3. However total rainfall for a 24-hr storm was found to be ~26 % less for the fan compared to the higher alpine catchments. Total rainfall for the 24-hr storm is also provided below in Figure 4.3.

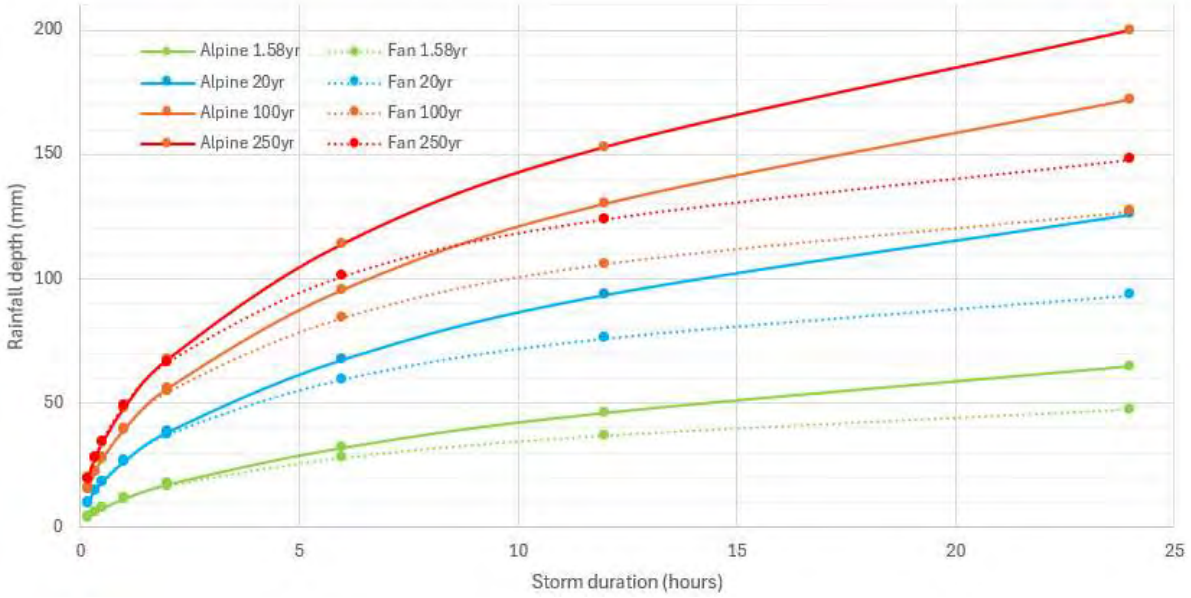

Figure 4.3: HIRDS depth-duration curves, plotted for the alluvial fan and alpine sub catchments.

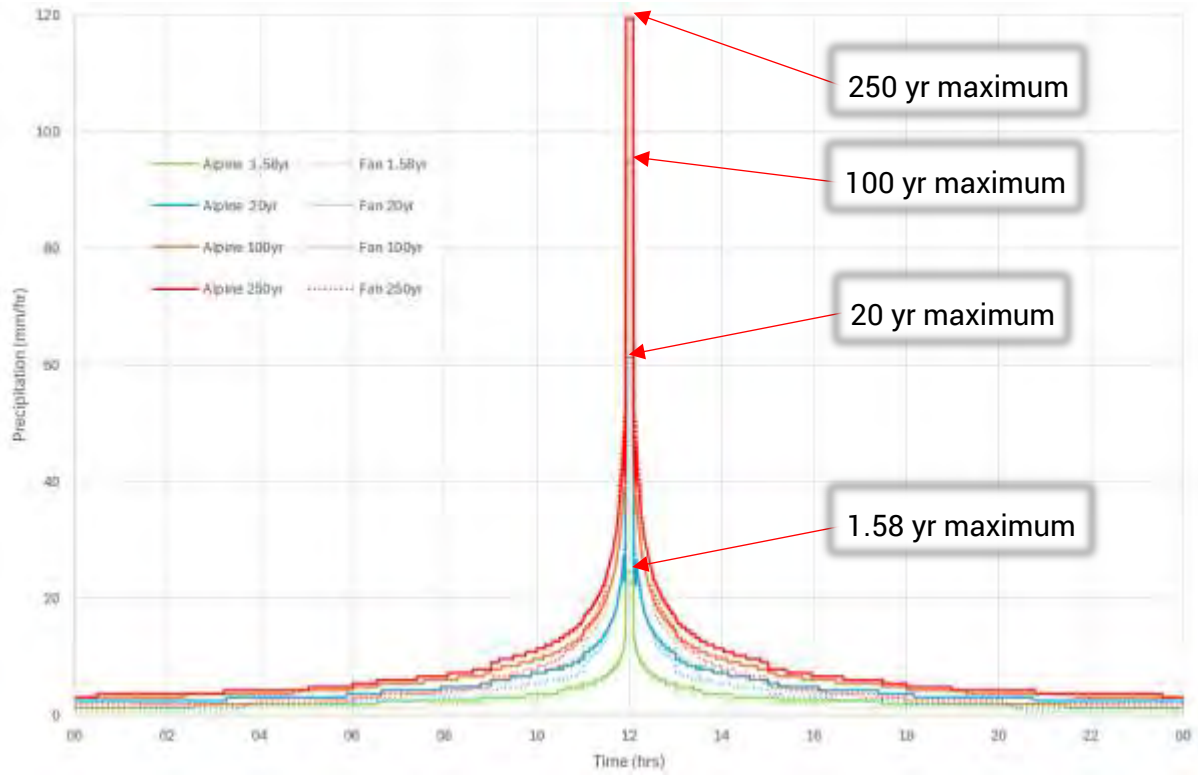

Figure 4.4: 24 hr design storm hyetographs (RCP8.5 2081-2100 scenario)

A synthetic 24-hr nested storm hyetograph for return periods of interest was produced from Figure 4.3 and used as storm rainfall input into the HEC-HMS hydrological model shown as Figure 4.4.

As the catchments are relatively small (<10 km^2) no areal reduction factor has been applied to point rainfall estimates from HIRDS[5].

4.4 Loss Calculation Method

The SCS Curve Number method[6] was used to calculate anticipated rainfall losses to infiltration. An initial abstraction value of 0.1 x S (potential maximum retention) was used as recommended by the Wellington Water Reference Guide for Design Storm Hydrology[5], as QLDC/ORC do not appear to have a documented recommended value. We note this is more conservative than the recommended[6] default value of 0.2 x S.

4.4.1 Alpine Catchments Curve Number

A curve number (CN) of 77 and initial abstraction of 7.6 mm was assigned to the three steep alpine catchments, based on several refences:

- This curve number is recommended as a calibrated value for silt loams in alpine tussock/grass by the Wellington Reference guide for Design Storm Hydrology[5].
- It is in the upper (more conservative) third of the range of values given for American semiarid “rangelands” with grass and shrub cover in good hydrological condition[6] (values range from 62-85).
- A curve number of 77 is given as the maximum calibrated value for 23 catchments ranging from 0.3 to 564 km^2 in New Zealand and Australia based on a 2023 study[7].

Site observations that corroborate the CN based on those references include:

- The catchment is in “good” hydrological condition with significant grass, tussock and scrub cover in the lower catchment, in addition to somewhat broken, permeable rock in the upper catchment.
- Where soil is present, depths of >0.5 m are observed across the majority of the catchment.
- Soils are confidently expected to be medium to high permeability based on site observations and previous subsurface investigations undertaken by GeoSolve in the area.
- Upper areas of the catchment without vegetation or soil cover are expected to have significant infiltration and subsurface flow/storage within gravel overlying bed rock (as opposed to widespread rapid overland flow). A portion of this subsurface flow will be too slow to contribute to the stormflow hydrograph.

[5] Wellington Water (2019) Reference Guide for Design Storm Hydrology, Standardised Parameters for Hydrological Modelling
[6] USDA (1985) SCS Technical Report 55
[7] A Shokri (2023) Development of a New Event-Based Rainfall-Runoff Equation Based on Average Rainfall Intensity During an Event, Environmental Modelling & Assessment https://doi.org/10.1007/s10666-023-09876-3

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4.4.2 Fan Catchments Curve Number

A curve number of 68 and initial abstraction of 12 mm was assigned to the fan catchments. This is a median value of reported curve numbers for semiarid "rangelands" with grass and shrub cover in good hydrological condition[6] and studies in New Zealand for similar alpine catchments[8]. The median value is considered conservative given the free draining nature of the alluvial fan soils, and a lower (less conservative) CN may be more representative. Previous infiltration testing work by GeoSolve on neighbouring sites with similar fan formations and geology to the north yielded very high infiltration rates in fan alluvium (as typical/expected).

Historical site inspections of the fan by GeoSolve during significant rainfall events, and by GeoSolve between September and December 2024, showed a notable lack of flow on the fan (even when accounting for snowfall higher in the catchment). Figure 4.5 shows flow in the Southern Creek Culvert at 4pm 3rd October after 11 mm of rain in the preceding 4 hours and an additional 26 mm of rain in the previous 24 hours. The Middle Creek and Northern Creek were dry at the road culverts on this date. Overland flow was not observed on the fan. This is considered to corroborate the high permeability of the fan.

Figure 4.5: Flow in the Southern Creek @ SH6 (4 pm 3-10-2024) after ~37 mm of rainfall in 28 hours

[8] Brian s. Caruso 2011 Flood modelling in a high-country mountain catchment, New Zealand: comparing statistical and deterministic model estimates for ecological flows

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Flow in the current primary flow paths was also observed to be low at the SH6 road culverts relative to flow at the fan apex, suggesting significant in-stream losses due to high permeability between the fan apex and SH6 (the site boundary).

During a site walkover on the 13th of November 2024 baseflow was estimated at ~50 l/s (0.05 m^3/s) at the fan apex for the Middle Creek flow path. At the location where the channel reached the power lines (~750m downslope of the fan apex) the flow path had run dry due to infiltration losses, as shown in Figure 4.6 below.

Figure 4.6: Middle flow path 13th November 2024 at hydrographic fan apex (top) and at powerlines (bottom).

In addition, all primary flow paths across the fan, with the exception of a very narrow gravel base in the southern flow path, have grass cover in the channel invert at the road. This

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suggests surface flow only reaches the road for a short duration during storm events when runoff exceeds the infiltration capacity of the stream bed/flow path. More frequent flow in these flow paths would be expected to scour/inhibit growth of terrestrial plants such as grass.

A large proportion of runoff from the fan apex is expected to travel as subsurface flow at the interface between permeable soils (alluvial fan or glacial outwash gravel deposits) and the less permeable dense glacial till. Test pit data from the site supports this; shallow perched groundwater flow was found in alluvial fan deposits in five test pits at depths between 1.3 and 4.3 m BGL on the toe of the alluvial fan in the eastern area of the site. A summary of test pits with shallow/perched groundwater is provided in Table 5.2 of the GeoSolve geotechnical report for the site[1] with test pit locations shown in Appendix A of that geotechnical report.

Subsurface flow will be relatively slow and therefore not contribute significantly to flood flow peaks. The proportion of runoff leaving the catchment as rapid surface flow (as opposed to the usual subsurface flow) is expected to increase during high return period events. However, a curve number of 68 for the fan surface is considered appropriately conservative for high return period events given the evidence for high permeability discussed above.

4.4.3 Comparison of total rainfall with total runoff

Total storm runoff is compared to total rainfall in Table 4.3 below to aid in comparison of the SCS curve number method losses with values from literature. Runoff/rainfall is taken as the total storm runoff volume divided by the total rainfall volume. The 100-year runoff coefficients for the alpine catchments were found to agree well with values for large storms in gauged small catchments in NZ[9].

While not directly comparable these value where also compared to the rational method runoff coefficients given in Table 4-2 of the QLDC LDSC. It is noted that the SCS Method used has resulted in higher (more conservative) runoff predictions than if the Rational Method had been used with the QLDC COP recommended runoff coefficients.

Table 4.3: Resultant runoff coefficients

Catchment type	Return period	Runoff/rainfall [with snowmelt] (mm/mm)
Alpine	20 year	0.51 [0.61]
	100 year	0.66 [0.79]
	250+ year*	0.67 [0.84]
Alluvial fan	20 year	0.39 [0.47]
	100 year	0.47 [0.57]
	250+ year*	0.51 [0.62]

*The definition of the 250+ year return period event is discussed in Section 4.8.

[9] A J Pearce et al (1979) Upstream Generation of Storm Runoff

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4.5 Transform Method

The SCS unit hydrograph method[6] was used in HEC-HMS to route excess precipitation to the applicable subbasin outlet. The calculation method is described in the HEC-HMS technical reference manual[10]. The standard Peak Rate Factor (PRF) of 484 was adopted instead of the maximum PRF of 600 for the following reasons:

- The alpine catchments are elongated with the majority of their area relatively distant to the outlet.
- All catchments have relatively low drainage density and runoff travel time will be dominated by shallow surface and subsurface flow as opposed to rapid channel flow.
- The fan catchments are relatively flat.

The lag time for each catchment was taken to be 0.6 x the Time of Concentration[11,10] provided in Table 4.2. This is considered to be conservative given the observed lag time discussed below, and comparison with other peak flow estimation methodologies.

An automated water level logger was placed in Middle Creek at the fan apex from 13th November 2024 to 3rd December 2024, to directly measure the lag time for the middle alpine catchment for comparison with the calculated lag time. A increase in stage at the measurement location in response to a rainfall event on the 28th of November is shown below in Figure 4.7. This indiciates a lag time of ~3 hours (180 mins) for a small rainfall event. Although lag time is expected to decrease for larger rainfall events this result suggests that the calculated lag time of 25 mins for the Middle Alpine catchment is conservative, being over 7 times faster than the gauged lag time (for a non-extreme event).

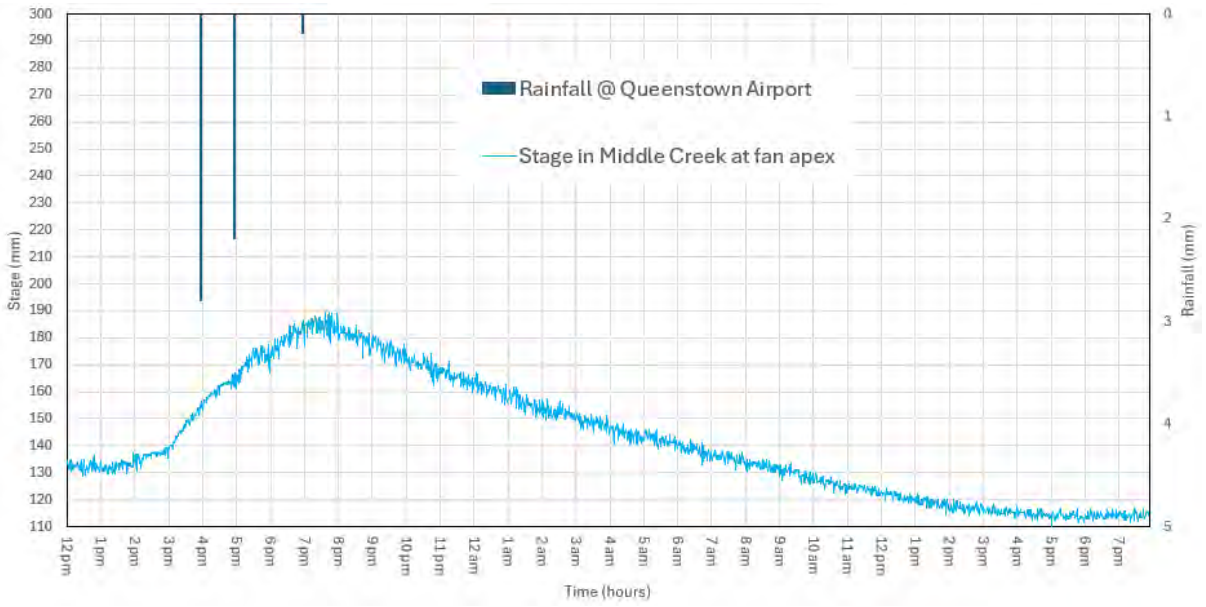

Figure 4.7: Rainfall-runoff graph for Middle Creek, 28th November 2024

[10] https://www.hec.usace.army.mil/confluence/hmsdocs/hmstrm/transform/scs-unit-hydrograph-model
[11] Waikato Reginal Council (2018) Waikato Stormwater Runoff Modelling Guide

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Although it is considered that the gauged data above emphasises the conservatism of the estimated lag time from calculative emperical methods, the more conservative calculated value has been used in this analysis. This is due to the the gauge having not recorded the lag time of a large storm event, and due to other potential sources of error in the measurements, such as:

- Difference in rainfall timing and quantity between the Middle Alpine catchment and Queenstown Airport (8 km NNW) due to location and topography.
- Increased run off in the evening in reponse to warm daytime temperatures melting snow and frozen water in the upper catchment (estimated to account for up to 15% of the observed response on the 28/11 based on inspection of the stage data for the period recorded).

4.6 Routing Method for Fan Flow Paths

A lag time was assigned for streamflow between the fan apexes and SH6/the site boundary in the HEC-HMS model. This was calculated from flow path length and average velocity taken from the HEC-RAS hydraulic modelling velocity output (Section 5) and is presented below in Table 4.4.

Table 4.4: Stream (reach) lag parameters

Reach	Length (km)	Lag time (mins)
Northern flow path	2.12	12
Middle flow path	1.47	8
Southern flow path	1.57	9

4.7 Debris Flood Bulking Factor

As opposed to the steep alpine sub catchments, rainfall falling directly upon the flatter and more vegetated alluvial fan sub catchments is not considered likely to create flows that entrain significant sediment, for the following reasons:

- Flow velocity and depth is relatively low/shallow in the flow paths on the fan.
- The well-established vegetation on the fans shows no sign of significant erosion/scour (though this has occurred near the fan apex from flows originating from rainfall on the alpine sub catchments).
- The slope on the fan is low relative to the alpine catchments, and the fan is expected to be a net depositional area for sediment from the alpine sub catchments during flood events.

For the reasons above, only flood flow originating from the alpine catchments has been bulked to represent significant sediment entrainment, a.k.a. a debris flood. Note that this is different from a debris flow, which display non-Newtonian properties (i.e. do not flow like water) and have been assessed separately in Section 6.

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A bulking factor of 1.25 for flood flows from the alpine catchments is adopted to account for debris floods. This value is taken as the upper bound provided by the New Zealand Geotechnical Society (NGS) guidance[12] for debris floods impacting "projects located at the downstream end of alluvial fans where flow is widely dispersed and diminished".

The peak flows of 'clearwater' floods have been multiplied by 1.25 to provide debris flood peak flows for the alpine catchments. The calculation of total stormwater volume for debris floods has been undertaken as follows:

As smaller storm events (<1.58 year ARI) occur regularly, sediment that may be entrained by those flows will be frequently flushed from the regular flow paths. However, floods resulting from greater than 1.58 year ARI storm events are likely to have significant sediment available for entrainment, as they reach levels undisturbed by more regular flows. As a result, only flood flows above the peak flow of a 1.58 year ARI event have been bulked by 1.25 in the storm hydrographs, to provide a total debris flood stormwater volume. This aligns with the sediment deposition patterns observed on the fan and is considered to be appropriately conservative.

4.8 Snowmelt

The upper third of the alpine catchments is subject to winter snow cover, with snow at lower elevations not observed to consolidate. A bulking factor was added to the design storm runoff for the alpine catchments to account for the potential increase in peak flow and flood volume as a result of snowmelt. This is considered to be a conservative approach given that the most extreme global warming climate change adjusted rainfall has also been applied.

The 100-year ARI flood values presented below incorporate both the conservative RCP8.5 (2081-2100) climate change scenario and sediment bulking factors and are considered to represent compound conservatism in estimation of the 100 year ARI (1% AEP) return period event. A flood event resulting from 100-year ARI rainfall (of the specific time of concentration of these catchments) that coincides with warm temperatures during a time of the year when a significant snowpack is present in the alpine catchments, is considered to actually represent a return period of greater than 100 years. It is, however, a feasible scenario that warrants consideration as part of a risk-based assessment for a climate trending to more extreme weather. For this reason, we have added a significant snow melt contribution to flooding estimates as described below.

Snowmelt was shown to increase peak flow ~20 % for the recent 2019 flood in the Waiho River catchment[13]. This is considered a suitable multiplication factor (1.2) to provide the 20 year & 100-year combined rainfall + snowmelt events.

Snowmelt was shown to provide ~37 % of total water input (Rain: 135 mm, Snowmelt: 80 mm) for the 1978 major flood in the nearby Fraser River catchment[14]. This is considered a

[12] New Zealand Geotechnical Society (2024) Slope Stability Geotechnical Guidance Series

[13] NIWA (2024) Better runoff and hazard predictions through national-scale snowmelt forecasting https://niwa.co.nz/hazards/better-runoff-and-hazard-predictions-through-national-scale-snowmelt-forecasting#:~:text=For%20example%2C%20during%20the%20destructive,the%20Waiho%20catchment%20by%2020%25.

[14] B Fitzharris et al (1980) Contribution of snowmelt to the October 1978 flood of the Pomahaka and Fraser Rivers, Otago

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suitable multiplication factor (1.37) to provide a 250-year combined rainfall + snowmelt event. This is termed a 250+ year in flood flow estimation given below.

To summarise, clearwater peak flows and volume have been increased by 20% for the 20- and 100-year ARI events, and the 250+ year ARI upper bound event has been increased by 37% to account for potential snowmelt contributions to runoff from the alpine catchments, which is considered to be a conservative approach on multiple levels.

4.9 Hydrological Model Outputs

An example of the hyetograph and clearwater hydrograph output from HEC-HMS is provided below in Figure 4.8. The 100-year ARI (1% AEP) event for the Middle Alpine catchment (MA) is pictured, which is shown in Appendix E in full size, along with images representing the other catchments.

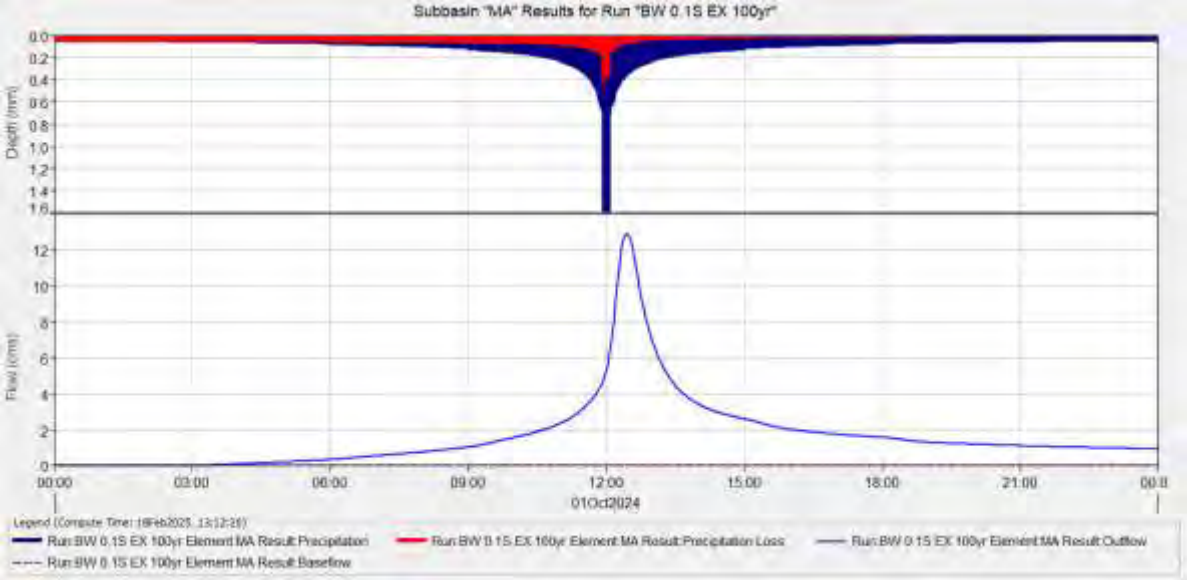

Figure 4.8: 100 year ARI hyetograph and hydrograph for the Middle Alpine catchment (MA) at the fan apex.

Time to peak in Table 4.5 below is defined with regard to the time after peak rainfall, which is set at 12hrs for the 24hr design storm, as shown in Figure 4.8 above (e.g. the Time of Peak for the Middle fan apex of 25 mins would be 12 hours and 25 mins on Figure 4.8 above).

An example showing the relative contributions of the SA and SF1 catchments to the Southern Culvert 1 (SC1) flow at the road is given provided in Figure 4.9. A full-size hydrograph for each flow path at the road is given in Appendix E.

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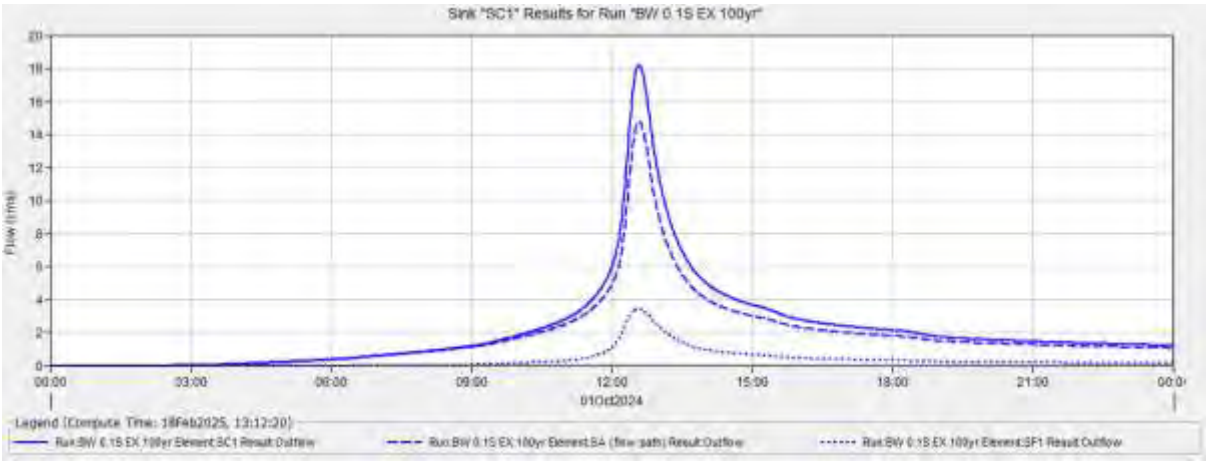

Figure 4.9: 100 year hydrographs for the Southern Culvert 1 (SC1) at SH6/the site boundary.

An example of a debris flood hydrograph (all flow bulked by 1.2 for snowmelt and flows above the 1.58 year ARI flow bulked 1.25 for sediment) for the Southern Alpine (SA) catchment is given provided in Figure 4.10.

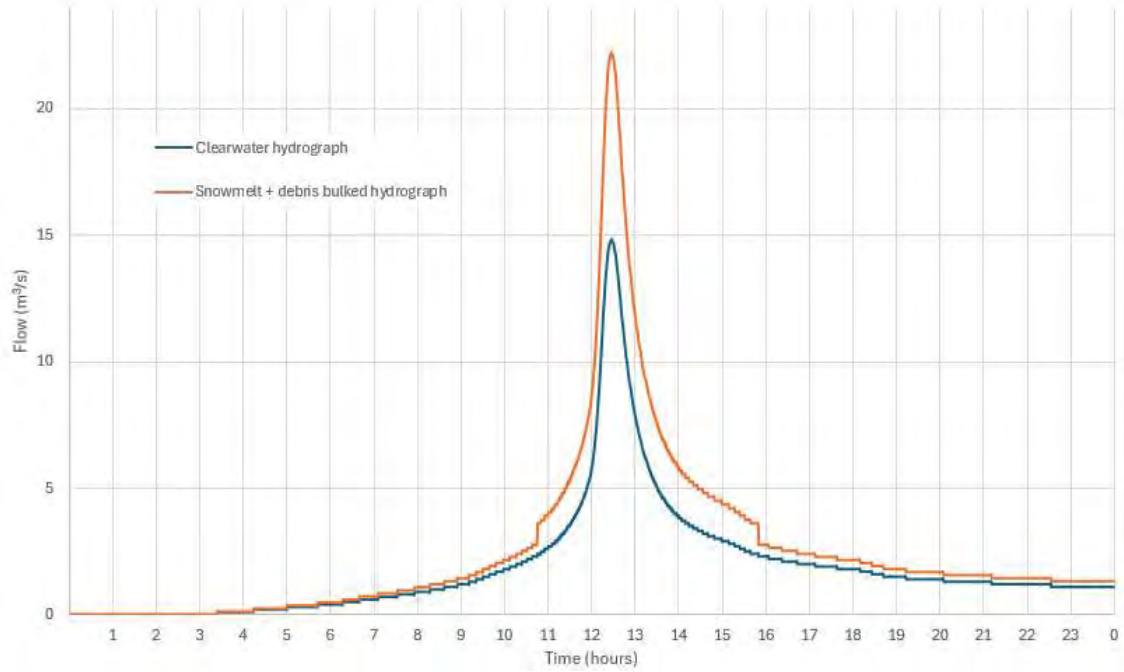

Figure 4.10: Example of bulked debris flow hydro graph from the Southern Alpine catchment.

Peak flows and total storm volumes, provided for each location of interest, are presented in Table 4.5 below. Catchment outflows at the road culverts are combined into Northern, Middle and Southern catchments i.e. SA+SF1+SF2 = Combined southern catchments at road. The peak flows and storm volumes determined were then used in the hydraulic modelling described in Section 5 below.

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Table 4.5: Hydrological model outputs

Location	Time to peak (mins)	Return period	Clearwater peak flowrate (m^3/s) [with snowmelt]	Clearwater total flood volume ($1000m^3$)	Debris flood peak flow (m^3/s)	Debris flood total volume ($1000m^3$)
Northern fan apex	17	20 year	3.4 [4.1]	42	5.1	44
		100 year	5.9 [7.1]	63	8.9	71
		250+ year	7.6 [10.4]	89	13	89
Combined northern catchments at road	31	20 year	7.6 [8.3]	85	9.3	92
		100 year	14.1 [15.3]	140	17.1	153
		250+ year	18.9 [21.7]	147	24.3	194
Middle fan apex	27	20 year	7.5 [9.0]	108	11.3	120
		100 year	12.9 [15.5]	169	19.4	195
		250+ year	16.7 [22.9]	238	28.6	243
Combined middle catchments at road	34	20 year	9.5 [11.0]	127	13.3	140
		100 year	16.8 [19.4]	201	23.3	229
		250+ year	22.1 [28.3]	278	34	285
Southern fan apex	26	20 year	8.6 [10.3]	122	12.9	135
		100 year	14.8 [17.8]	191	22.2	219
		250+ year	19.1 [26.2]	268	32.7	273
Combined southern catchments at road	33	20 year	11.9 [13.6]	154	16.2	172
		100 year	21 [24.0]	246	28.4	278
		250+ year	27.7 [34.8]	339	41.3	349

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5 Alluvial Fan Flooding Risk Assessment

5.1 General

The proposed development is located within an alluvial fan hazard area marked as "active, floodwater-dominated" based on regional scale mapping[15] as shown in Figure 3.3. Evidence of recent flooding was not observed during site visits. Observation of recent scour and erosion were limited to small areas on over-steepened banks adjacent to current flow paths.

An alluvial fan flooding and debris flow risk assessment has been undertaken in response to the hazard mapping. This section covers the alluvial fan flooding risk and Section 6 covers the alluvial fan debris flow risk.

A site-specific alluvial fan flooding assessment has been undertaken using flood hydrographs from Section 4 as inputs to 2D hydraulic modelling using the Hydrologic Engineering Centres River Analysis System (HEC-RAS) software, while acknowledging that the flow paths on the fan will migrate over time in response to sediment transport and deposition (see Section 5.2).

Pre-development and post-development alluvial flood hazard (especially in regard to the proposed mitigation measures) across the site has been assessed for three likelihood scenarios. Consequence and likelihood have been considered in order to qualitatively assess the risk.

The change in discharge at the downstream site boundary as a result of the proposed diversion channel has also been assessed; as well as the potential for flooding to reach roads and neighbouring properties.

5.2 Alluvial Flooding Hazard Likelihood Scenarios

Three likelihood scenarios have been identified for alluvial flooding hazard:

1. Almost certain (20 year)
2. Likely (100 year)
3. Unlikely (250+ year (250 - 1000 year))

A 250-year rainfall event, without additional contributing factors, is considered to have a Possible likelihood. When combined with conservative estimates of snowmelt contributions and/or flow path avulsion, the likelihood is assessed as Unlikely. To ensure a conservative risk assessment, the scenario is evaluated using the lowest return period of 250 years (Possible likelihood) while accounting for the potential consequences of compounding effects from snowmelt and avulsion.

Avulsion on the alluvial fan is considered as part of the Unlikely scenario. This combines the 250+ year rainfall event with:

[15]OPUS (2009) Otago Alluvial Fans Project. Report #1205, Version 2

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- Avulsion of the southern channel into the middle channel at the hydrographic fan apex.
- Avulsion of the middle channel to the south
- Migration of both channels to the centre of the fan

It is noted that the allowance for potential avulsion scenarios is in addition to the conservative input parameters developed and described in Section 4.

Avulsion of Middle creek to the Northern Creek at the Road is not considered as this would result in less flow impacting the area proposed for development (Lot 8) and more flow through upper areas of Lot 12 which will remain largely undeveloped. Avulsion of Northern Creek into Middle Creek is not possible as the northern creek currently runs at the lowest point between the northern and middle alluvial fans and cannot rise onto the middle alluvial fan.

5.3 Alluvial Flooding Processes

As discussed in Section 4.7 a debris flood has been conservatively allowed for by bulking the calculated clearwater flows for the steep alpine catchments.

> *"A debris flood is a rapid flow of water charged with debris. Debris floods are distinguished from clearwater floods when sediment on the bed begins to move together, en-masse, and larger particles become suspended because of bedload destabilisation. Sediment concentration is typically less than 25% by volume"* [12]

Debris floods peak discharges are comparable with clearwater flooding and flow properties remain Newtonian, i.e. they flow like water. As such they are modelled with hydraulic flood modelling software. Debris flows with higher concentrations capable of altering flow characteristics are discussed in Section 6.

Debris flooding from the alpine catchments and clearwater flooding contributions from the fan catchments have been combined to provide inputs for the alluvial flooding model discussed in the following sections.

5.4 Alluvial Flooding Model

HEC-RAS version 6.5 was used to hydraulically model the area in order to inform the flood risk for the site. To create the base terrain for the model the following Digital Elevation Models (DEM) where used.

- 2016 Light Detection and Ranging (LiDAR) was downloaded for the area from LINZ[16] for the alpine area of the Remarkables to the east of the site.
- 2021 LiDAR was downloaded for the area from LINZ[17] for site and surrounding areas.

[16] https://data.linz.govt.nz/layer/99115-otago-queenstown-lidar-1m-dem-2016/
[17] https://data.linz.govt.nz/layer/105898-otago-queenstown-lidar-1m-dem-2021/

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- Client supplied ground models for the proposed diversion and other development earthworks for the site area.

LiDAR for the modelled areas is considered to represent current topography well, and no significant changes to the catchment topography have been observed since the LiDAR surveys where undertaken.

A 2D flow area covering the area of interest was defined. This defines the area in which the model will calculate water flow and is shown in Figure 5.1 below.

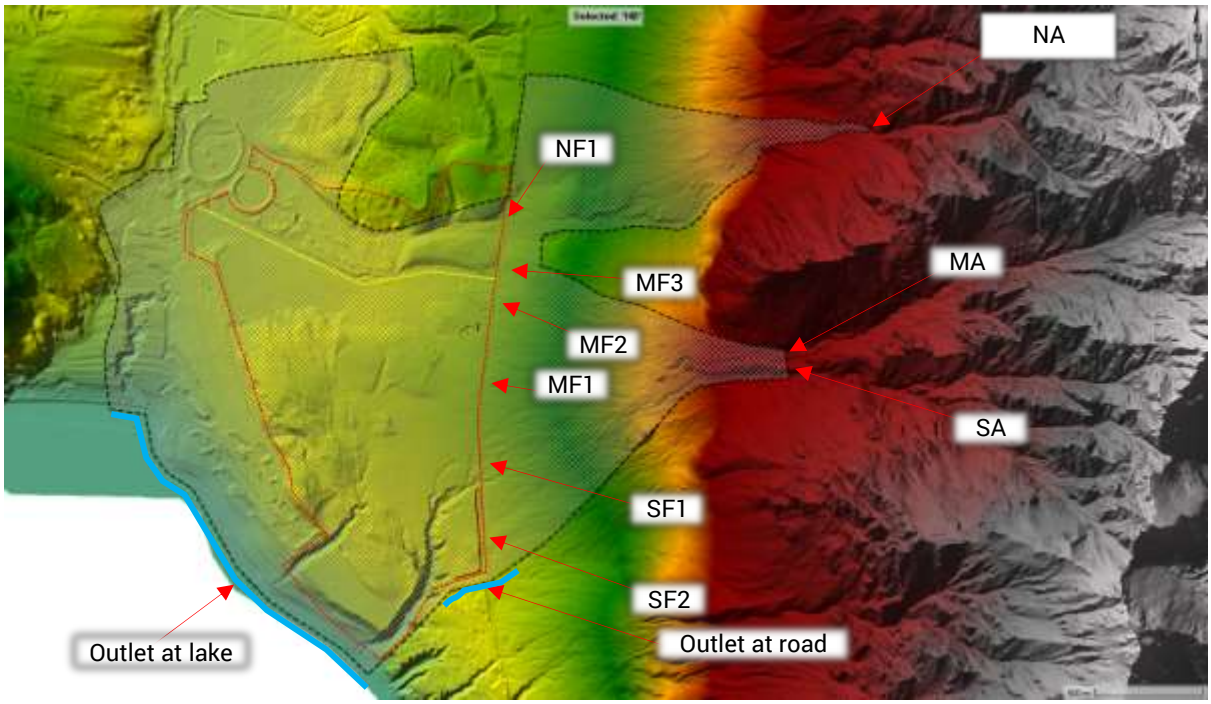

Figure 5.1: HEC-RAS 2D model area (2D calculation area boundary shown as a dashed black line). Colouring of terrain is an elevation 'heat map' of the LiDAR data.

The maximum cell size for the 2D flow area was 10 m. Cells of between 5 and 10 m were carefully aligned with the channel boundaries/overbanks to ensure the channel invert and high ground adjacent to the channels was properly represented by the cell faces. Sensitivity testing was performed with smaller cell sizes, and increased model convergence/accuracy was not observed, though greatly increased run time and decreased model stability resulted. Modelling the large peak flows (relative to channel sizes) across the steep alluvial fan was found to work best with the carefully aligned cells as opposed to the typical cartesian grid of smaller cells (especially where cell faces did not coincide with the channel overbanks). Smaller cell sizes (4 m) and appropriately placed break lines were used at the culvert outlet at the north-west corner of the site, and in some areas of the diversion channel where required for model resolution. An example of model 2D mesh is given in Appendix F.

Inflow and outflow boundary conditions were added as per Table 5.1 below. 24 hour inflow hydrographs from the hydrological modelling described in Section 4 were used for all

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hydrograph inputs to the hydraulic model. Red arrows in Figure 5.1 indicate the location of inlet boundary conditions (inlet hydrograph flow inputs).

The model outlet at the lake was set to a constant stage hydrograph to represent flow into the lake. Outflow along the road drain at the southern model boundary was defined with a normal depth outflow boundary condition.

Table 5.1: HEC-RAS boundary conditions

Boundary Condition	Label	Type	Data source
Inflow - Northern alpine catchment	**NA**	Inlet hydrograph	HEC-HMS 24hr design storm hydrograph output
Inflow - Northern fan catchment	**NF**		
Inflow - Middle alpine catchment	**MA**		
Inflow - Middle fan catchment 1	**MF1**		
Inflow - Middle fan catchment 2	**MF2**		
Inflow - Middle fan catchment 3	**MF3**		
Inflow - Southern alpine catchment	**SA**		
Inflow - Southern fan catchment 1	**SF1**		
Inflow - Southern fan catchment 2	**SF2**		
Outflows in road drain to the south	**Outlet at road**	Normal depth	Slope from DEM
Outflows into Lake Wakatipu	**Outlet at lake**	Stage hydrograph	Lake level (315 mRL)

Manning's n within the modelled area was varied with depth. Given the relatively shallow flow on steep, rough terrain, the depth was considered to have a greater effect than the land cover. For areas with flow depth exceeding 0.1 m, such as channels, the Mannings roughness was set to 0.06 to reflect an appropriate value for an irregular natural stream with obstruction from vegetation, rocks and debris[18]. For sheet flow areas with flow depth less than 0.1 m Mannings n is set to 0.1 to reflect the higher resistance to flow that would be experienced by shallow sheet flow when flowing over rougher terrain (such as rocks & vegetation) of a similar or greater scale than that of the flow depth. An image of the Manning's n values layer used in the hydraulic modelling is provided in Appendix F.

Lower Mannings n values of around 0.03 may be appropriate for the lower sections of the existing grass lined channel along the northern boundary of the site. However, the higher Mannings number used (0.06) is considered appropriately conservative for the purpose of evaluating channel capacity and overbank flooding.

All culverts are assumed to be blocked. This is considered appropriate given the small culverts sizes (0.6 - 1 m diameter) and likelihood of blockage in an extreme flow event due to the potential for entrained sediment/debris in flood flows.

5.5 Alluvial Flooding Model Results

5.5.1 Flood Hazard Level

Flood hazard (depth x velocity), as pictured in the HEC-RAS results in the following sections, has been defined in terms of the combined flood hazard curves provided in Smith

[18] Christchurch City Council (2003) Waterways, Wetlands and Drainage Guide - Part B Design

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et al[19] (see Figure 5.2). These flood hazard curves were used to evaluate the hazard severity across the site. Descriptions of the defined flood hazard severity levels (H1-H6) are provided below in Figure 5.2.

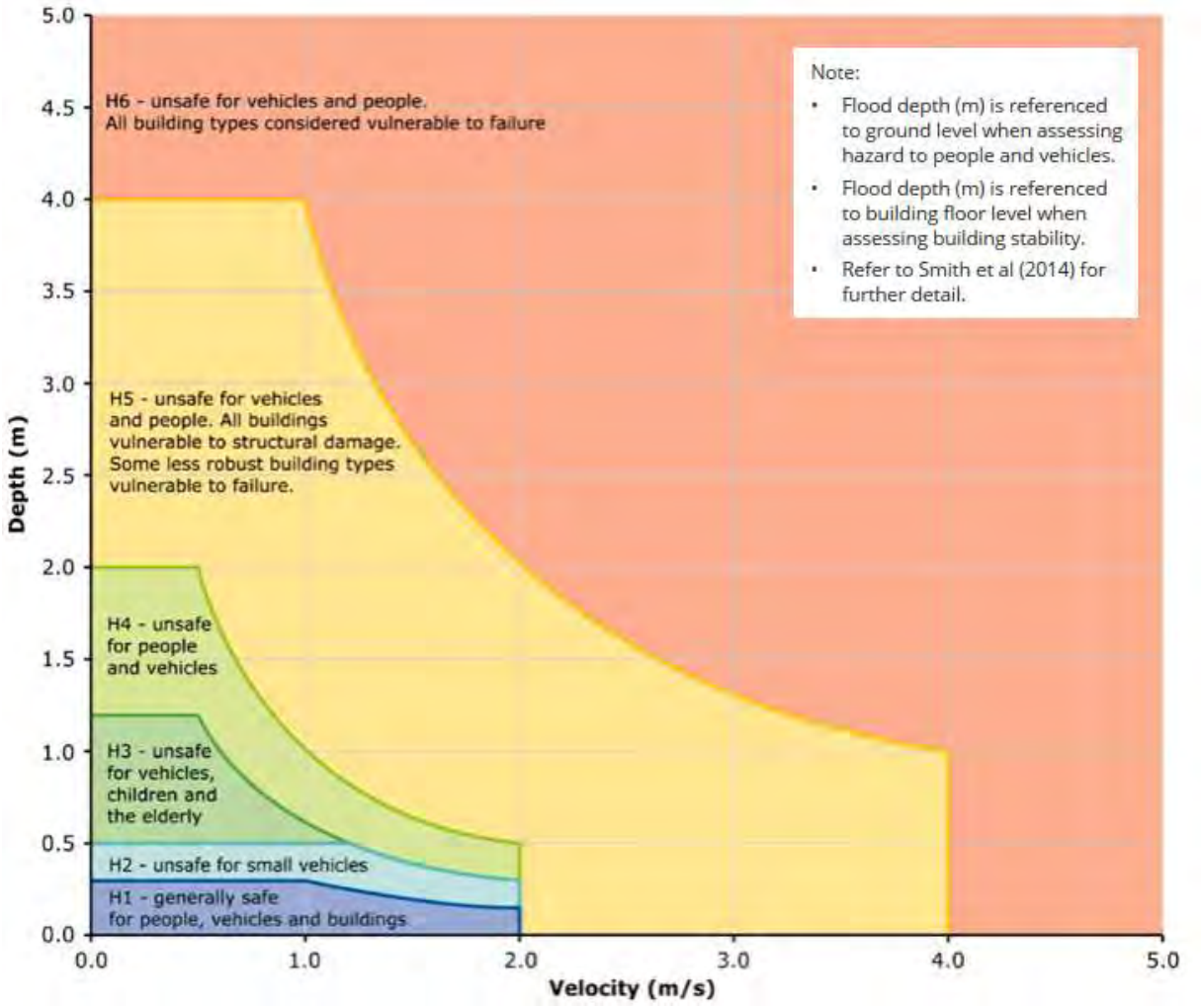

Figure 5.2: Combined flood hazard curves (from Smith et al (2014)[19]

A flood hazard level of H4 or above in an area of residential or mixed-use development is considered to correlate to a moderate consequence as defined in Appendix D. A flood hazard of H2 -H3 in an area of residential or mixed-use development is considered to correlate to a minor consequence as defined in Appendix D.

5.5.2 Pre-development Scenario

Debris flood hazard for a 100-year ARI ('Likely') debris flood event in existing flow paths is shown below in Figure 5.3 Additional results for an 20-year ARI ('Almost Certain') and 250+ year ARI ('Possible') pre-development scenarios, including avulsion, are shown in Appendix F and discussed below.

[19] Smith, G. P., Davey, E. K., & Cox, R. J. (2014). Flood Hazard. WRL Technical Report 2014/07. University of New South Wales Water Research Laboratory.

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For all scenarios a H5-H6 flood hazard is shown in the primary northern flow path along the northern boundary of Lot 8 and the incised southern flow path through the site. It is understood that development is limited to public trails and reserve in these areas based on the provided development plans. Residential or mixed-use development in these areas is assessed to increase the consequence of a debris flood in these areas to moderate-major and is not recommended. Provided residential/mixed-use development is not undertaken in these areas, the consequence of flood flows in these channels paths is assessed as insignificant.

Without mitigation measures, the flood hazard is shown as H3-H5 for debris flooding in the northeastern corner of Lot 8. Mixed-use development is proposed in this area based on provided development plans and mitigation measures are therefore recommended.

Without mitigation measures, the flood hazard is shown as H3-H4 for debris flooding in the southeastern corner of Lot 8. Residential development is proposed in this area based on provided development plans, and mitigation measures are therefore recommended.

Development in these areas is assessed to have a consequence of minor for a likely debris flood event up to moderate for a possible event if not mitigated. Mitigation in the form of diversion channels along the northern eastern and southern site boundaries is recommended and details of the proposed diversion is given in Section 5.5.3.

Shallow sheet flow with the lowest possible hazard classification of H1 is shown across other areas of the development site. It is considered that this would be prevented from reaching those areas of the site by the proposed diversion channels.

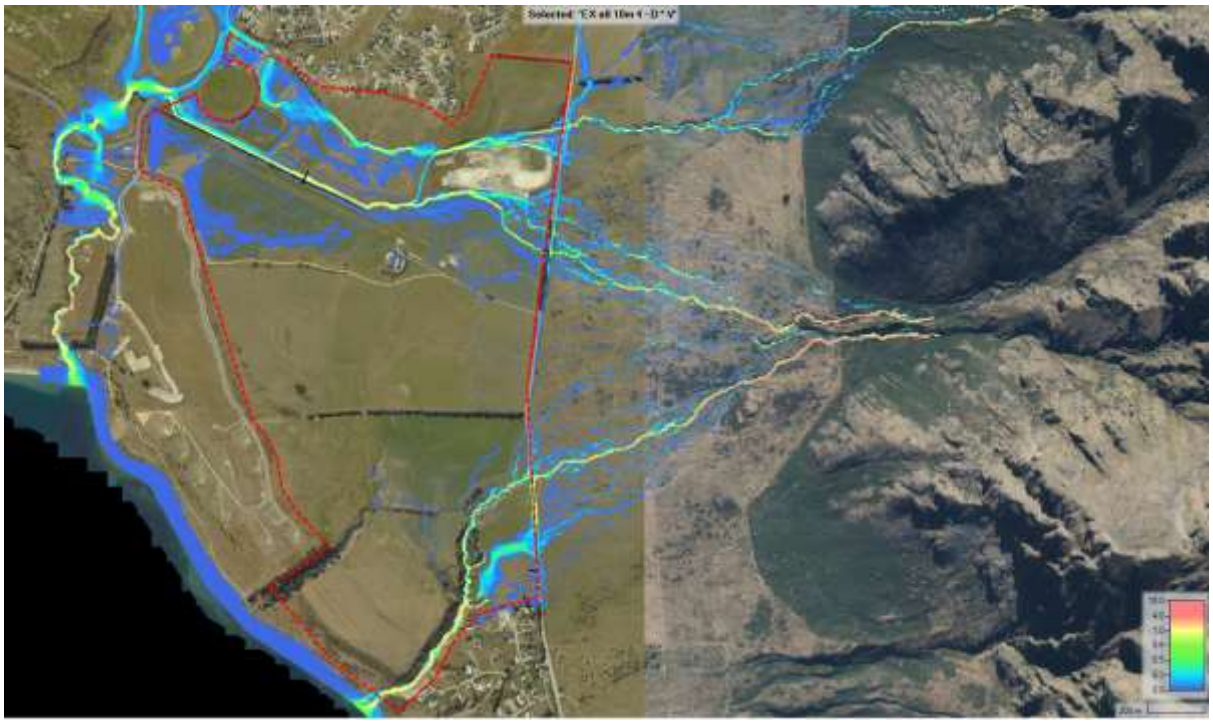

Figure 5.3: Debris flood hazard for a 'Likely' event, which is a 100 year ARI with conservative input parameters (site boundary is shown in red).

Lateral migration of the primary flow paths across the alluvial fan is considered possible during the design life of the development. Pre-development flood hazard across the site for a 250+ year event is shown in Appendix F.

Pre-development debris flood hazard for a 250+ year event combined with avulsion/migration scenarios for the Southern and Middle Creeks are also shown in Appendix F. These scenarios are considered to represent the maximum credible events for debris flooding at the site.

Avulsion/migration of the Southern Creek north or the Middle Creek south is considered in the diversion design discussed in the following section.

5.5.3 Post-development Scenario

To mitigate flood hazard to the site from the upper catchments, diversion channels are proposed to direct flows from upstream catchments around the development areas. Diversions proposed are shown as blue arrows below in Figure 5.4 below. Grass-lined channels are proposed with rock rip-rap lining used in steeper reaches to lower flow velocity and mitigate scour. Detailed diversion design will be presented in separate stormwater design reporting for the development by Stantec.

This hazard assessment addresses the flooding hazards from the upslope eastern catchments and the efficacy of the proposed diversions with regard to mitigation of alluvial fan flooding hazard. The southern diversion channels will not receive any runoff originating from within the site or neighbouring land to the south. As such, the assessment of capacity in this report is considered to represent all flow contributions for these channels.

However, it cannot fully assess the capacity or efficacy of the lower northern diversion channel without the inclusion of flow contributions from the development site and the properties to the north. Stormwater flow from within the development and adjacent properties to the north has been assessed by separate stormwater design reporting and design by Stantec. Geosolve understands that Stantec has been engaged to provide a complete assessment for all diversion channels and potential flooding impacts along the development boundaries using the peak flows, volumes, and hydrographs determined for the upslope eastern catchments from the hydrological modelling presented in this report.

This is particularly pertinent to the northwestern corner of the proposed development where discharge at the site boundary has the potential to have an impact on downstream flooding. Geosolve understands that reporting by Stantec will detail the measures taken to ensure discharges at the boundary are not increased as a result of the development. To support Stantec's assessment, Section 5.5.4 utilizes existing hydraulic modelling undertaken in this report to show that the upper section of the proposed northern diversion channel does not have a significant impact on peak flows compared to the existing pre-development flow path.

Diversion channels, ~2 m in depth, are proposed for the majority of the eastern boundary to allow for potential flow path migration across the fan. Diversions redirect flow from the fan into the northern or southern flow path through the site and away from areas proposed for development. The existing flow path shown as the northern diversion in Figure 5.4 is to be

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widened to provide additional capacity and protect developed areas from overbank flooding.

The proposed roundabout will have an upstream diversion channel and bund capable of diverting flow into the main diversion channels on the west side of the road. This provides continuous protection from flooding along the eastern boundary to allow for potential migration of the flow paths across the fan. The roundabout is at the topographical apex of the eastern boundary and diversions flow to the north and south respectively.

The supplied DEM of the diversions is shown in Figure 5.4, which is current at the time of writing but may be updated as the design progresses. All HEC-RAS model parameters remained the same as the pre-development model with the exception of:

- The existing terrain (DEM) within the site was replaced with the proposed terrain after earthworks to form diversion channels and other earthworks.
- The depth-varied Mannings n value layer was updated to reflect the new locations of diverted flow paths within the site.

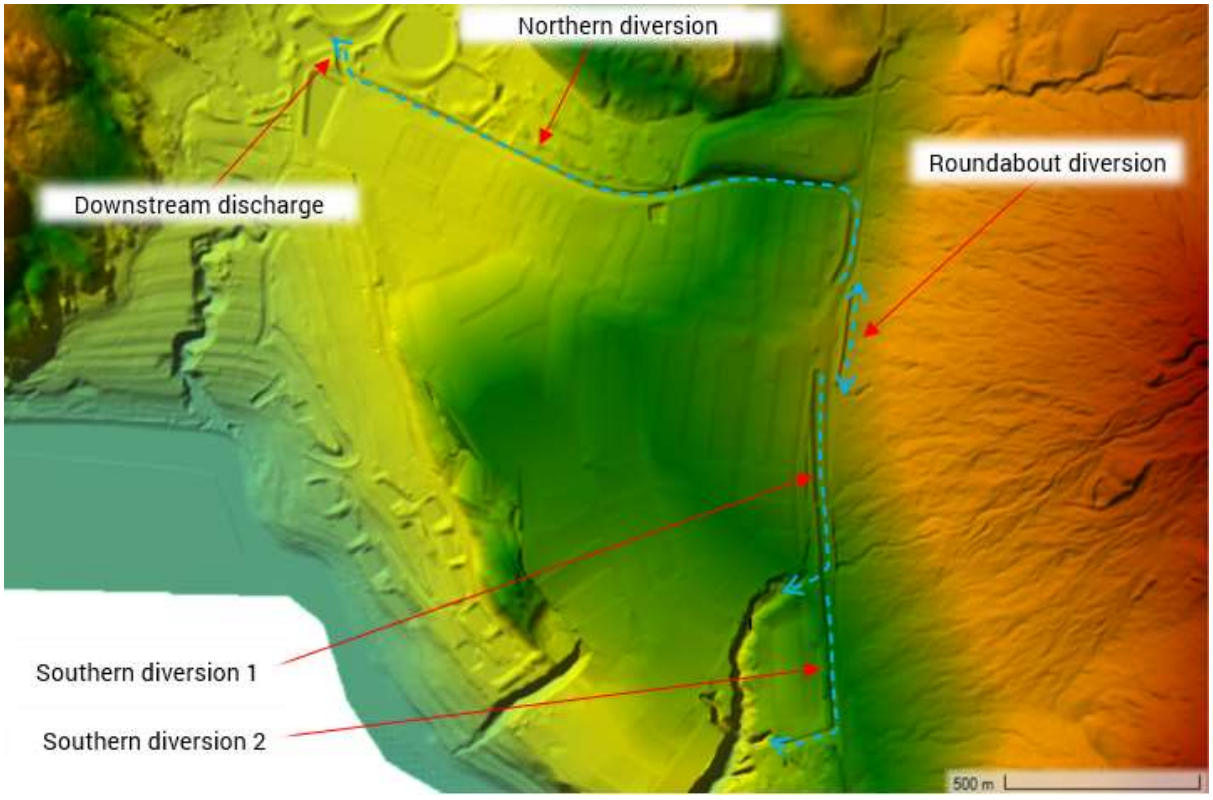

Figure 5.4: Proposed diversion channels as a DEM provided by Stantec.

Debris flood model results for a post-development 100-year ARI event are shown below in Figure 5.6. Additional flood model results showing 250+ year return period events and avulsion scenarios are shown in Appendix F.

Aerial imagery is excluded from post-development flood model results for the post development case to clearly show proposed diversion earthworks and land surfaces within the site.

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For all modelled scenarios, the proposed diversion channels are shown to eliminate external flood hazard in all areas of the site proposed for development. Shallow flow shown in Figure 5.6 within the proposed development areas is due to modelled flow "leaking" out of diversion channels due to the channel embankment high-ground not aligning exactly with computational cell faces. This is not considered to have any effect on the assessment of diversion channel capacity. Inspection of the maximum water surface elevation in the channels showed flow would be entirly contained within the diversion channels for the 100-year event with a minimum of 500 mm of freeboard. An indicative cross section of water surface elevation within the currently proposed northern diversion channel is provided below in Figure 5.5 and futher cross sections are provided in Appendix F.

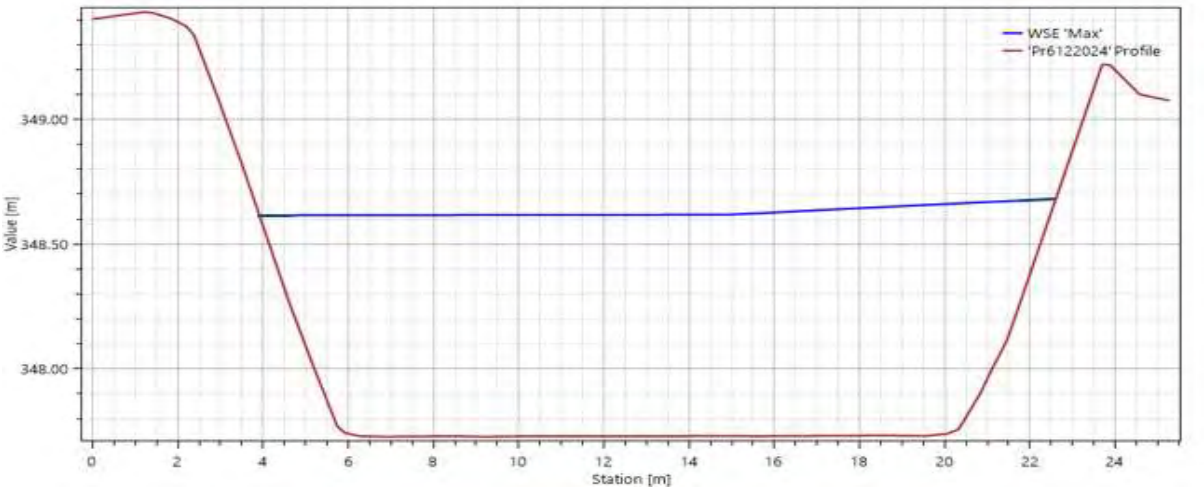

Figure 5.5: Maximum water surface elevation in the currently proposed northern diversion channel, looking downstream (~50 m east of outlet at the western property boundary, (location shown in Appendix F)

In the post-development model results (with flood hazard mitigation measures), higher flood hazard is restricted to the diversion channels, flow path along the northern boundary and the incised southern flow path through the site. No development is proposed in these areas based on provided development plans. Provided development is not undertaken in these areas, the consequence of flooding is assessed as Insignificant for the post-development scenario. As discussed in Section 5.5.2 residential or mixed-use development in these areas is not recommended due to flood hazard.

The anticipated flood conditions (levels, depths and flowrates) along the boundaries have been assessed, both before and after development, and the model results show no adverse impacts on flood hazards affecting the road or neighbouring properties.

No development on the upslope side of Kingston Road is proposed other than earthworks adjacent to the roundabout at the entrance to the development. As a result, post-development flow running south beyond the modelled area in the existing swale on the upslope side of Kingston Road will remain the same as the pre-development flow.

The roundabout is located at the topographical high point of the fan (along the road centreline). As such, development of the roundabout is not considered to increase the risk of road flooding provided appropriate drainage into existing swales and the proposed

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diversion channels is provided for. Detailed design of drainage around the roundabout to be provided by Stantec in stormwater design reporting for the site.

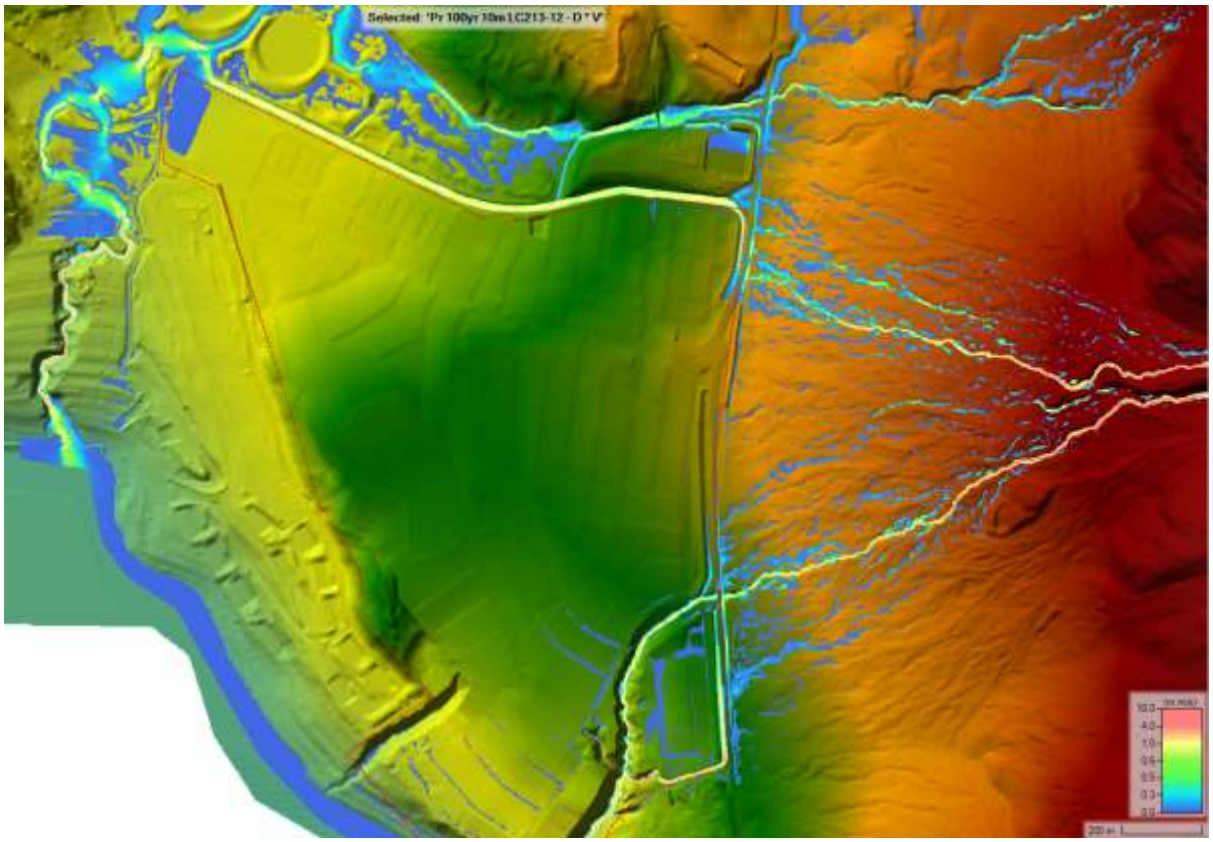

Figure 5.6: Post development debris flood hazard for a 100-year ARI design event with conservative input parameters (Lot 8 boundary shown in red). Note that the <0.1 m depth flow adjacent to channels within the development is considered to be due to minor "leakage" between computational cells, not anticipated to occur.

5.5.4 Post-development Downstream Discharge

The effect of the diversion on downstream hydrological regimes at the northwestern corner of the site was assessed by comparing pre and post development hydrographs. This downstream point of discharge for the site is shown in Figure 5.4.

A comparison of the pre and post development hydrographs produced by HEC-RAS for the 100-year ARI design storm is shown in Figure 5.7. This indicates a ~1.3% increase in peak flow for the post-development discharge. The post-development peak flow from the 20-year design storm was also evaluated and shown to be less than 1% greater than pre-development.

This is considered a less than minor increase from the pre-development hydrological regime even with the very conservative flood flows modelled. An increase of this magnitude is considered to have negligible impact on flooding downstream of the site.

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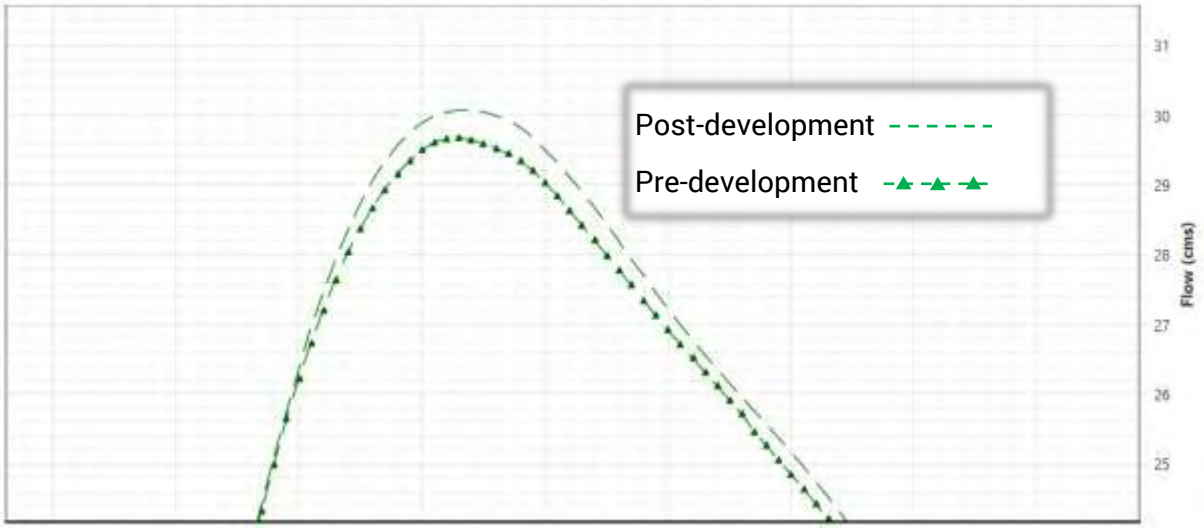

Figure 5.7: Pre-development & post-development 100-year ARI hydrographs. Note that the y axis does not start at 0 as the graph is zoomed to allow the small relative difference in flow to be visible. The x axis is not visible for the same reason.

A relatively high (more conservative) Manning's n value of 0.06 for flow that exceeds 0.1 m in depth has been adopted for both existing flow paths (grass lined or natural stream bed) and proposed diversion channels (grass or rock lined channels). A high Manning's n value is considered appropriate when assessing flow capacity to allow for unknowns such as potential amenity planting or other future obstructions in the channel which may increase flow depth.

Using the same Manning's n value for the pre and post development flow path along the northern boundary is considered appropriate to assess the effect the northern diversion has on downstream discharge at the northwestern corner of the site. The existing flow path is predominantly a smooth grass lined channel as shown in Figure 5.8 below. As such, the Manning's n value of the proposed grass and rock lined diversion channel in this area is expected to be no greater than the existing flow path.

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Figure 5.8: Existing flow path on northern boundary of Lot 8.

The proposed diversion channel below the road in the southeast corner of the site will collect and divert any flow coming over SH6 onto the site into the incised Southern Creek. As a result, there will be no increase in downstream discharge to adjacent properties at this location.

As the proposed diversions have negligible impact on downstream discharges, diversion channels are considered the only form of mitigation required to address alluvial flooding hazard from upstream catchments.

5.6 Alluvial Flooding Hazard Risk Summary

Three likelihood scenarios have been identified for assessment of debris flood hazard as per the methodology in APP6 (Appendix D). The results from all three scenarios are considered in the qualitative risk assessment discussed below.

The primary type of development proposed at the site is residential housing. For this assessment we consider that individual risk to life for residents (at home) is the dominant subset of total risk due to the relatively high occupancy compared to transient population such as people in vehicles or pedestrians. We have used the proposed location of permanent residential population to evaluate consequence for natural hazards impacting the site.

The consequence is conservatively assessed as **minor** to **moderate** without flood mitigation measures as discussed in Section 5.5.2. The flooding risk to the site without mitigation measures is conservatively assessed as **Tolerable** for all likelihood scenarios.

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With the addition of the proposed mitigation measures discussed in Section 5.5.3, the consequence is assessed as **Insignificant** for risk to life and property damage. The flooding risk to the site with mitigation measures is assessed as **Acceptable** for all three likelihood scenarios.

As the qualitative risk level is assessed as **Acceptable** for the proposed development a quantitative risk assessment is not considered warranted for debris flood hazard at this site. It is noted that the assessment of risk from debris flood also covers the risk posed by 'clearwater' flood. Potential risk from debris flow is addressed in Section 6 below.

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6 Alluvial Fan Debris Flow Risk Assessment

6.1 General

An analysis has been undertaken to assess the potential risk debris flow poses to the site. The assessment comprises:

- Review of historic aerial photography and 1m LiDAR.
- A review of the Queenstown Lakes District Council and Otago Regional Council natural hazard register maps.
- A review of information currently held on the GeoSolve database for sites in the local area.
- A walkover and detailed mapping and interpretation of catchment and fan morphology by an Engineering Geologist and a Water Engineer.
- Review of GeoSolve geotechnical reporting and test pits for the site.
- Quantitative evaluation of the catchment to assess volume and run out distance of a debris flow event based on direct observations, empirical relationships from literature, hydrological analysis and 2D numerical modelling in RApid Mass Movement Simulation (RAMMS) Debris Flow.
- Qualitative risk assessment.

6.2 Debris Flow Hazard Processes

Alluvial fan hazards result from potential mass movement and flooding processes in the upslope catchment. The NZGS Slope Stability Guidance[12] (SSG) gives the following summary of these processes:

> *"Clear-water Floods, Debris Floods, Hyperconcentrated Flows, Debris Flows and Debris Avalanches are part of a continuum of processes and are primarily described based on sediment concentration, velocity, typical slope gradient and peak discharge."*

Figure 6.1 below from the SSG shows the general relationship between these processes.

Debris flows are a mass movement process that consists of a fully saturated liquefied mass of water and sediment. Once moving, the mixture of sediment and water behaves as a very dense liquid due to high pore pressure. Therefore, a debris flow is far more mobile than a non-saturated debris avalanche and can travel much greater distances. Debris flows differ from flooding and can be much more destructive for the following reasons:

- Debris flows typically occurred in pulses, with peak flowrates 10-50 times greater than flood flows[12]. As a result, debris flows are capable of retaining greater flow depth and momentum out of incised channels and will not necessarily follow existing flow paths.
- Debris flows typically have 1.67 - 3.5 times the volume of a clearwater flood[12] due to sediment and debris entrainment.
- Debris flows are capable of transporting large boulders and organic debris due to the high density of the fluid component (fine sediment and water).

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- Debris flow may result from the mobilisation of significant entrainable material in the upslope confined channel during a storm, the formation and breach of a landslide dam, or a combination of the above (or other) factors.

However, debris flows have a high viscosity and cohesion compared to normal flooding and will stop when velocity and depth decreases below a certain value. As a result, the estimation of the runout distance is critical to assess the hazard posed from debris flows.

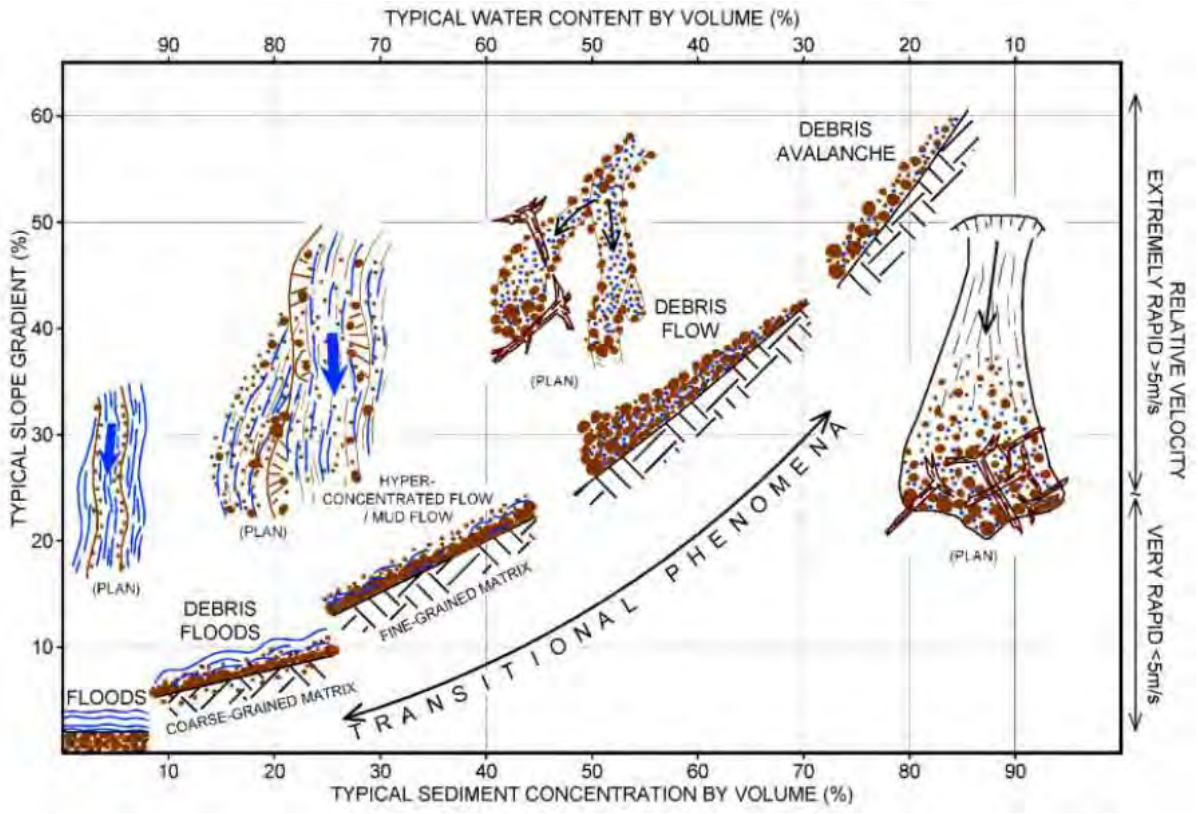

Figure 6.1: Steep catchment hazard processes as a function of sediment/water concentration, channel gradient and velocity.

6.3 Upper Catchments

Site inspection and review of aerial photography indicates numerous historic and recent landslides are evident in the three upslope catchments above the site. Instability typically comprises rock avalanche, rock fall, schist debris landslides, rotational soil failures and shallow soil debris flows. While the landslides do not reach the site, they can reach drainage channels and provide entrainable material for future debris floods or debris flow events.

An inventory of the identified landslides is provided in Appendix B, and the location of each identified landslide is shown on Appendix A, Figure 1b. The landslide inventory includes an assessed lower and upper bound total area of each identified landslide. The lower bound area was typically calculated from the observed existing landslides, while the upper bound area assumed a future total failure of the soil within the mapped area. The upper bound area is considered representative of an unlikely seismic or rainfall event.

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Included in the landslide inventory is an approximate lower and upper bound volume of sediment available to be entrained following a range of significant rainfall and/or seismic events capable of reaching a drainage channel. Coarse sediment clasts (>600 mm) resulting from rock avalanches and rock fall have not been included in the assessed volume of available sediment due to the lack of boulders above this size in the existing debris flow deposits.

For the purpose of assessing the volume of available assessed entrainable sediment, the upper catchments have been grouped into 5 soil zones. The extents and the assessed soil depths of each soil zone are based on site observations, experience from intrusive investigations in similar sites, and a review of aerial photography.

The 5 soil zones are described in Table 6.1 below and have been included for each identified landslide on the landslide inventory in Appendix B.

Table 6.1: Description of 5 soil zones used for the assessment of available fine-grained sediment.

Soil Zone	Description	Assessed Lower Bound Soil Depth (m)	Assessed Lower Bound Soil Depth (m)
A – No Soil	Areas of exposed rock with no soil	-	-
B – Tallus Slopes	Areas of collected debris avalanche and rock debris	0.5	2.0
C – Shallower Soil	Slopes generally above an elevation of 1100 m with some areas below 1100 m	0.5	1.0
D – Moderate Soil	Generally south facing slopes below an elevation of 1100 m.	1.0	2.0
E – Deeper Soil	Generally north facing slopes below an elevation of 1100 m	2.0	3.0

The lower and upper bound soil depths were combined with the lower and upper bound landslide areas to calculate the total sediment available to be entrained following a range of significant rainfall and/or seismic events capable of reaching a channel. The total sediment available from Soil Zone B – Talus Slopes was limited to clasts <600 mm.

The existing sediment within the channels available to be entrained following a range of significant rainfall events was also assessed based on site observations and a review of aerial historical photography.

The availability of sediment available for mobilisation in these catchments is likely to have been higher in the past than currently observed. Typically, increased volumes of material are available in the immediate post glacial period. Slope instability following the loss of ice

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support and the associated changes in overland flow, erosion and deposition processes around the margins of the ice is considered likely to have contributed material to the formation of the alluvial fans.

Intermittent periods of increased material availability can also be expected following a large seismic event, which may trigger instability in the catchment.

Periods of elevated material availability will gradually reduce as the material migrates down through the catchment. The timing of this process will be determined by multiple factors, primarily the size and frequency of the rainfall events following the instability, the location of the instability and the grading of the material.

6.4 Fan Landform

For the purpose of debris flow run-out assessment the hydrographic fan apex is defined as the point where a large debris flow would cease to be confined and spread out across the fan. This is below the topographical fan apex. Fan apexes are indicated below in Figure 6.2. and in Figure 1a, Appendix A.

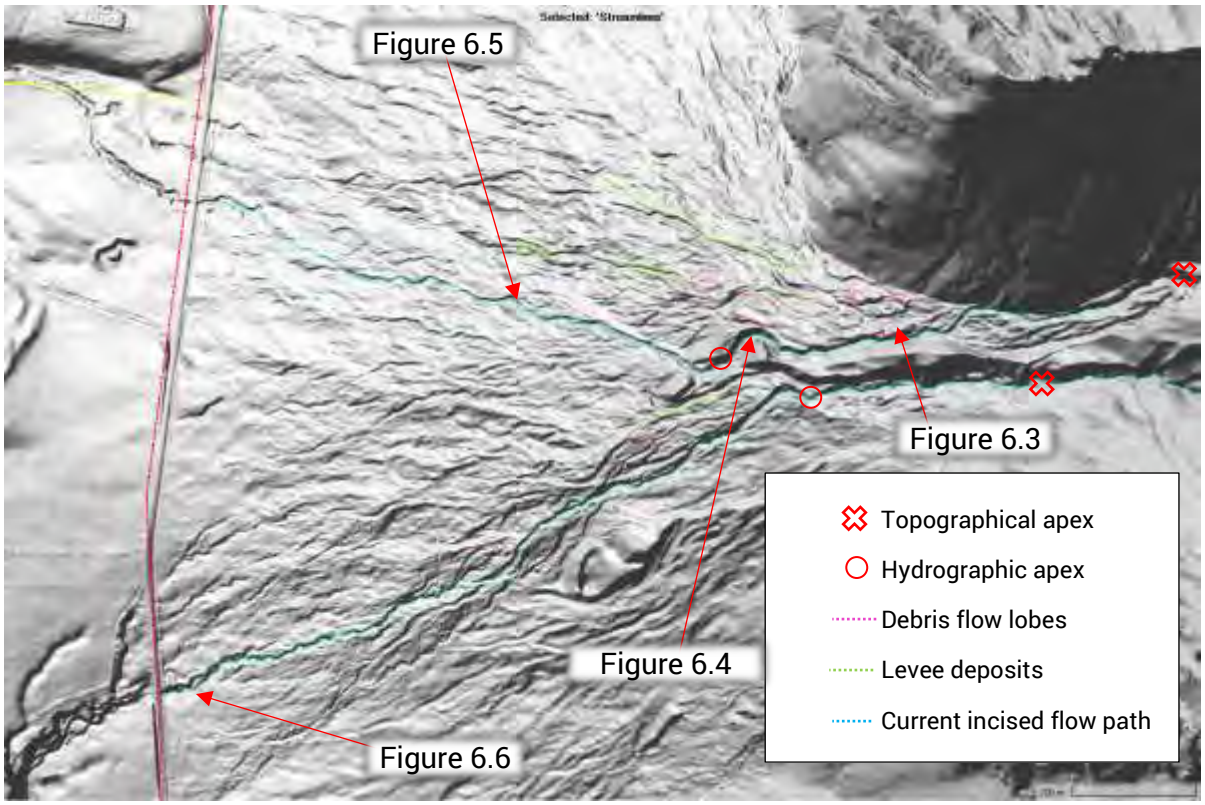

Figure 6.2: Combined Middle Creek and Southern Creek fan landform

There is extensive evidence of large historic debris flow events near the apex of the fans, see Figure 6.3. Coarse grained lobate and ridge-like features characteristic of debris flows can be observed either side of the current primary incised flow paths and paleochannels. Examples of observed debris flow morphology are indicated on Figure 6.2.

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Figure 6.3: Bouldery debris flow lobes/levees near the topographical apex of the fan, looking west.

Topsoil development around the apexes of the alluvial fans is limited to 0.25 - 0.5 m of loess. Well-sorted alluvial deposits are also noticeably absent in exposed outcrops. Angular to sub-rounded boulders are present across the surface and on exposed outcrops, with a trend toward larger more numerous boulders towards the fan apex. Large boulders up to 600 mm in diameter were observed near the fan apex. A site photograph of typical debris flow deposits is shown in Figure 6.4 below. Many boulders observed in debris flow deposits where sub-rounded, indicating these are likely to be glacial deposits remobilised by debris flows. Debris flow deposits are characterised by:

- Lack of stratification and particle sorting.
- Random clast orientation.

The middle of the fan has more subdued topography with predominantly finer sediment on the surface with exposed sub rounded boulders on the surface, see Figure 6.5.

The lower fan (<300 m east of the road) was observed to have a surface more characteristic of fluvial flooding, such as rounded cobbles/gravels and areas of deeper silts/sands (Figure 6.6). This infers the lower fan area to the east of the road, and western fan area that encroaches into the proposed development site, has been formed by processes dominated by alluvial flooding.

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Figure 6.4: Outcrop showing debris flow deposits. Middle Creek ~100 m below hydrographic fan apex.

Figure 6.5: Middle Creek mid-way down the fan looking southeast.

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Figure 6.6: Southern Creek above SH6 looking southeast

Test pits and deep bore holes have been undertaken on the development site (to the west of the road) as part of GeoSolve's geotechnical reporting. No debris flow type deposits were found. This indicates that debris flows are unlikely to have reached the site in the geological past.

Historical runout distances were estimated from direct observation of fan deposits and surface geomorphology. The LiDAR digital terrain model was also inspected to observe fan morphology (Figure 6.2).

As shown in Section 6.5 below the upper fans are steeper than typical floodwater-dominated alluvial fans, while the lower slope angles are consistent with a floodwater dominated fan landform.

6.5 Catchment & Fan Morphometric Assessment

The catchments and fans were assessed based on their Melton Ratio (relationship between catchment slope and area) and topography. These morphometric variables were compared with published[20] values from other schist catchments in the Southern Alps with observed debris flood/flow events, see Figure 6.7.

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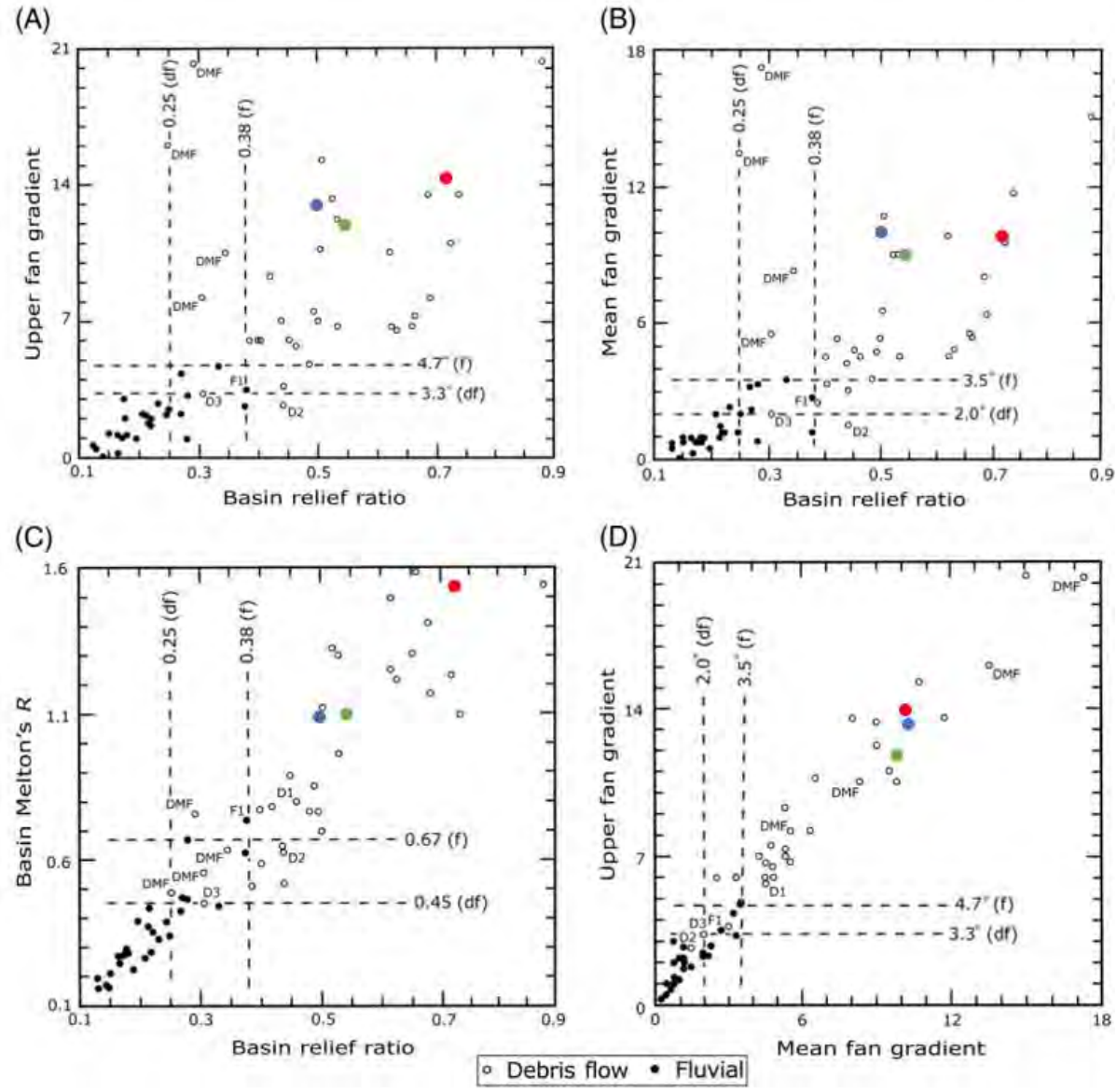

Figure 6.7: Catchment variable comparison with plots of observed debris flood/flow events for schist basins in the Southern alps (De Scally et al[20]) Observed catchment variables from this catchment/fan are shown in: Red = Northen Catchment, Blue = Middle Catchment & Green = Southern Catchment.

The above comparison indicates the upper fans have been formed primarily by debris flow events as opposed to alluvial flooding, while the Melton/relief ratios of each catchment show the upper catchments are likely to be able to produce debris flow events (assuming sufficient debris is available for entrainment during intense rainfall) as well as debris floods or 'clearwater' floods (when less or no debris is available for entrainment in the upper catchment).

[20] De Scally FA, Owens IF, Louis J (2010) Controls on fan depositional processes in the Schist ranges of the Southern Alps, New Zealand, and the implications for debris flow hazard assessment. Geomorphology 122 (2010) 99-116

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6.6 Debris Flow Hazard Likelihood Scenarios

Three likelihood scenarios have been identified for assessment of debris flow risk:

1. Likely (100 years)
2. Possible (100-1000 years)
3. Unlikely (1000-2500+ years)

The use of the relatively high return period events for all debris flow is considered appropriate. This is due to the relative magnitude of debris flow required to present a risk to the site and lack of recent debris flow activity. Shorter return period events were found to be even less likely to reach the site.

6.7 Debris Flow Volume

Potential debris flow volume was calculated based on direct assessment of sediment availability in the upper catchments, as discussed in Section 6.3. The volumes used for modelling are provided in Table 6.2 for each likelihood scenario, i.e. likely, possible and unlikely.

Marchi (2019) presents a statistical analysis correlating debris flow event volume to catchment size. The debris flow volumes for an unlikely event calculated based on available sediment in each catchment is compared with data from Marchi (2019) In Figure 6.4 below. The calculated sediment volumes fall between the 98th and 99th percentiles for the given catchment size. This indicates the assessment of sediment availability is conservative given that site observations show fine erodible sediment is currently relatively limited, and no observations of events of that magnitude in the geological history of the site have been recorded.

A comparison of water volumes available for a 100-year storm (Section 4.9) with the available sediment concludes the catchment is currently sediment limited with regards to debris flow potential even for the conservative sediment volumes estimated for an unlikely event. As such, it has been conservatively assumed that the entire estimated volume of sediment in the upper catchments is feasibly mobilizable and could be entrained during a single event.

No recent debris flow deposits are present of the fan. Observed debris flow deposits may date back as far as the immediate post-glacial period. The fan has undergone post-depositional modification, including erosion, reworking, or burial by later flows. This makes it difficult to compare the current sediment availability volume estimates with historical deposit volume. However, the volume for observed deposits from single debris flow events are approximately estimated to be closer in scale to the estimated ‘Likely’ or ‘Possible’ volumes estimated in Table 6.2.

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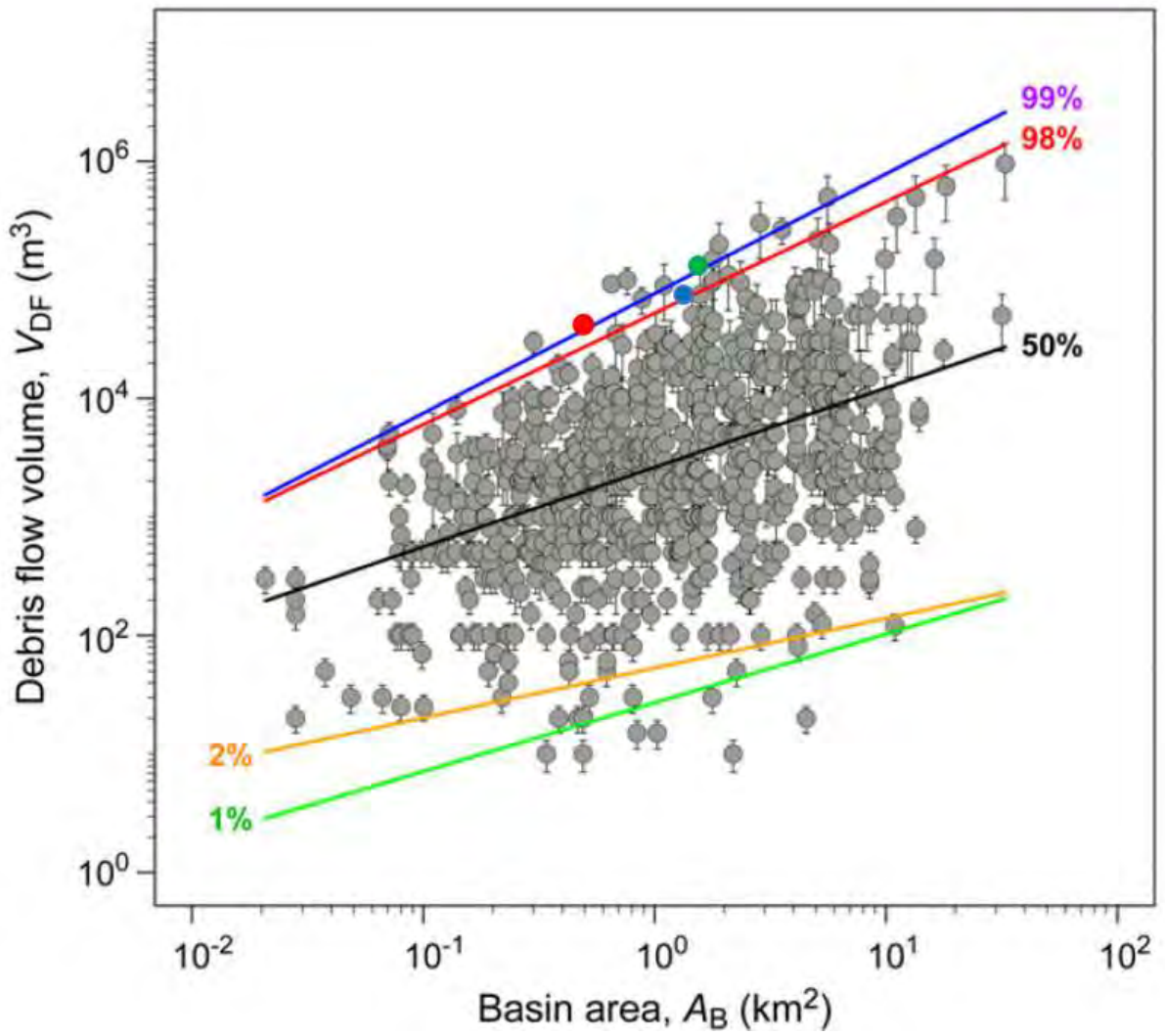

Figure 6.8: Figure 4 from Marchi et al, Relationship between the debris flow volume and catchment area. Assessed volume and area for each catchment are plotted as dots: Red = Northen Catchment, Blue = Middle Catchment & Green = Southern Catchment. Note that the positioning of the catchments' dots on the figure represent how conservative the assumptions being applied to them are compared to the collected data.

6.8 Run-out Distance

Potential debris flow run-out distance was assessed based on the items below:

- Direct assessment of debris flow deposits and geomorphology on the fan (Section 6.4)
- Empirical relationships between the potential debris flow volume and run-out distance from literature (Section 6.8.1)
- 2D numerical modelling in RAMMS (Section 6.8.3)

Results are shown in Table 6.3 and compared with existing QLDC hazard mapping.

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6.8.1 Empirical Run-out Distance Calculations

Runout distances were calculated for the "Unlikely" event volumes using the empirical relationship between debris flow volume and run-out distance given in Equation 3 of Hurlimann et al 2008[21]. This equation predicts a run out distance from the fan apex based on a debris flow volume. While this calculation contains considerable simplifications and uncertainty it does give a useful comparison between observed fan geomorphology on this site and typical debris flow run-out distances.

The calculated runout distances using the above equation (shown in Table 6.3) are consistent with a decrease in observable debris flow landforms and boulder deposits, which contributes to the confidence in the result. The calculated distance is considered to be a useful estimate of run out distance for a debris flow event in the open area of the fan where flow is not contained in significant channels. However, it is not considered to represent an upper bound for runout distance of a more channelised debris flow event such as a debris flow from the southern fan apex to the southern flow path.

6.8.2 RAMMS Model Input Parameters

RAMMS debris flow software has been used to model potential debris flow paths and run-out distances. RAMMS is a numerical simulation model developed to calculate the motion of geophysical mass movements (such as debris flows) from initiation to runout in three-dimensional terrain[22].

RAMMS simulation settings are given below in Table 6.2. A sensitivity check was undertaken for the Voellmy friction coefficients and other parameters within RAMMS. The adopted values and reasoning are given below.

A range of values for the viscous turbulent friction coefficient (ξ) for granular debris flows is given as 100 - 200 (m/s^2) in the RAMMS user manual. The most conservative end of this range (100) was adopted resulting in greater run out distances. Given the lack of recent calibration events this is considered appropriately conservative. Run-out distance was not found to be highly sensitive to this parameter.

The dry-coulomb type friction coefficient (μ) is estimated as $\tan(\alpha)$, where α is the slope angle in the observed deposition zone[22]. The average slope midway between the fan apex and road is ~8.5° for the combined middle/southern fan. This is considered an appropriate value for the deposition zone slope as observable debris flow geomorphology largely ends at or above this point. This slope yields a μ value of 0.15. Runout distance is affected by this parameter. The value used is considered to be appropriately conservative based on detailed assessment of all available information, comparison with empirical runout estimation methods and QLDC/ORC hazard mapping. As a sensitivity check, model results for a μ value of 0.11 are included to simulate a debris flow with a very low friction coefficient (high mobility). This level of mobility is considered unrealistic for a non-channelised granular debris flow.

[21] Hurlimann et al (2008) Evaluation of approaches to calculate debris-flow parameters for hazard assessment
[22] RAMMS (2022) Debris Flow User manual

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The default stopping criteria of 5% was assessed as appropriate based on inspection of model results using the method described in the RAMMS user manual. The default value for density was retained as detailed information of recent debris flow material is not available. Density was not found to strongly affect run-out distance.

Peak flow rate for release hydrographs was taken as 50 x the peak clearwater flow estimated for each flow path at the fan apex. This was judged the most appropriate flow rate given the observed channel sizes. A sensitivity check was undertaken with a value of 10 x the peak clearwater flow rate as a lower bound and a value calculated from Figure 2 of Rickenmann 1999[23] as the upper bound. Runout distance was not shown to be highly sensitive to hydrograph peak flow.

Velocity at release was approximated iteratively based on observed modelled velocity in the channel down slope of the release hydrograph where the degree of confinement and slope is similar to the release point. Runout distance was not shown to be highly sensitive to hydrograph peak flow.

The volumes and above parameters used are considered to represent conservative values appropriate for a new development risk assessment.

[23] Rickenmann D (1999) Empirical Relationships for Debris Flows

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Table 6.2: RAMMS simulation release settings, including volumes

Parameter	Catchment	Value		
DEM resolution (m)	All	1		
Simulation Resolution (m)	All	1		
Lambda	All	1		
Constant density (kg/m^3):	All	2000		
μ	All	0.15 & 0.11		
ξ (m/s^2)	All	100		
Yield Stress	All	n/a		
Erosion	All	n/a		
Curvature	All	On		
Stopping criteria (momentum threshold) (%):	All	5%		
Simulation stopped due to;	All	LOW FLUX		
Release type	All	Hydrograph		
Inflow direction (degrees)	North	190		
	Middle	195		
	South	180		
Volume (1000 m^3) (likely, possible, unlikely scenarios)	North	3,930	10,200	44,300
	Middle	6,200	18,250	69,000
	South	16,450	40,250	126,500
Peak flowrate (m^3/s) (unlikely)	North	230		
	Middle	560		
	South	635		
Time to peak (seconds)	All	10		
Velocity at release (m/s)	All	6		
Release duration (mins) (likely, possible, unlikely)	North	6.4		
	Middle	4.1		
	South	6.64		

6.8.3 RAMMS Model Results

Results for the unlikely events are shown below in Figure 6.9 & Figure 6.11, with the site boundary in red. As shown, even the conservative Unlikely debris flow events for the Northern catchment do not reach the road. This is consistent with field geomorphic mapping, empirical assessment of run-out distance and existing hazard mapping (Figure 3.3 & Table 6.3)

For the Middle and Southern catchments, a debris flow event reaching the road is shown to be feasible for the conservative Unlikely event, but only when a very high mobility is assumed in modelling. In addition, significant flow depths are predicted to be confined to the primary channel at the road. Flow is also shown to not run onto site even without the flow diversions/flood mitigation measures proposed in Section 5.

Events smaller than the 1000-2500+ year ARI 'Unlikely' event are not presented as they do not pose a hazard to the site. For the same reason the Unlikely debris flow events are considered as the worst-case scenario for assessment of risk to the site from debris flow.

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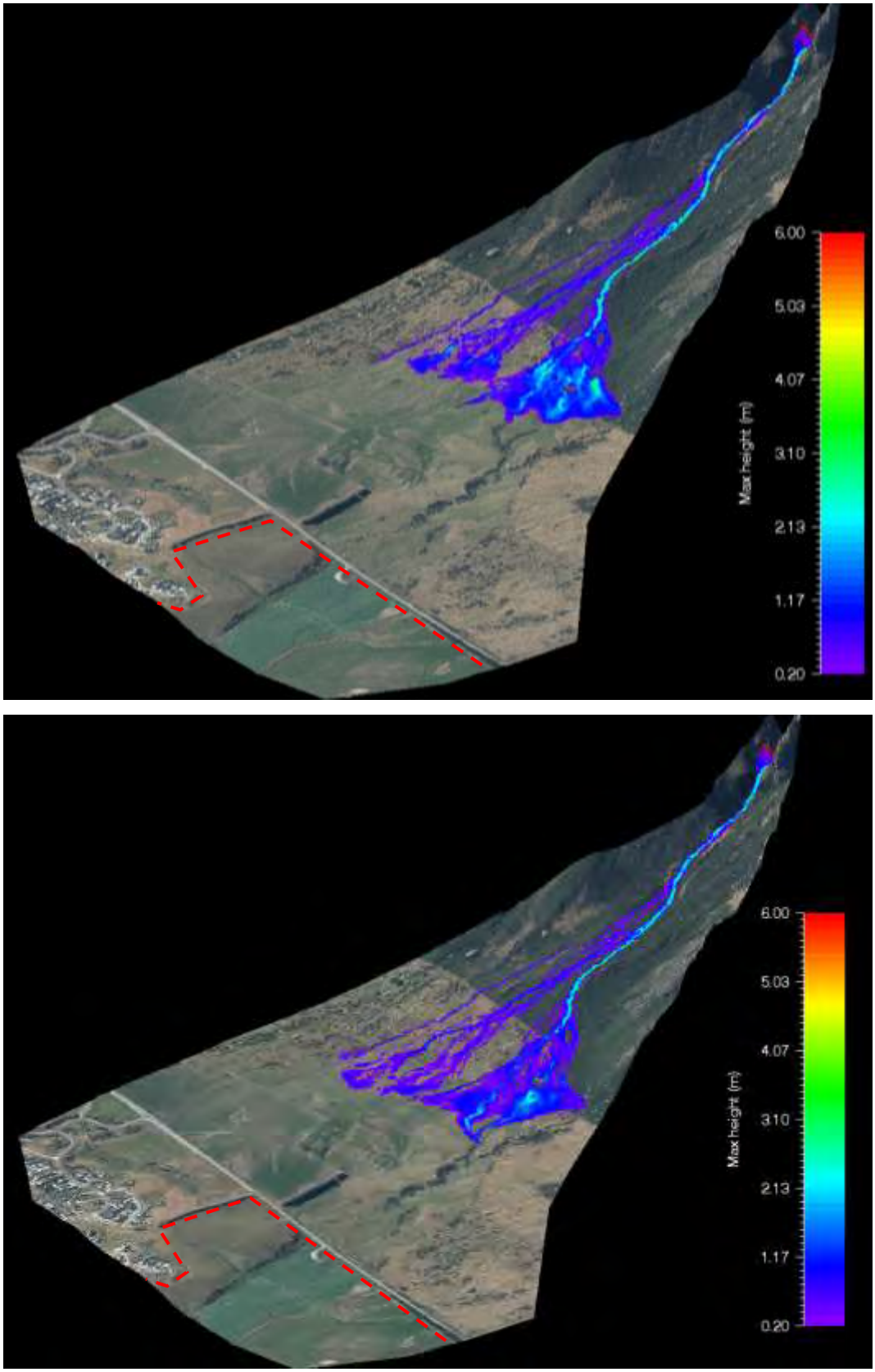

Figure 6.9: RAMMS result showing maximum depth of an unlikely debris flow event released from the Northern fan apex with a dry-coulomb type friction coefficient (μ) of 0.15 (top) & 0.11 (bottom).

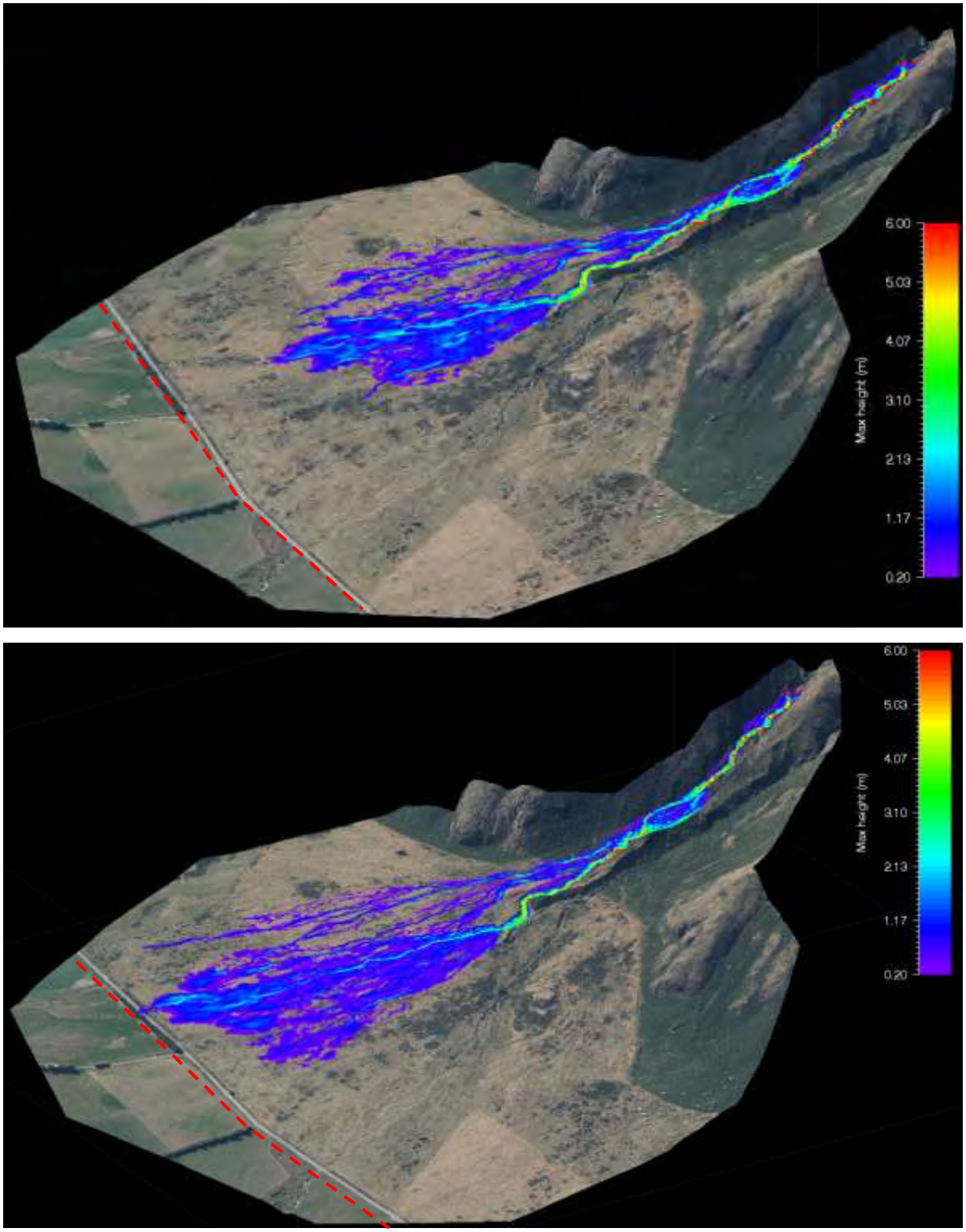

Figure 6.10: RAMMS result showing maximum depth of a unlikely debris flow event released from the Middle fan apex with a dry-coulomb type friction coefficient (μ) of 0.15 (top) & 0.11 (bottom).

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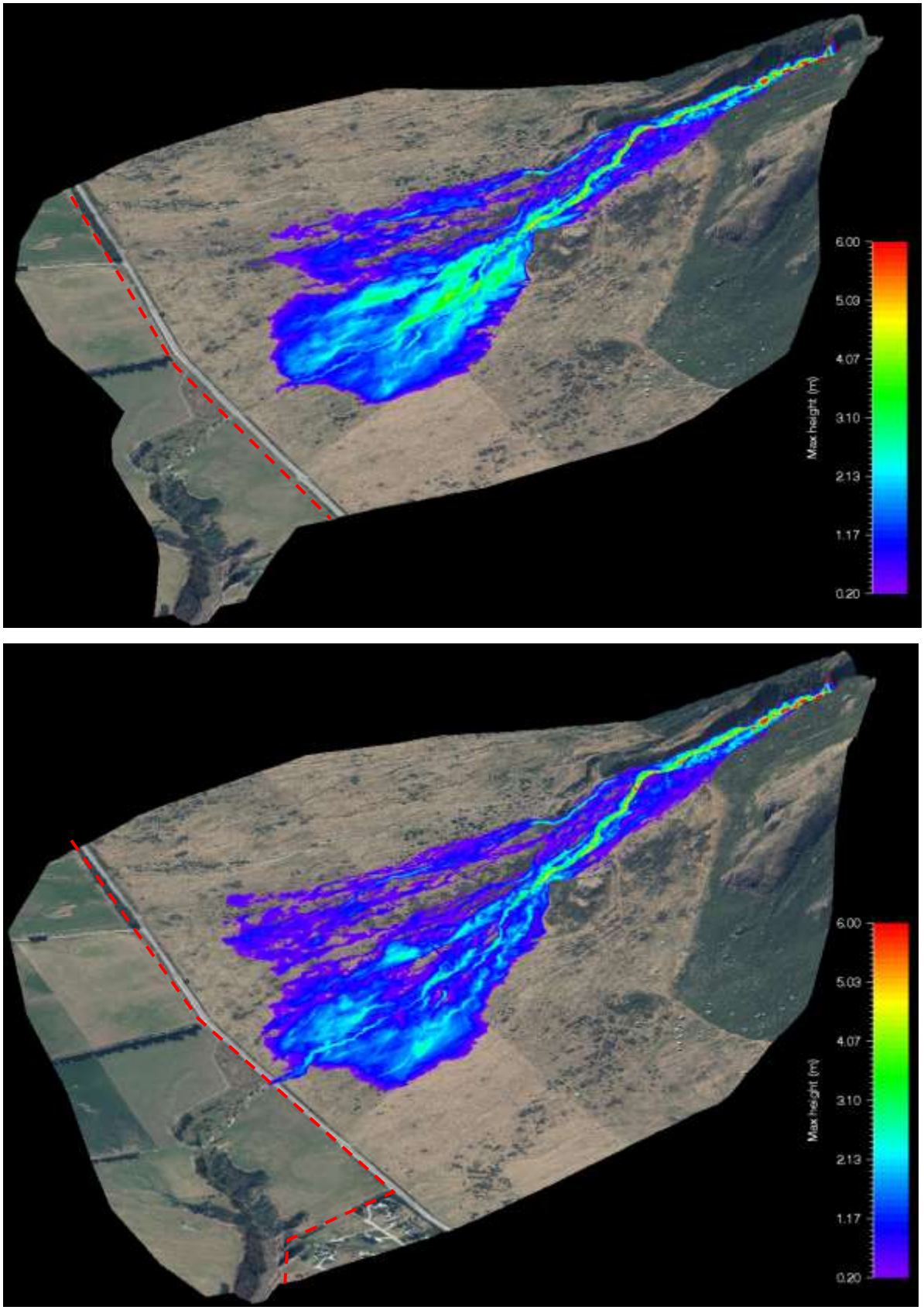

Figure 6.11: RAMMS result showing maximum depth of a unlikely debris flow event released from the southern fan apex with a dry-coulomb type friction coefficient (μ) of 0.15 (top) & 0.11 (bottom).

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As shown in the results above and Table 6.3 below the results for an unlikely event modelled in RAMMS with a μ value of 0.15 is consistent with or more conservative than site observations, regional scale hazard mapping and empirical estimates of run-out distances.

Table 6.3: Debris Flow run-out distance Summary

Release point	Maximum runout distance for an unlikely event (distance to site)			
	Direct observation	Hazard mapping	Empirical	RAMMS, u=0.15
Northern fan apex	~800 m	~1200 m	531 m	850 m (600 m)
Middle fan apex	~500 m	~650 m	616 m	650 m (250 m)
Southern fan apex	~700 m	~1000 m	754 m	1150 m (130 m)

The above results represent a debris flow event with rheology reflecting a high sediment concentration. Relatively minor hyper-concentrated (muddy) flows beyond the runout distances shown are possible. However, these are considered to be accounted for in the conservative debris flood model results and flood mitigation measures presented in Section 5 above.

6.9 Debris Flow Hazard Risk Summary

Three likelihood scenarios have been identified for assessment of a debris flow hazard. The results from all 3 scenarios are considered in the qualitative risk assessment discussed below.

As the Likely and Possible events are not shown to reach the road for any flow path, the hazard resulting from the **Unlikely** event is used to assess the consequence.

For debris flows originating from the northern fan apex, the consequence is assessed as **insignificant** as the debris flow is not shown to reach the site. As a result, the risk from this flow path is assessed as **Acceptable**.

An **Unlikely** debris flow originating from the Middle and Southern fan apex is shown to stop at or above the site boundary. In addition, significant depth is present only in the immediate vicinity of the channel immediately upstream of the road. The consequence is assessed as **insignificant**.

The road is shown to dissipate residual flow momentum, and the flood diversion channel and bunds proposed in Section 5 will provide additional protection to the development. However, the risk from debris flow is considered **Acceptable** with or without proposed mitigation measures.

As the qualitative risk level is assessed as Acceptable a quantitative risk assessment is not considered warranted for debris flow hazard at this site.

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7 Rock Fall Risk Assessment

7.1 General

The potential for rock fall has been identified from the Remarkables east of the site. A rock fall hazard assessment has therefore been completed. Three assessment methods have been undertaken including, rock fall debris runout mapping, a shadow angle empirical assessment and 3D Rock Fall Analysis using RAMMS (RApid Mass Movement Simulation) modelling software.

Photo 7.1: Photo looking east from the Homestead Bay development showing the Remarkables.

7.2 Geomorphology and Rock Outcrop Mapping

The eastern site boundary is approximately 1 km from the toe of the steeply sloping Remarkables mountain range. The western face of the Remarkables range contains terraced rock bluffs of significant height with numerous rock fall source areas.

The unweathered rock mass was observed to typically comprise grey to dark grey, moderately strong, semi-pelitic schist. The exposed surface of the rock mass was typically slightly weathered, especially along defects, but the rock is not significantly weakened.

The topography between the toe of the Remarkables range and the site is an alluvial fan feature sloping towards the site at approximately 12° at the fan topographic apex and 4° at the fan distal margins.

The western face of the Remarkables comprises three main ridgelines which trend approximately east to west. Several smaller ridgelines are also present with the same general trend.

The southern side of the ridgelines slopes with the foliation towards the south at approximately 35°. The gradient increases to approximately 50 ° at higher elevations.

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Sub-vertical defects, perpendicular and parallel to the foliation have interacted causing several ‘wedge’ style failures observable on the southern sides of the ridgelines. Similar interactions between the joint sets and foliation have occurred to form the steeper slopes at higher elevation, where the reduced soil thickness and increased exposure to freeze/thaw weathering resulted in a reduced defect spacing.

Photo 7.2: Site photo showing an example of a ‘wedge’ style failure on the south facing slopes of the middle catchment.

Large areas of accumulated rock fall debris are present at the base of the failures.

In contrast the northern sides of these ridgelines generally slope at approximately 50°, however are dominated by subvertical cliff faces caused by historic and on-going toppling failures of the rock mass. Figure 7.1 below shows an idealised ground model through the ridgelines.

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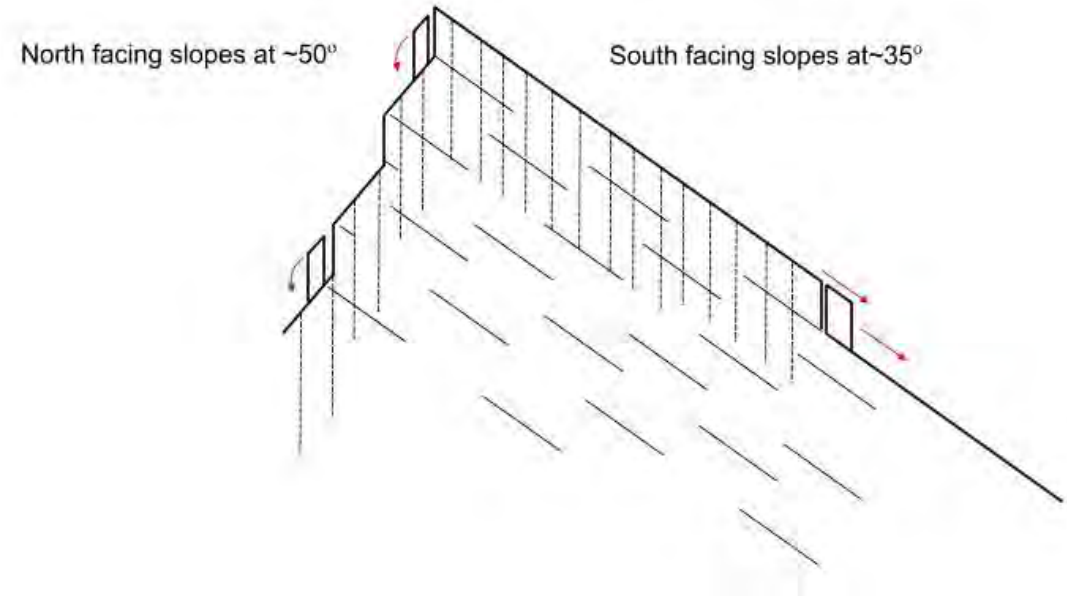

Figure 7.1: Sketch showing the joint set and foliation interactions creating the northern and southern slopes of the main ridgelines.

7.2.1 Rock Defects

Persistent rock defects (foliation and joints) are present in the rock mass as identified by site inspection and historical aerial photography. Table 7.1 below lists the identified main defect sets. Due to the difficulty in undertaking close inspection the list is not considered exhaustive.

Table 7.1: List of observed defect sets.

Defect Set Type and Number	Observed Dip Angle Range (degrees)	Observed Dip Direction Range (bearing)	Average Observed Dip Angle (degrees)	Average Observed Dip Direction Angle (bearing)	Observed Defect Set Spacing (m)
Foliation (F)	37-58	204-208	46	205	
Joint Set 1 (JS1)	73-80	231-269	78	249	
Joint Set 2 (JS2)	83-85	272-285	84	277	1 to 6
Joint Set 3 (JS3)	66-68	261-275	67	268	
Joint Set 4 (JS4)	35	251	35	251	
Joint Set 5 (JS5)	85-87	330-340	86	335	

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7.2.2 Rock Fall Source Areas

Due to the difficulty in undertaking close inspection of the steep slopes a basic terrain analysis using LiDAR data (Otago – Queenstown LiDAR 1m DEM 2016) extracted from the LINZ Data Service was undertaken to identify the most likely locations of potential rock fall sources.

The rock fall sources were inspected using a combination of remote site inspection (typically with the use of binoculars due to the access difficulties) and a review of historical aerial photography.

Three separate rock fall sources have been identified:

1. All outcrops – all areas of exposed rock and boulders within the catchment, including the 'pinnacles' described below.
2. Talus Slopes – areas of rock fall debris collected on steep slopes typically below large outcrops.
3. 'Pinnacles' – large, steep, protruding rock outcrops typically associated with the upper elevations of the catchment.

Photo 7.3: Site photo showing examples of the 'Pinnacles' rock fall source.

The three identified rock fall source area locations are shown of Appendix A – Figure 2b.

7.3 Rock Fall Debris Runout Mapping

The distribution of rock fall debris boulders has been mapped using a combination of site observations and a review of publicly available historical aerial photography.

No evidence of rock fall debris was observed inside the Homestead Bay development site. The site has been farmed since publicly available aerial photos began (1959) and it is possible that boulders may have been removed to facilitate farm work.

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The site is separated from the nearest rock outcrops by a minimum of 1 km of farmland. The farmland is scattered with boulders, which extend to within approximately 100 m from the site eastern boundary.

As shown on Figure 7.2, the boulders assessed to be the result of rock fall extend to approximately 450 m from the site eastern boundary. The number of rock fall debris boulders observed generally reduces with distance from the rock outcrops. There is little evidence in the historic aerial photographic record of widespread clearing or reworking of the farmland.

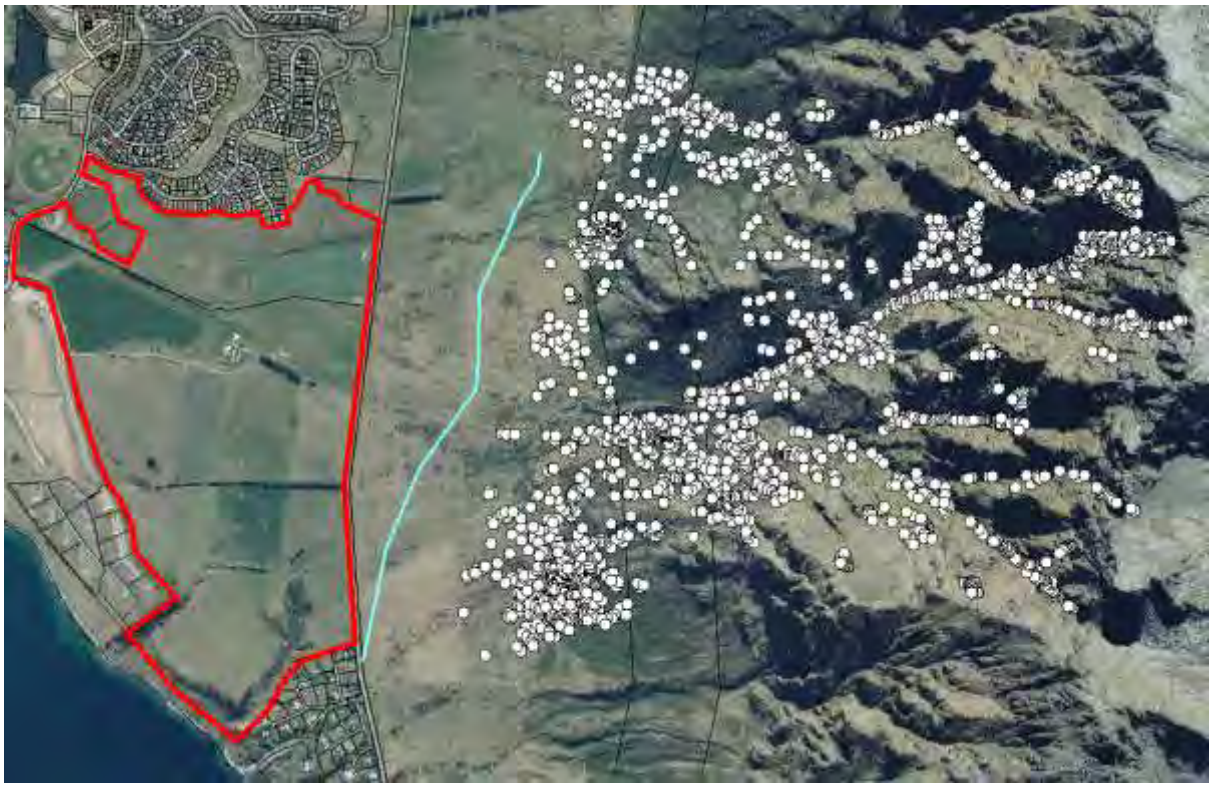

Figure 7.2: Plan showing the location of the observed rock fall debris boulders in white. The site boundary is shown in red. The 21-degree shadow angle line is shown in blue.

The majority of the rock fall debris in the upper catchment was observed to have collected in the numerous channel and gully features (topographic funnelling). These channels are have significant influence on the run-out direction of rock fall debris.

Mapped fallen boulders from the source area bluffs typically ranged in size from 0.5 – 10 m³ in volume and are elongated to tabular in shape. No rounded rock fall debris, other than those weathered since coming to rest were observed. Isolated larger boulders were also identified and for the purposes of this assessment were assessed to be up to 25m³. Very large rock fall boulders are located 420 metres upslope from the eastern boundary of the site, part of the “Jardines Boulders” climbing area.

In summary, based on the site observations and review of historic aerial photography, there is no evidence that rock fall debris has historically reached the site.

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7.4 Rock Fall Shadow Angle

Determining the shadow angle footprint provides an empirical method to assess the expected downslope limit of rock fall runout[24]. The shadow angle is the angle of a straight line between the highest point of the talus slope and the stopping point of the longest runout boulder for a given rock fall. A minimum shadow angle of 21° is recommended.

The shadow angle has been assessed for the site. As shown on Figure 7.2, the 21° shadow angle from the closest source areas to the site is located between approximately 45 and 500 m upslope of the eastern site boundary.

The 21° shadow angle either generally matches or exceeds any observed rock fall debris. The shadow angle of the observed rock fall debris ranges between 22° and 27°.

The shadow angle assessment method indicates that the site is unlikely to be affected by rock fall.

7.5 3D Rock Fall Analysis

A 3-dimensional rock fall analysis has been completed using RAMMS (RApid Mass Movement Simulation). This analysis was used to simulate hypothetical rock fall across several rock fall scenarios and considers the influence of the site topography and surface coverage. The aim of this assessment is to identify the potential rock fall trajectories and run out distances in relation to the site.

The modelled run out trajectories and distances were verified against the site observations discussed in Section 7.3.

7.5.1 Rock Fall Scenarios

In accordance with APP6 and as discussed in Appendix D, three likelihood rock fall scenarios have been identified for seismically driven rock fall and rainfall driven rock fall based on the observations described in Section 7.2. The six scenarios identified are described in Table 7.2 below.

[24] Massey et al. 2014. Determining rockfall risk in Christchurch using rockfalls triggered by the 2010 – 2011 Canterbury earthquake sequence. Earthquake Spectra. 30(1):155-181.doi:10.1193/021413eqs026m.

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Table 7.2: Identified seismically and rainfall driven rock fall scenarios.

Rock Fall Scenario	Description	Assessed Frequency and Liklihood*	Assessed Boulder Volume Range (m^3)	Assessed Boulder Source Area
Seismic 1	Small to medium sized boulders failing along foliation and defect sets including the more weathered surficial boulders	1/50 years (Almost certain)	1 to 10	All outcrops
Seismic 2	Boulders failing along unweathered joint sets	1/500 years (Possible)	5 to 25	All outcrops
Seismic 3	Complete failure of protruding outcrops at higher elevations	1/2501 years (Unlikly)	100 to 250	'Pinnacles'
Rainfall 1	Frittering (or freeze/thaw) of weathered outcrops and remobilisation of smaller talus slope debris	1/25 years (Almost certain)	0.2 to 1	All outcrops and talus slopes
Rainfall 2	Soil failure causing debutressing of outcrops, remobilsation of larger talus slope debris, partial collapse of weathered rock mass including freeze/thaw	1/500 years (Possible)	5 to 25	All outcrops and talus slopes
Rainfall 3	Total collapse of weathered rock mass	1/2501 years (Unlikly)	5 to 100	All outcrops
*Liklihood in accordance with Table 6 of APP6.				

7.5.2 RAMMS Model Details

The 6 rock fall scenarios were modelled in 5 RAMMs analysis using the characteristics of the rocks created in the RAMMS Rock Builder, as shown in Table 7.3 below.

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Table 7.3: Summary of RAMMS Analysis Models

RAMMs Analysis #	Rock Fall Scenarios Modelled	Rock Fall Source Areas	Boulder Boulder Range (m^3)*	Boulder Shape
1	Rainfall 1	All rock outcrops and talus slopes	0.1 to 1	Mostly Flat with some Long
2	Seismic 1	All rock outcrops	1 to 10	Mostly Flat with some Long
3	Seismic 2 & Rainfall 3	All rock outcrops	5 to 25	Flat, Long
4	Seismic 3	'Pinnacles'	100	Flat, Long
5	Rainfall 2	All rock outcrops and talus slopes	5 to 25	Flat, Long, Semi-Rounded
*Ramms has maximum boulder volume of 100 m^3 that can be modelled therefore boulders greater than this are not included in the analysis.				

The slope terrain material was modelled using the RAMMS predefined terrain categories. The slope terrain materials were defined using the RAMMs User Manual and by completing sensitivity checks across a range of materials.

This assessment assumes no vegetation is present. It is often difficult to predict the influence of vegetation on rock fall runout, bounce heights and energies. Therefore, a more conservative, vegetation free approach has been taken. This approach also allows for future unplanned removal of the vegetation, e.g. by fire.

A summary of the RAMM simulation settings and the characteristics of each rock created for the RAMM simulations has been included in Appendix C.

7.5.3 RAMMS Results

The modelled rock fall trajectories for the analysis described above are shown below.

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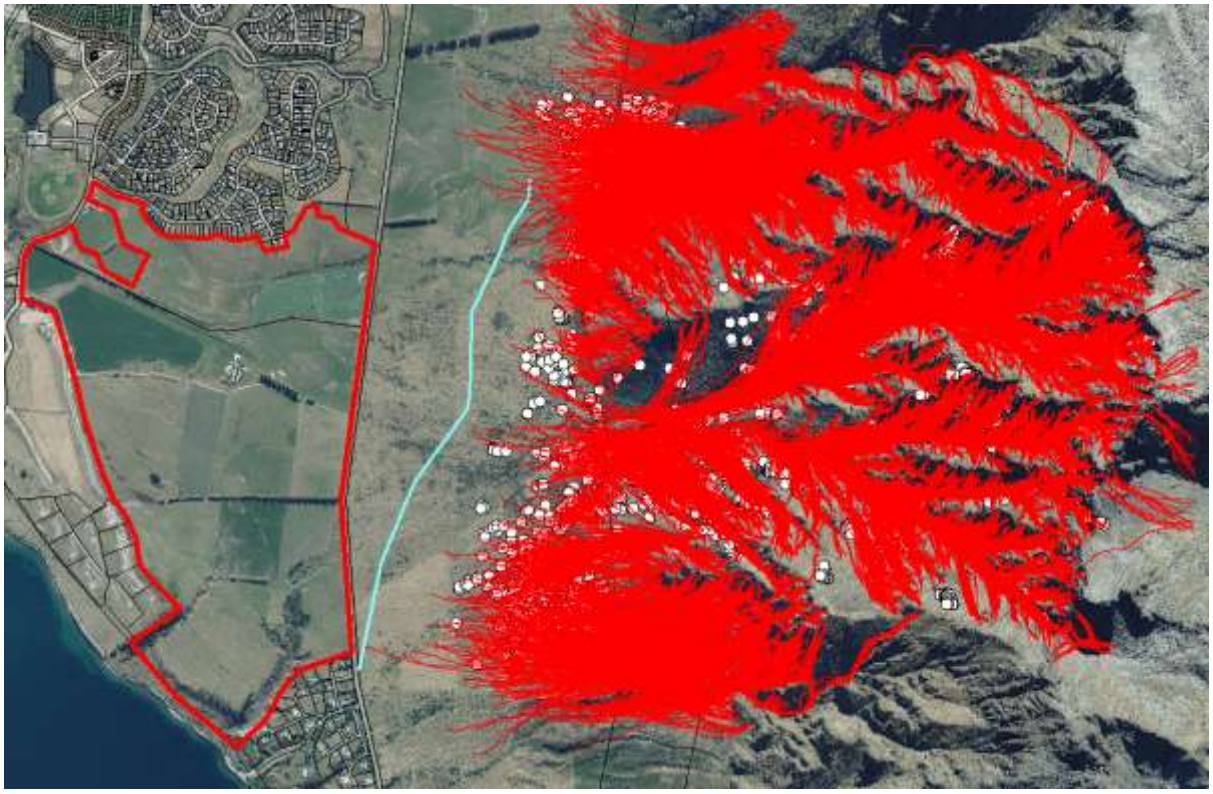

Figure 7.3: Modelled rock fall trajectory results (Analysis 1) including the proposed development area (red), the 21degree shadow angle (blue) and the mapped rock fall debris boulders (white dots)

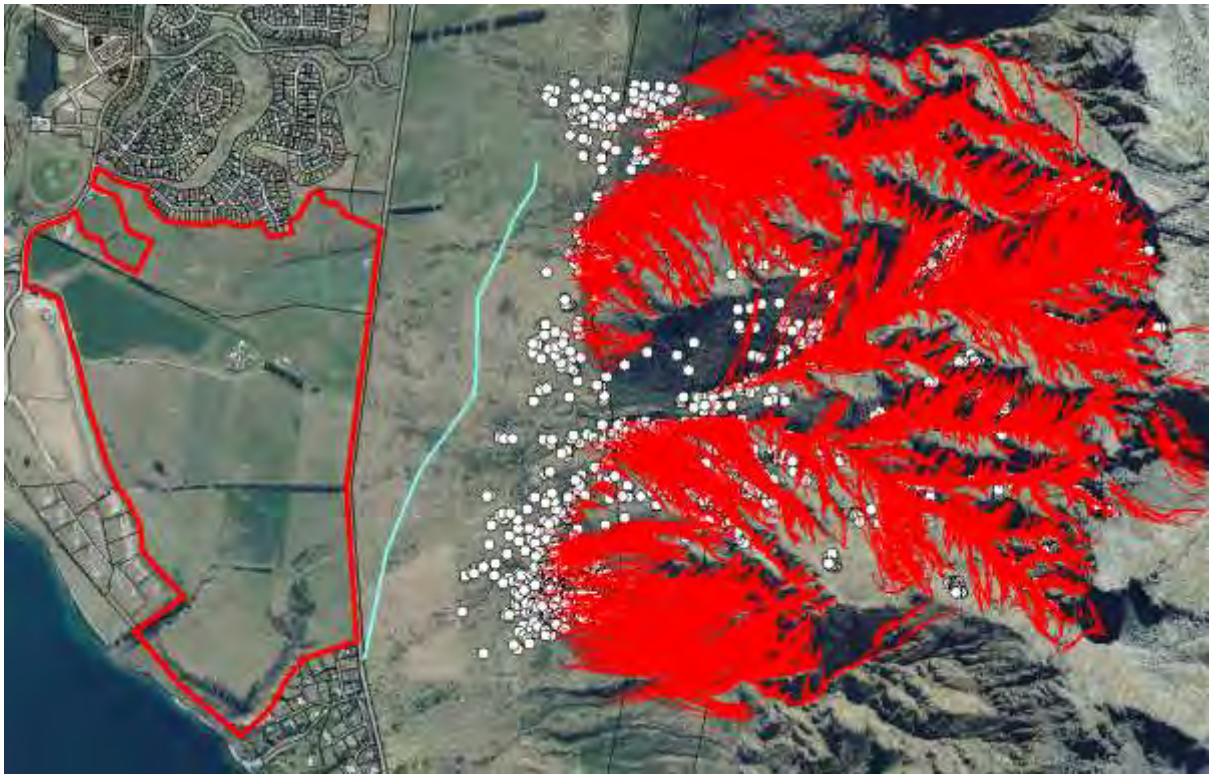

Figure 7.4: Modelled rock fall trajectories results (Analysis 2) including the proposed development area (red), the 21degree shadow angle (blue) and the mapped rock fall debris boulders (white dots)

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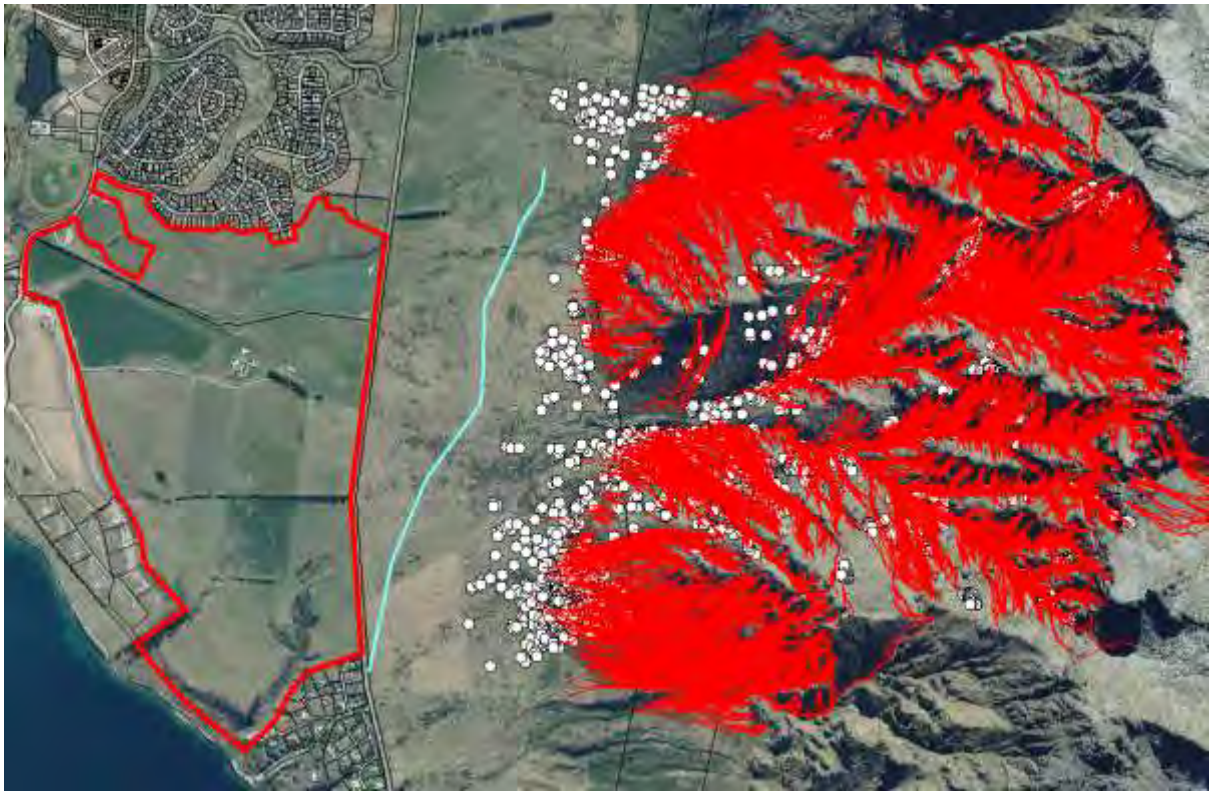

Figure 7.5: Modelled rock fall trajectories results (Analysis 3 & 5) including the proposed development area (red), the 21degree shadow angle (blue) and the mapped rock fall debris boulders (white dots)

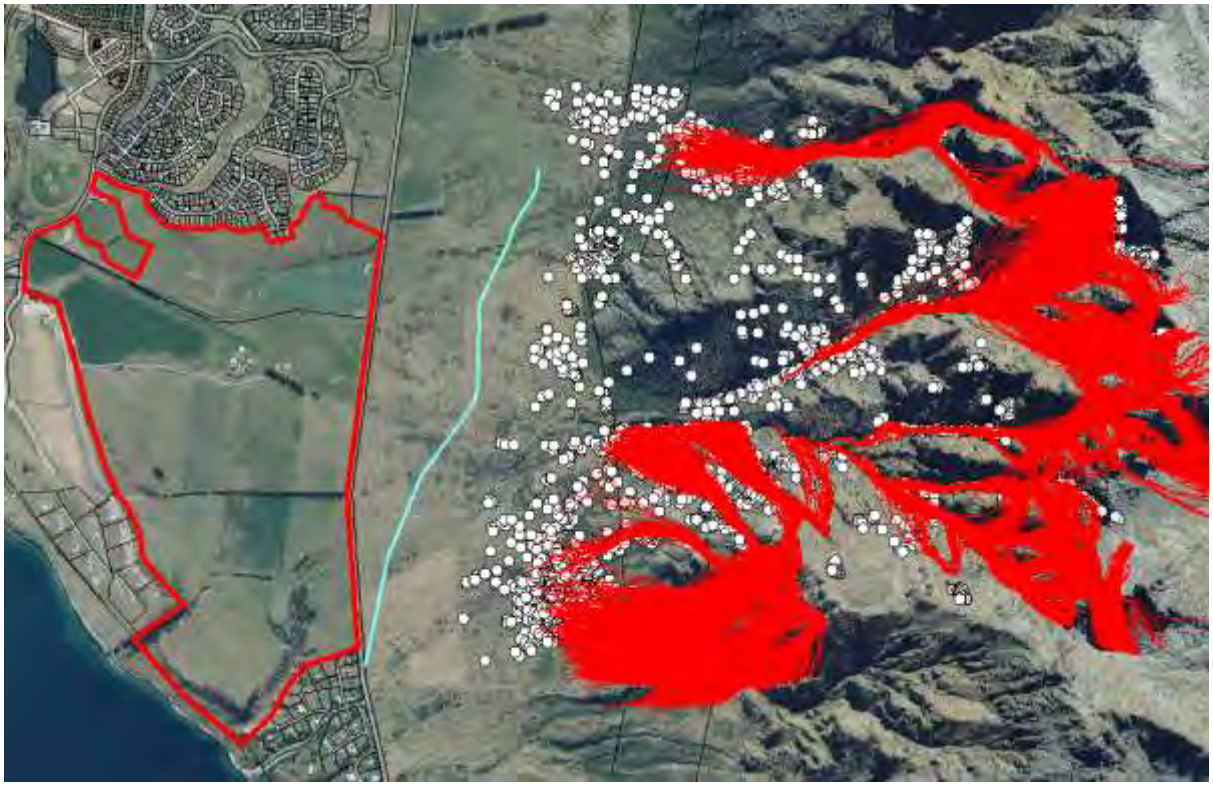

Figure 7.6: Modelled rock fall trajectories results (Analysis 4) including the proposed development area (red), the 21degree shadow angle (blue) and the mapped rock fall debris boulders (white dots)

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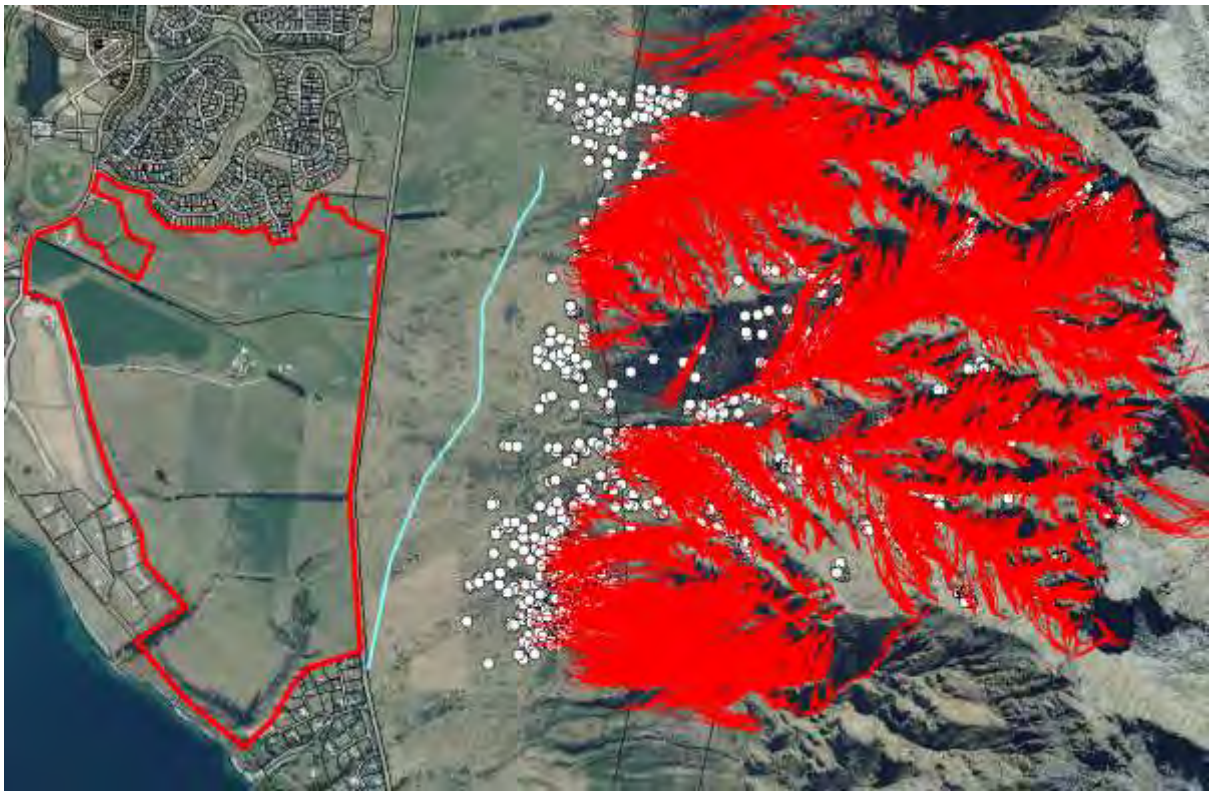

Figure 7.7: Modelled rock fall trajectories results (Analysis 5) including the proposed development area (red), the 21degree shadow angle (blue) and the mapped rock fall debris boulders (white dots)

The 3D RAMMS modelling shows that no rock fall trajectories will enter the eastern site boundary. The modelling is in agreement with the field geomorphic mapping and the empirical shadow angle assessment.

7.6 Qualitative Risk Assessment

A qualitative risk assessment has been completed in accordance with the guidance provided in the risk matrix framework set out in APP6.

Table 7.4: Rock fall runout summary

Minimum distance between rock fall debris runout and site		
Direct observation	Empirical	RAMMs
~450 m	45 m	55 m

All three methods described above indicate that rock fall runout will not reach the site. The potential consequence of a rock fall event to the proposed development is therefore assessed to be insignificant. Table 7.5 below summaries the qualitative risk assessment for each of the six rock fall scenarios described in Section 7.5.1.

Table 7.5: Summary of qualitative risk assessment based on the guidance provided in APP6

Rock Fall Scenario	Assessed Liklihood	Assessed Consequence	Assessed Risk based on APP6
Seismic 1	Almost Certain	Insignificant	Acceptable
Seismic 2	Possible	Insignificant	Acceptable
Seismic 3	Unlikly	Insignificant	Acceptable
Rainfall 1	Almost Certain	Insignificant	Acceptable
Rainfall 2	Possible	Insignificant	Acceptable
Rainfall 3	Unlikly	Insignificant	Acceptable

7.7 Rock Fall Hazard Risk Summary

Based on the rock fall assessments described above and the qualitive risk assessment the rock fall risk at the site is considered Acceptable in accordance with APP6. No further assessment of this hazard is considered necessary for the proposed development.

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8 Debris Avalanche Hazard

8.1 General

Cliff collapse is defined as a type of slope instability involving multiple boulders which inundate the ground beneath simultaneously in an event called a debris avalanche.

Historic and active slope instability in the form of cliff collapse has been identified in 2 locations at the western end of ridgelines that extend west from the Remarkables. The two areas are identified as the:

Northern Cliffs

Southern Cliffs

Both cliffs generally face west. The cliff locations are shown on Appendix A, Figure 1a. Both cliffs were mapped using a combination of site inspection (typically with the use of binoculars due to the access difficulties) and a review of historical aerial photography.

As discussed in Section 7.2, site observations of the cliff faces and other rock outcrops across the assessment area show the potential for high volume instability events to occur at high return periods (greater than 1/2500 years). The risk posed by a debris avalanche to the site has therefore been assessed.

8.1.1 Trigger Events and Return Periods

The timing of the last significant cliff collapse of both cliffs described below is unclear. Cliff collapse events are expected to have been largest in magnitude and most frequent in the immediate post glaciation period and have reduced in size and frequency since then. A key trigger for cliff collapse is expected to be a close proximity seismic events. The nearest known active Faults are the NW Cardrona Fault and the Nevis Fault Zone located 20 km east of the site[25]. These faults are assessed to have calculated recurrence intervals (RI) of 5,500 and 9,000 years. The Alpine Fault is approximately 100 km to the northwest and has a calculated (RI) of approximately 290 years. The cliffs will have been subject to many Alpine Fault movements since ice retreat. An Alpine Fault movement will subject the Queenstown area to strong and prolonged ground shaking, however, geomorphic evidence suggests the frequency of debris avalanche occurrence is less than the RI of the Alpine Fault.

[25] General distribution and characteristics of active faults and folds in the Queenstown Lake and Central Otago Districts, Otago. GNS Science Consultancy Report 2018/17, March 2019.

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8.2 Northern Cliffs

8.2.1 General

The Northern Cliffs are located at the end of the ridgeline which separates the northern and middle catchments, as shown on Photo 8.1 below.

Photo 8.1: Photo showing the location of the Northern Cliffs in red taken from the corner of Kingston Road and North Zone.

- The top of the cliffs are approximately 1200 m to the east of the site eastern boundary and are approximately 470 m topographically higher.
- The cliffs are approximately 360 m high, have an approximate average slope angle of 50° and have a total surface area of approximately 140,000m^2.
- The farmland between the base of the cliffs and the site grades at approximately 6° to the west.

8.2.2 Geomorphological Observations

- The cliffs are discontinuous, with some areas comprising more gently sloping soil covered slopes and others comprising steeper rock outcrops.
- The cliffs are typically either unvegetated or covered by grass and tussock.
- The unweathered rock mass was observed to typically comprises grey to dark grey, weak to moderately strong, semi-pelitic schist. The exposed surface of the rock mass was typically slightly weathered, especially along defects, but the rock is not significantly weakened.
- No evidence of tension cracks were observed above the cliffs, however difficulty accessing the area for close inspection should be noted.

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- Several subvertical joint sets were observed interacting to form large potentially unstable blocks indicating that cliff collapse is a valid possibility. The traces of the major observed joint sets are shown on Appendix A, Figure 2a.
- Differentiation between debris originating from individual rock fall events and a debris avalanche event is difficult, however a small area of large boulders with similar levels of post settlement weathering are observed extending approximately 200 to the northwest of the cliffs as shown in Figure 8.1 below. These boulders are visible in a 1959 aerial photo.
- The debris extends out from the toe of the cliff approximately 200 m and is approximately 800 m from the eastern boundary of the proposed development site.

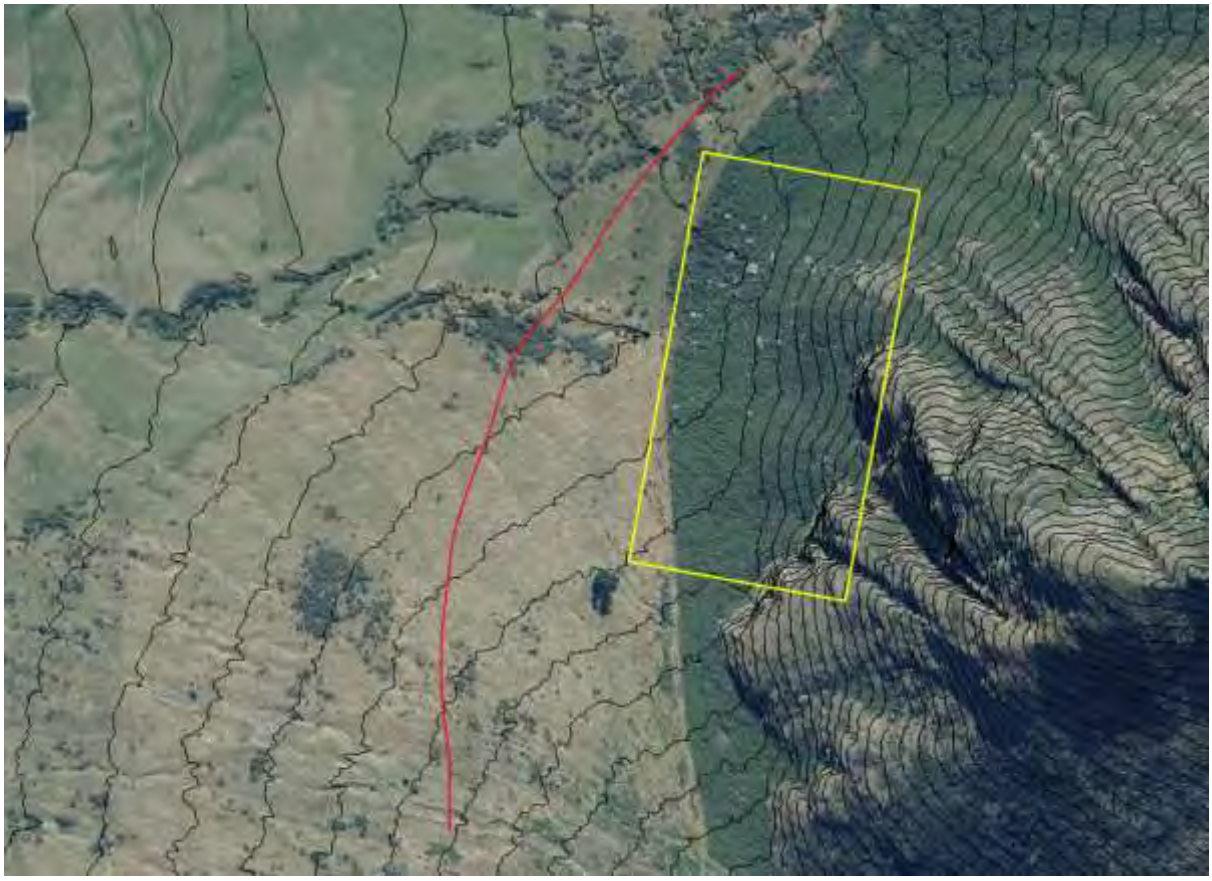

Figure 8.1: Annotated aerial photo showing the location of the inferred maximum extent of cliff collapse debris in red in relation to the Northern Cliffs. The rock fall debris area below some of the rock outcrops is highlighted in the yellow box.

8.3 Southern Cliffs

8.3.1 General

The Southern cliffs are located on the western flanks of a generally southeast to northwest trending ridgeline on the true left side of the Southern Catchment.

- The top of the cliffs is approximately 1,920m to the east of the site eastern boundary and are approximately 938 m topographically higher.

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- At their maximum, the cliffs are approximately 595 m high although the majority of the cliffs are considerably less in height.
- The cliffs have an approximate average slope angle of 45° and have a total surface area of approximately 211,900m^2.
- Accumulated rock fall and historic avalanche debris is located at the base of the cliffs and grades at approximately 35°.
- The farmland between the base of the cliffs and the site grades at approximately 8°.

Photo 8.2: Photo showing the location of the Southern Cliffs in red taken from Kingston Road.

8.3.2 Geomorphological Observations

- The cliffs are generally continuous, with some areas comprising more gently sloping soil and debris covered slopes and other comprising steeper rock outcrops..
- The cliffs are typically either unvegetated or covered by grass and tussock.
- The unweathered rock mass was observed to typically comprises grey to dark grey, moderately strong, semi-pelitic schist. The exposed surface of the rock mass was typically slightly weathered, especially along defects, but the rock is not significantly weakened.
- No evidence of tension cracks were observed during on or above the cliffs, however difficulty accessing the area for close inspection should be noted.
- Several subvertical joint sets were observed interacting to form large potentially unstable blocks. The traces of the major observed joint sets are shown on Appendix A, Figure 2a.
- Differentiation between debris originating from individual rock fall events and a rock fall avalanche event is difficult, however the slopes directly below some of the rock outcrops are covered in debris. An area of large boulders, known as the Jardines Boulders, extends approximately 900 m out from the foot of the cliffs as shown in Figure 8.2 below. This is approximately 450 m from the eastern boundary of the proposed development site.

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Figure 8.2: Annotated aerial photo showing the location of the inferred maximum extent of cliff collapse debris in red in relation to the Southern Cliffs. The rock fall debris area below some of the rock outcrops is highlighted in the yellow box.

8.4 Qualitative Risk Assessment

A qualitative risk assessment has been completed using empirical methods to assess the expected downslope limit of debris avalanche runout[26].

In accordance with the APP6 three seismic events have been considered as triggers for a cliff collapse:

1. Almost certain (50 year ARI)
2. Possible (500 year ARI)
3. Unlikely (2500 year ARI)

Two methods have been used to assess the maximum cliff collapse debris volume for each of the three seismic events and the results are shown in Table 8.1 and Table 8.2 for the Northern and Southern Cliffs respectively:

- Method 1 used the GNS Rock Fall Activity Rate System (RoARS) online tool[27]. The RoARs tool considers the average slope angle, the slope height, the surface area and the horizontal peak ground accelerations (PGA). A range of debris volumes have been calculated using half of the maximum cliff height and the maximum cliff height to account for the variable shape and height of the cliffs. The debris volume based on the maximum cliff height is considered conservative.
- Method 2 used a combination of site observations and review of aerial photography to assess the worst-case cliff collapse debris volume. Persistent defect traces at the two cliffs are shown on Appendix A, Figure 2a.

[26] De Vilder SJ, Massey CI. 2020. Guidelines for natural hazard risk analysis on public conservation lands and waters – Part 1: a commentary on analysising landslide risk to point and linear sites. Lower Hutt (NZ): GNS Science. 64p. Consultancy Report 2020/53.

[27] https://slidenz.net/data-tools/roars-tool/

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The PGA for each of the three seismic events have been taken from Table A1 of Module 1 of the Earthquake Geotechnical Engineering Practice[28] for the Queenstown area.

Table 8.1: Calculated maximum debris volume for the Northern Cliffs

Seismic Event	PGA (m/s^2)	Method 1 - Calculated maximum debris volume range (RoARS) (m^2)	Method 2 - Assessed maximum debris volume (Site Observations) (m^2)
Almost Certain (1/50 years)	1.37	1,619 - 11,228	*
Possible (1/500 years)	4.02	2,851 - 19,754	*
Unlikely (1/2500 years)	7.26	3,890 - 26,946	23,000
*Cliff collapse is not considered a failure mechanism triggered by 1/50 years and 1/500 years seismic events. Failure is considered more likely to be in form of rock fall, which has been assessed in Section 0.			

Table 8.2: Calculated maximum debris volume for the Southern cliffs

Seismic Event	PGA (m/s^2)	Method 1 - Calculated maximum debris volume range (RoARS) (m^2)	Method 2 - Assessed maximum debris volume (Site Observations) (m^2)
Almost Certain (1/50 years)	1.37	3,984 - 19,134	*
Possible(1/500 years)	4.02	7,017 - 33,664	*
Unlikely (1/2500 years)	7.26	9,575 - 45,920	35,000
*Cliff collapse is not considered a failure mechanism triggered by 1/50 years and 1/500 years seismic events. Failure is considered more likely to be in form of rock fall, which has been assessed in Section 0.			

Figure 6.9 from the Guidelines for Natural Hazard Risk Analysis shows the empirical relationship between the ratio of the change in height between the top of the cliff, the site, the horizontal dry debris avalanche runout distance (ΔH/L) and the volume of dry debris. The graph shows the potential runout distance increases with debris volume. Based on the

[28] Ministry of Business, Innovation and Employment. 2021. Module 1: Overview of the geotechnical guidelines. Building Performance

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inverse relationship between likelihood of a seismic event and the debris volume, the unlikely scenario (1/2500 years) is considered to have the worst-case runout distance.

This relationship for the Northern and Southern cliffs using the maximum calculated debris volume from a 1/2500 year seismic event is shown on Figures 7.3 and 7.4 below.

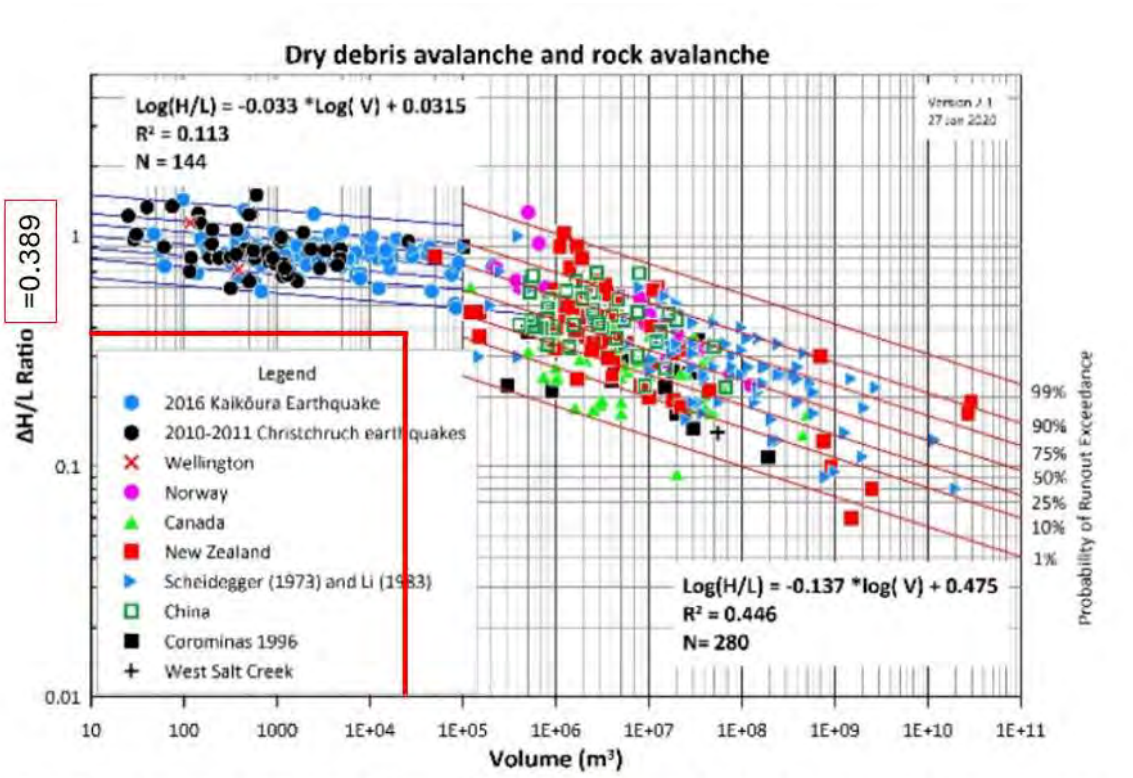

Figure 6.9 Empirical relationship between ΔH/L ratio and volume of dry (i.e. earthquake-triggered) debris avalanches (<100,000 m³) and rock avalanches(>100,000 m³).

Maximum Debris Volume following 1/2500-year seismic event = 26,946m3

Figure 8.3: Annotated Figure 6.9 from the Guidelines for Natural Hazard Risk Analysis showing the relationship the ΔH/L ratio from the top of the cliffs to the site and the maximum calculated debris volume from a 1/2500 year seismic event for the Northern cliffs.

The empirical relationship indicates that, based on the calculated maximum debris volume of 26,946m^3 a ΔH/L ratio of approximately 0.510 is required to achieve a 1% probability that debris from a rock avalanche originating from the Northern Cliffs would reach the site. The calculated ΔH/L ratio of 0.389 is significantly below the required 0.510 and so this method indicates debris will not reach the site.

Table 8.3: Rock avalanche runout summary from Northern Cliffs

Minimum distance between assessed rock avalanche debris runout and site			
Direct observation of boulders at surface	Empirical (ΔH/L ratio = 0.500)	Worst Cast RAMMs runout trajectory for seismic events*	Worst case RAMMs runout trajectory*
395 m	~350 m	710 m	545 m
* as discussed in Section 7.5.			

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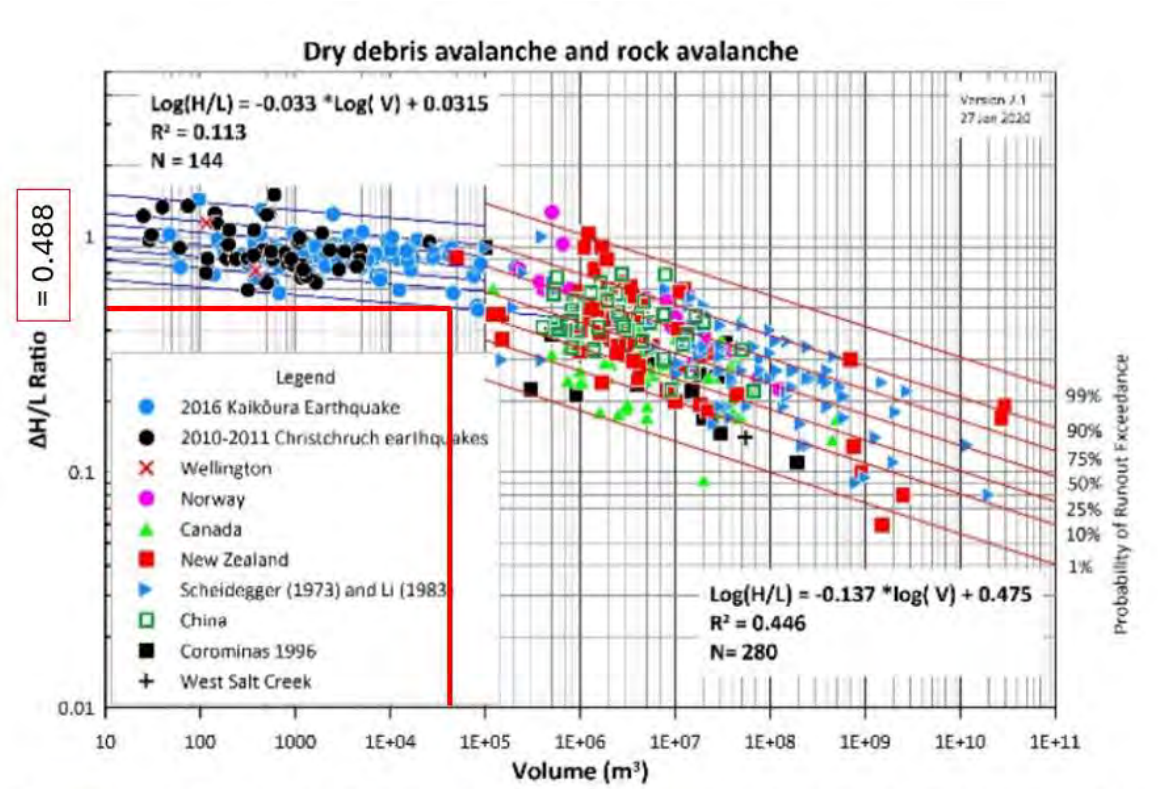

Figure 6.9 Empirical relationship between ΔH/L ratio and volume of dry (i.e. earthquake-triggered) debris avalanches (<100,000 m³) and rock avalanches(>100,000 m³).

Maximum Debris Volume following 1/2500-year seismic event = 45,920m3

Figure 8.4: Annotated Figure 6.9 from the Guidelines for Natural Hazard Risk Analysis showing the relationship the ΔH/L ratio from the top of the cliffs to the site and the maximum calculated debris volume from a 1/2500 year seismic event for the Southern cliffs.

The empirical relationship indicates that, based on the calculated maximum debris volume of 45,920[3] a ΔH/L ratio of approximately 0.500 is required to achieve a 1% probability that debris from a rock avalanche originating from the Northern Cliffs would reach the site.

Table 8.4: Rock avalanche runout summary from Southern Cliffs

Minimum distance between assessed rock avalanche debris runout and site				
Direct observation of boulders at surface	Western extent of talus slope below cliffs	Empirical (ΔH/L ratio = 0.500)	Worst case RAMMs runout trajectory for seismic events*	Worst case RAMMs runout trajectory*
450 m	610 m	~55 m	690 m	45 m
* as discussed in Section 7.5.				

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8.5 Rock Avalanche Risk Summary

Site observations and empirical assessment agree and show a 1/2500 year or smaller seismic event triggered rock avalanche originating from the Northern and Southern cliffs will not reach the site. The consequence from a debris avalanche to the site is therefore not considered significant for the development proposal.

The risk level is assessed as Acceptable for all three likelihoods considered. As the qualitative risk level is assessed as Acceptable a quantitative risk assessment is not considered warranted.

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9 Lake Seiche Hazard Assessment

9.1 Lake Seiche Hazard

In the event of severe shaking, or sudden displacement of a large volume of lake water, the Lake may 'slosh' within its basin, potentially generating waves that may affect the site. This effect is known as 'seiche'. Based on mountain topography and seismic environment it is inferred that such events may potentially have occurred around Lake Wakatipu in the geologic past.

A destructive seiche could be generated by either:

- severe seismic shaking, or
- significant sudden displacement or tilting of the lakebed which could only be seismically induced, or
- substantial landslide into or within the lake, which could be of terrestrial origin or sub lacustrine.

There is no known record of destructive lake seiche events within historic human occupation, and on this basis, we consider the occurrence of such an event within the development's lifetime to be of low probability.

The site boundary is ~20 metres above the lake level and the lowest proposed development is ~30 m above lake level. A lake seiche in excess of this magnitude/height is likely to have a very high return period.

9.2 Lake Seiche Hazard Risk Summary

As the return period for lake seiche significant enough to reach the site is considered to be high it is deemed a **rare** event.

For a **rare** lake seiche the consequence is conservatively assessed as **moderate**. However, due to the low probability, the risk from lake seiche is assessed as **Acceptable**.

As the qualitative risk level is assessed as **Acceptable** a quantitative risk assessment is not considered warranted for lake seiche hazard at this site.

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10 Conclusions and Recommendations

- Debris flooding (including allowing for 'clearwater' flooding) from the alluvial catchments has been assessed to be Possible along the entire eastern boundary of the site from existing flow paths and potential migration of flow paths. Flood hazard risk is assessed as **Tolerable** for proposed mixed-use development at the site without mitigation measures.
    - Channels to divert flood flows to the existing northern and southern flow paths through the site as detailed in Section 5.5.3 are recommended to mitigate flood risk. With these proposed diversion channels, flood risk is assessed to be **Acceptable** for proposed mixed use development at the site.
    - The proposed diversion channels were assessed to have a less than minor effect on hydrological regime at the downstream site boundary and no effect on flooding for the road or neighbouring properties.
- Debris flow events from the alpine catchments are assessed as possible. However, even an Unlikely (conservatively large) debris flow originating from the Northern Fan apex is not shown to reach the site by a considerable margin. An Unlikely debris flow originating from the Middle or Southern Fan apexes is shown to stop at or above the site boundary. The risk from debris flow is assessed as Acceptable for the proposed development without mitigation measures, and the proposed flood hazard mitigation measures provide further assurance that the risk is within the **Acceptable** category.
- The three methods of assessing potential rock fall runout trajectories all showed that rock fall debris originating from the Remarkables will not reach the site. As a result, the risk posed by rock fall is assessed as **Acceptable** for the proposed residential development at the site without mitigation measures.
- Empirical methods showed that rock avalanches originating from the collapse of the two cliffs most likely to affect the site do not reach the site. As a result, the risk is assessed as **Acceptable** for this hazard.
- Due to the elevation of the site the likelihood of a lake seiche event reaching the site is considered very low. As a result, the risk is assessed as **Acceptable** for this hazard.
- Development of the site is considered acceptable with respect to the hazards assessed in this report provided the recommendations with respect to flood risk are incorporated during the detailed design of the subdivision.
- The assessment has been undertaken considering the existing geomorphology. If an extreme super-design event, with a low likelihood of occurrence but beyond the required planning timeframes, results in major geomorphological change in the catchments, we recommend inspection and appropriate remediation be undertaken.

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11 Applicability

This report has been prepared for the sole use of our client, RCL Ltd, with respect to the particular brief and on the terms and conditions agreed with our client. It may not be used or relied on (in whole or part) by anyone else, or for any other purpose or in any other contexts, without our prior review and written agreement.

Report prepared by:

.....

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Appendices:

Appendix A – Geosolve Drawings
Appendix B – Landslide inventory
Appendix C – RAMMS Rock fall Model Inputs
Appendix D –Methodology for Natural Hazard Risk Assessment
Appendix E – Additional HEC-HMS hydrological model results
Appendix F – Additional HEC-RAS flood model results

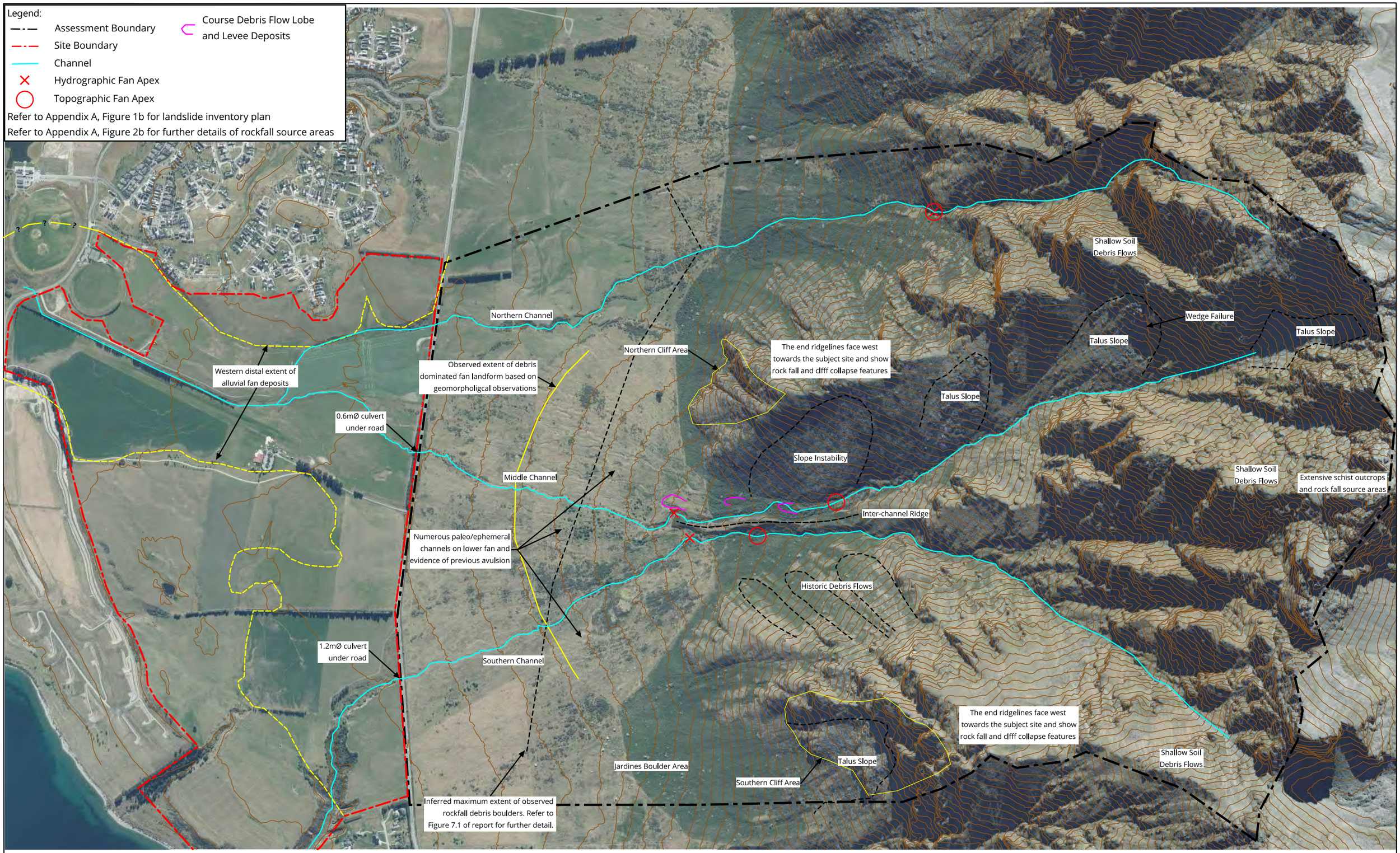
Appendix A: GeoSolve Drawings

Legend:

- Assessment Boundary
- Site Boundary
- Channel
- Hydrographic Fan Apex
- Topographic Fan Apex
- Course Debris Flow Lobe and Levee Deposits

Refer to Appendix A, Figure 1b for landslide inventory plan

Refer to Appendix A, Figure 2b for further details of rockfall source areas



Notes:

1. These drawings have been prepared for the benefit of RCL Homestead Bay Limited with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

CAD FILE:	220556.02	DRAWN	JMJ	12/24
SCALE (AT A3):	1:12,000	DRAFTING CHECKED	SR	12/24
PROJECT NUMBER:	220556.02	APPROVED	PDF	01/25

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GEOTECHNICAL
WATER RESOURCES
PAVEMENTS

RCL Homestead Bay Limited

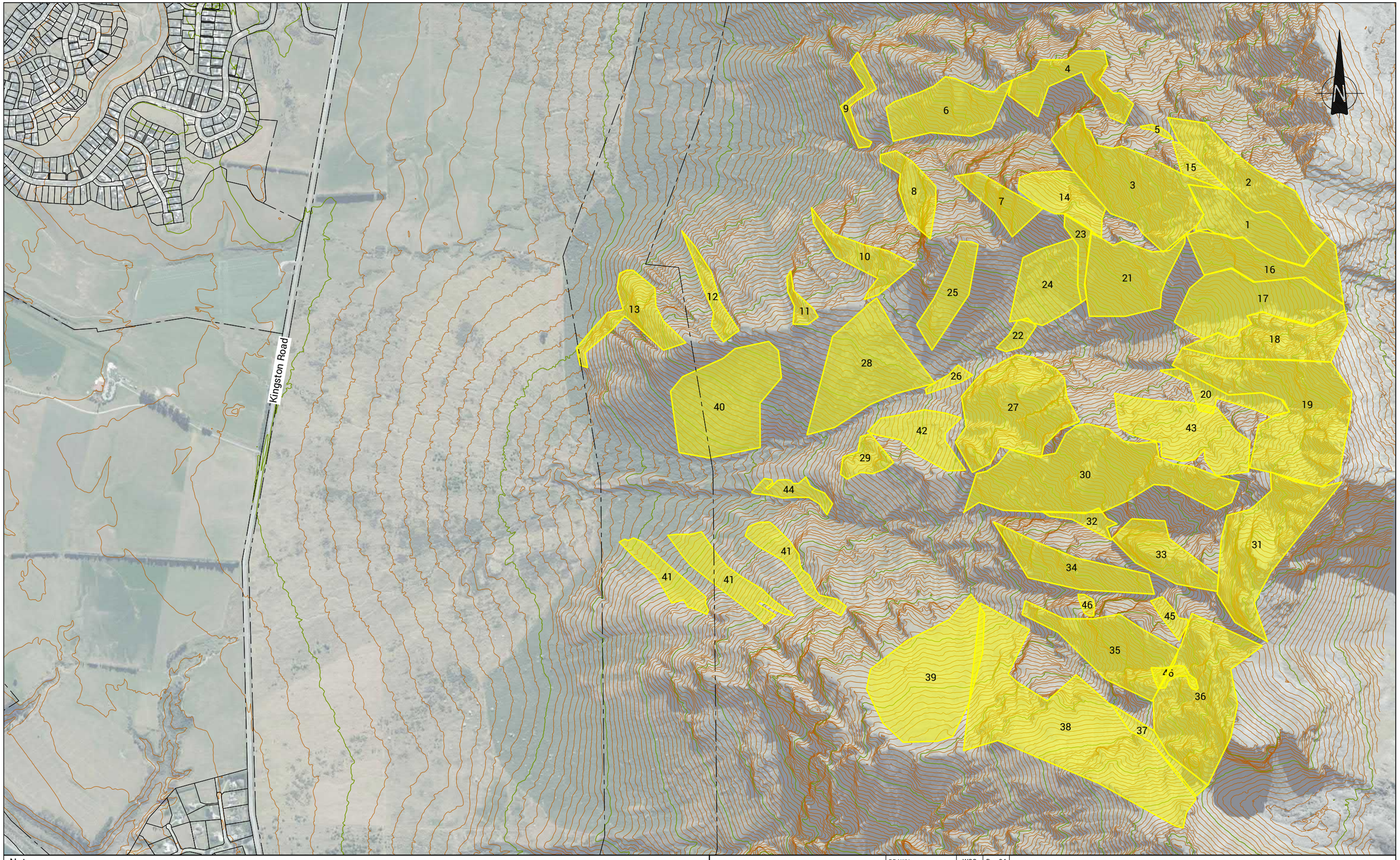
Homestead Bay

Natural Hazard Assessment

Geomorphology Summary Plan

FIG No: Appendix A, Figure 1a

REV: 1



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Legend:

41 Landslide

SCALE 1:11,000

0 110 220 330 440 550 (m)

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DRAWN	WCG	Dec.24
DRAFTING CHECKED		
APPROVED		
CADFILE: 220556.02.dwg		
SCALES (AT A3 SIZE): 1:10,000		
PROJECT No: 220556.02	FIG No: Appendix A, Figure 1b	REV. 0

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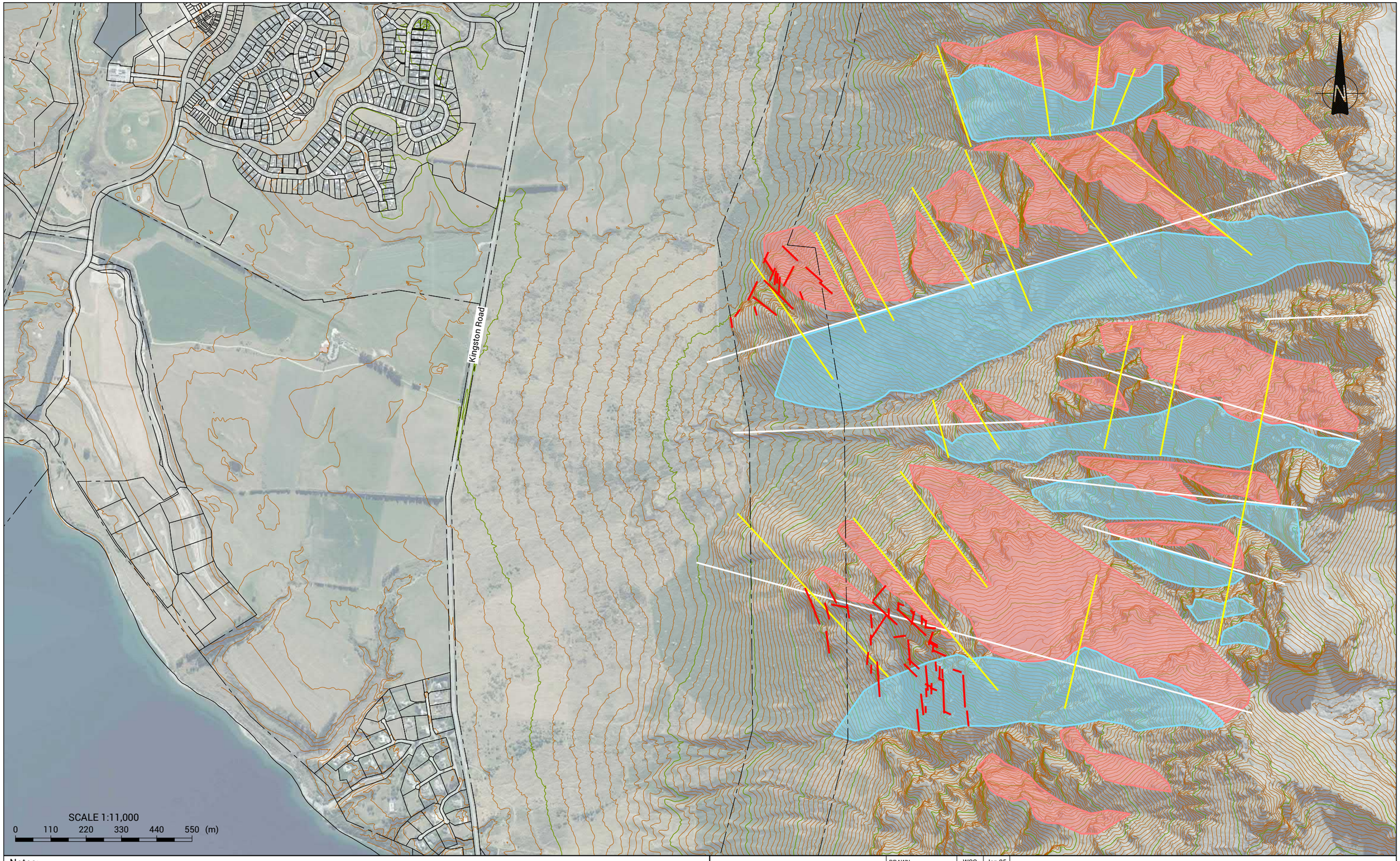
Homestead Bay

Hydrological Assessment

Landslide Inventory Plan



Notes:
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Legend:

- Approximately E-W Trending Ridgelines
- Steeply dipping defect set roughly orthogonal to the ridgelines
- Northern side of the ridgelines formed by a N-NW dipping defect set
- Southern side of the ridgelines formed by a S-SE dipping defect set
- Rock Defect Trace

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PROJECT No: 220556.02		

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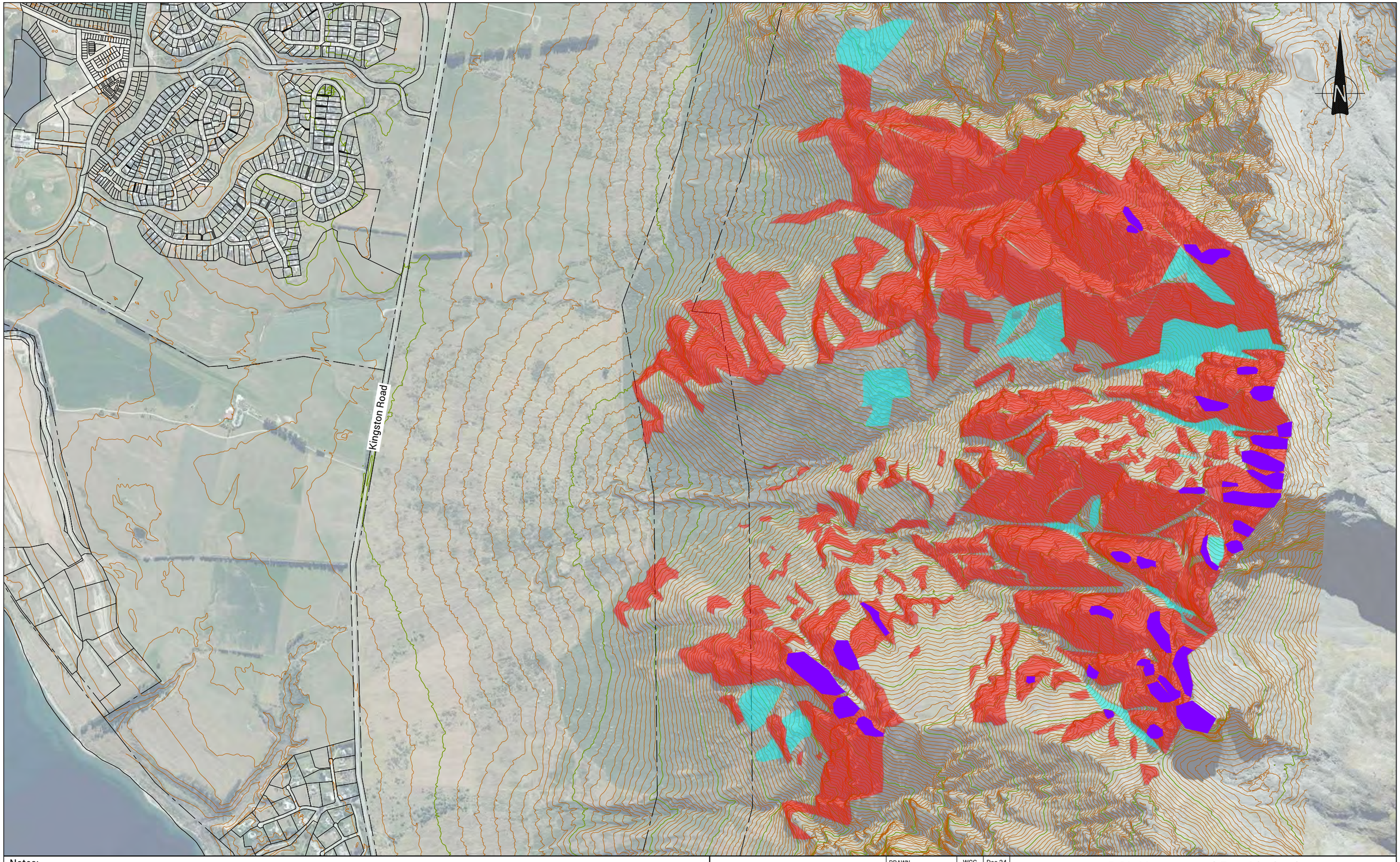
Hydrological Assessment

Structural Interpretation of the West Facing Remarkables

FIG No: Appendix A, Figure 2a

REV. 0



Notes:
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Legend:

- All Rock Outcrops
- Talus Slopes
- Pinnacles

SCALE 1:13,000

0 130 260 390 520 650 (m)

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CADFILE: 220556.02.dwg		
SCALES (AT A3 SIZE): 1:13,000		
PROJECT No: 220556.02		

RCL Homestead Bay Limited

Homestead Bay

Hydrological Assessment

Rockfall Source Area

FIG No: Appendix A, Figure 2b

REV. 0

Appendix B: Landslide Inventory

Appendix B - Landslide Inventory Table - Northern Catchment

Identification Number	Landslide Description	Location	Size category	Date of occurrence	Feature Type	Movement Type	Material Type	Debris Type	Vegetation cover	Main Trigger	Assessed Liklihood (Seismic)	Assessed Liklihood (Rainfall)	Causal Factors	Area (min) m2	Area (max) m2	Worst Case Soil Zone	Sediment Volume (min) m3	Sediment Volume (max) m3	Activity	Rate	Aspect	Assessed max sediment volume contribution to debris flow m3		
																						1/50 year	1/100 year	1/1000 year
1	Rockfall Debris/Tallus Slope	See Site Plan	Medium	Ongoing	Landslide Area	Remobilsation of boulders	Rock	Boulders	Nil	Rainfall/Seismic	Possible	Almost Certain to Possible	Unknown	20,000	40,000	B	10,000	80,000	Active (historically)	n/a	Southwest to South	0	200	1,000
2	Rockfall source area on crest of catchment above #1	See Site Plan	Large	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	West to South	N/A	N/A	N/A
3	Rockfall source area with some cliffs	See Site Plan	Large	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	West to South	N/A	N/A	N/A
4	Rockfall source area with some cliffs	See Site Plan	Large	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	West to South	N/A	N/A	N/A
5	Shallow soil failure immediately above creek	See Site Plan	Medium	Unknown	Landslide Area	Rotational	Soil	Chaotic	Grass	Rainfall/Seismic	Possible	Possible	Erosion	1,500	2,000	C	750	2,000	Creep	n/a	Southwest	250	400	1,500
6	Rockfall source area	See Site Plan	Large	Ongoing	Rock Outrcrop	Toppling	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	South	N/A	N/A	N/A
7	Rockfall source area with some cliffs	See Site Plan	Medium	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	West	N/A	N/A	N/A
8	Cliffs with rockfall sources	See Site Plan	Medium	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	West	N/A	N/A	N/A
9	Cliffs with rockfall sources	See Site Plan	Large	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	Northwest to Southwest	N/A	N/A	N/A
10	Rockfall source area with some cliffs	See Site Plan	Large	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	Northwest to Southwest	N/A	N/A	N/A
11	Cliffs with rockfall sources	See Site Plan	Small	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	West	N/A	N/A	N/A
12	Rockfall source area with some cliffs	See Site Plan	Small	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	West	N/A	N/A	N/A
13	Cliffs with rockfall sources	See Site Plan	Large	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	Northwest to Southwest	N/A	N/A	N/A
14	Steep slope with several shallow debris flows	See Site Plan	Small	Ongoing	Landslide Area	Debris Flow	Mixture	Chaotic	Grass and bare soil	Rainfall	Unlikely	Almost certain	Erosion	5,000	30,000	C	2,500	30,000	Potentially active	n/a	North	200	400	1,500
15	Steep slope with several shallow debris flows	See Site Plan	Small	Ongoing	Landslide Area	Debris Flow	Mixture	Chaotic	Grass and bare soil	Rainfall	Unlikely	Almost certain	Erosion	1,000	10,000	C	500	10,000	Potentially active	n/a	North	200	1,000	7,500

Appendix B - Landslide Inventory Table - Middle Catchment

Identification Number	Landslide Description	Location	Size category	Date of occurrence	Feature Type	Movement Type	Material Type	Debris Type	Vegetation cover	Main Trigger	Assessed Liklihood (Seismic)	Assessed Liklihood (Rainfall)	Causal Factors	Area (min) m2	Area (max) m2	Worst Case Soil Zone	Sediment Volume (min) m3	Sediment Volume (max) m3	Activity	Rate	Aspect	Assessed max sediment volume contribution to debris flow m3		
																						1/50 year	1/100 year	1/1000 year
1	Rockfall Debris/Tallus Slope	See Site Plan	Medium	Ongoing	Landslide Area	Remobilsation of boulders	Rock	Boulders	Nil	Rainfall/Seismic	Possible	Almost Certain to Possible	Unknown	20,000	40,000	B	10,000	80,000	Active (historically)	n/a	Southwest to South	0	200	1000.00
2	Rockfall source area on crest of catchment above #1	See Site Plan	Large	Ongoing	Rockfall	Toppling	Rock	Boulders	Nil	Ranfall/Seismic	1/25 - 1/50 (Almost Certain)	1/100 (Almost Certain)	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	West to South	N/A	N/A	N/A
16	Rockfall source area with some cliffs above #17	See Site Plan	Medium	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	South to Southwest	N/A	N/A	N/A
17	Rockfall Debris/Tallus Slope	See Site Plan	Large	Ongoing	Landslide Area	Remobilsation of boulders	Rock	Boulders	Nil	Rainfall/Seismic	Possible	Almost Certain to Possible	Unknown	50,000	70,000	B	25,000	140,000	Active (historically)	n/a	Southwest to South	0	500	2,000
18	Rockfall source area above #17	See Site Plan	Medium	Ongoing	Rock Outrcrop	Toppling	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	North to West	N/A	N/A	N/A
19	Rockfall source area above #20	See Site Plan	Medium	Ongoing	Rock Outrcrop	Toppling	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	West	N/A	N/A	N/A
20	Rockfall Debris/Tallus Slope	See Site Plan	Small	Ongoing	Landslide Area	Remobilsation of boulders	Rock	Boulders	Nil	Rainfall/Seismic	Possible	Almost Certain to Possible	Unknown	7,500	15,000	B	3,750	30,000	Active (historically)	n/a	West	0	200	1,000
21	Steep slope with several shallow debris flows	See Site Plan	Small	Ongoing	Landslide Area	Debris Flow	Mixture	Chaotic	Grass and bare soil	Rainfall	Unlikely	Almost certain	Erosion	10,000	50,000	C	5,000	50,000	Potentially active	n/a	South	500	2,000	8,000
22	Debris flow above creek	See Site Plan	Small	Unknown	Landslide Area	Debris Flow	Mixture	Chaotic	Bare soil and boulders	Rainfall	Unlikely	Almost certain	Erosion	5,000	7,500	C	2,500	7,500	Potentially active	n/a	South	200	1,000	2,500
23	Rockfall source area with some cliffs	See Site Plan	Small	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	South to West	N/A	N/A	N/A
24	Several areas of rockfall debris/Tallus Slope	See Site Plan	Medium	Ongoing	Landslide Area	Remobilsation of boulders	Rock	Boulders	Nil	Rainfall/Seismic	Possible	Possible	Unknown	10,000	40,000	B	5,000	80,000	Active (historically)	n/a	Southwest	0	0	0
25	Steep slope with several shallow debris flows	See Site Plan	Small	Ongoing	Landslide Area	Debris Flow	Mixture	Chaotic	Grass and bare soil	Rainfall	Unlikely	Almost certain	Erosion	5,000	25,000	C	2,500	50,000	Potentially active	n/a	South	200	500	1,000
26	Several debris flows above creek	See Site Plan	Small	Unknown	Landslide Area	Debris Flow	Mixture	Chaotic	Grass and bare soil	Rainfall	Unlikely	Almost certain	Erosion	1,500	5,000	E	3,000	15,000	Active	n/a	Northwest	100	250	500
27	Rockfall source area with some cliffs	See Site Plan	Large	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	North to Southwest	N/A	N/A	N/A
28	Steep slope with scattered rockfall source	See Site Plan	Large	Ongoing	Rock Outcrops	Toppling	Mixture	Chaotic	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	South	N/A	N/A	N/A
29	Rockfall source area with some cliffs	See Site Plan	Large	Ongoing	Rock Outrcrop	Toppling	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	Northwest to west	N/A	N/A	N/A
40	Schist Landslide	See Site Plan	Large	Ongoing	Landslide Area	Creep	Mixture	Chaotic	Grass and bare soil	Rainfall/Seismic	Unlikely	Almost certain	Foliation	60,000	90,000	D	60,000	180,000	Potentially active	Creep	North	500	1,500	5,000
42	Steep slope with several shallow debris flows	See Site Plan	Medium	Ongoing	Landslide Area	Debris Flow	Mixture	Chaotic	Grass and bare soil	Rainfall	Unlikely	Almost certain	Erosion	5,000	30,000	E	10,000	90,000	Active (historically)	n/a	West	500	2,000	4,000
43	Steep slope with several shallow debris flows between rock outcrops	See Site Plan	Large	Ongoing	Landslide Area	Debris Flow	Mixture	Chaotic	Grass, bare soil and boulders	Rainfall	Unlikely	Almost certain	Erosion	5,000	60,000	C	2,500	60,000	Active (historically)	n/a	North	200	1,000	4,000

Appendix B - Landslide Inventory Table - Southern Catchment

Identification Number	Landslide Description	Location	Size category	Date of occurrence	Feature Type	Movement Type	Material Type	Debris Type	Vegetation cover	Main Trigger	Assessed Liklihood (Seismic)	Assessed Liklihood (Rainfall	Causal Factors	Area (min) m2	Area (max) m2	Worst Case Soil Zone	Sediment Volume (min) m3	Sediment Volume (max) m3	Activity	Rate	Aspect	Assessed max sediment volume contribution to debris flow m3		
																						1/50 year	1/100 year	1/1000 year
30	Rockfall source area with some cliffs	See Site Plan	Large	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	South to West	N/A	N/A	N/A
31	Rockfall source area with some cliffs and tallus slopes	See Site Plan	Large	Ongoing	Rock Outrcrop and Landslide Area	Toppling/Cliff Collapse/Remobilisation of Bounders	Rock	Boulders	Nil	Seismic	Possible	-	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	North, West and South	N/A	N/A	N/A
32	Rockfall Debris/Tallus Slope	See Site Plan	Small	Ongoing	Landslide Area	Remobilsation of boulders	Rock	Boulders	Nil	Rainfall/Seismic	Possible	Almost Certain to Possible	Unknown	5,000	10,000	B	2,500	20,000	Active (historically)	n/a	West	0	500	1,000
33	Rockfall source area with some cliffs	See Site Plan	Medium	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	Southwest	N/A	N/A	N/A
34	Rockfall source area with some cliffs	See Site Plan	Medium	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	West to South	N/A	N/A	N/A
35	Rockfall source area with some cliffs	See Site Plan	Medium	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	South West	N/A	N/A	N/A
36	Rockfall source area with some cliffs above #37	See Site Plan	Medium	Ongoing	Rock Outrcrop	Toppling/Cliff Collapse	Rock	Boulders	Nil	Rainfall/Seismic	Almost certain	Possible	Unknown	N/A	N/A	N/A	Boulders	Boulders	Active (historically)	n/a	West	N/A	N/A	N/A
37	Rockfall Debris/Tallus Slope	See Site Plan	Medium	Ongoing	Landslide Area	Remobilsation of boulders	Rock	Boulders	Nil	Rainfall/Seismic	Possible	Almost Certain to Possible	Unknown	8,000	15,000	B	4,000	Boulders	Active (historically)	n/a	West	Within channel	Within channel	Within channel
38	Steep slope with several shallow debris flows	See Site Plan	Large	Ongoing	Landslide Area	Debris Flow	Mixture	Chaotic	Grass and bare soil	Rainfall	Unlikely	Almost certain	Erosion	10,000	50,000	C	5000	50,000	Potentially active	n/a	North	5,000	10,000	20,000
39	Steep slope with several shallow debris flows	See Site Plan	Large	Ongoing	Landslide Area	Debris Flow	Mixture	Chaotic	Grass and bare soil	Rainfall	Unlikely	Almost certain	Erosion	80,000	120,000	C	40,000	120,000	Potentially active	n/a	North	500	2,000	5,000
41	Several historic debris flows	See Site Plan	Large	Unknown	Landslide Area	Debris Flow	Mixture	Chaotic	Grass	Rainfall	Unlikely	Almost certain	Erosion	60,000	80,000	E	120,000	240,000	Potentially active	n/a	North West	0	1,000	6,000
44	Soil failure above creek	See Site Plan	Medium	Unknown	Landslide Area	Rotational	Soil	Chaotic	Grass and bushes	Rainfall/Seismic	Possible	Possible	Erosion	7,500	15,000	D	7,500	30,000	Creep	n/a	South	1,000	5,000	8,000
45	Steep slope with several shallow debris flows	See Site Plan	Small	Ongoing	Landslide Area	Debris Flow	Mixture	Chaotic	Grass and bare soil	Rainfall	Unlikely	Almost certain	Erosion	1,000	2,500	C	500	2,500	Potentially active	n/a	North	200	1,000	2,000
45	Steep slope with several shallow debris flows	See Site Plan	Small	Ongoing	Landslide Area	Debris Flow	Mixture	Chaotic	Grass, bare soil, rock	Rainfall	Unlikely	Almost certain	Erosion	1,000	5,000	C	500	5,000	Potentially active	n/a	North	500	1,000	2,500
46	Steep slope with shallow debris flow	See Site Plan	Small	Ongoing	Landslide Area	Debris Flow	Mixture	Chaotic	Bare soil	Rainfall	Unlikely	Almost certain	Erosion	1,500	2,000	C	750	2,000	Potentially active	n/a	North	750	1,250	2,000
47	Rockfall source area with some cliffs and tallus slopes	See Site Plan	Large	Ongoing	Rock Outcrop and Landslide Area	Toppling/Cliff Collapse/Remobilisation of Bounders	Rock	Boulders	Nil	Rainfall/Seismic	Possible	Almost Certain to Possible	Unknown	N/A	N/A	B	Outside catchment	Outside catchment	Active (historically)	n/a	North, West and South	N/A	N/A	N/A

Appendix C: RAMMS Rock Fall Model Inputs

Table 11.1: RAMMS simulation settings

General	
Digital Elevation Model (DEM) source data	Otago – Queenstown LiDAR 1m DEM 2016 (LINZ)
DEM Grid Resolution (m)	5
Terrain (RAMMS predefined setting)	
Overall Terrain Material	Medium Hard
Rock Outcrops	Extra Hard
Talus Slopes	Hard
Western section of slope adjacent to State Highway 6	Medium
Forest Drag (RAMMS predefined setting)	
Assessment Area	No Forest
Boulder Release	
No. of Modelled Simulations – Analysis 1	20,343
No. of Modelled Simulations – Analysis 2	16,457
No. of Modelled Simulations – Analysis 3	15,873
No. of Modelled Simulations – Analysis 4	15,342
No. of Modelled Simulations – Analysis 5	21,930

Table 11.2: Values of the characteristics of each rock created for the RAMMS simulation

Boulder No.	X (m)	Y (m)	Z (m)	Volume (m3)	Density (kg/m3)	Mass (kg)	RAMMS Block shape
Analysis 1							
1	0.72	0.72	0.60	0.239	2700	644.9	Flat_1.2_0.2m3
2	0.92	0.92	0.77	0.505	2700	1363.0	Flat_1.2_0.5m3
3	1.13	1.01	0.56	0.493	2700	1330.6	Flat_2.0_0.5m3
4	0.61	0.75	0.42	0.096	2700	258.7	Real_Flat_1.8_0.1m3
5	1.13	1.37	0.77	0.590	2700	1594.3	Real_Flat_1.8_0.6m3
6	0.78	0.95	0.80	0.249	2700	672.3	Real_Long_1.2_0.2m3
Analysis 2							
1	2.05	1.85	1.03	3.004	2700	8110.0	Flat_2.0_3.0m3
2	2.26	2.04	1.13	4.022	2700	10859.0	Flat_2.0_4.0m3
3	2.45	2.20	1.22	5.059	2700	13659.1	Flat_2.0_5.1m3

4	2.79	2.51	1.39	7.505	2700	20262.7	Flat_2.0_7.5m3
5	3.08	2.77	1.54	10.064	2700	27171.9	Flat_2.0_10.1m3
6	3.53	2.11	1.76	10.064	2700	27172.1	Long_2.0_10.1m3
7	1.33	1.62	0.91	0.975	2700	2631.6	Real_Flat_1.8_1.0m3
8	1.55	1.89	1.06	1.540	2700	4159.3	Real_Flat_1.8_1.5m3
9	1.83	2.23	1.25	2.526	2700	6820.7	Real_Flat_1.8_2.5m3
Analysis 3							
1	2.45	2.20	1.22	5.059	2700	13659.1	Flat_2.0_5.1m3
2	3.51	3.16	1.76	15.012	2700	40533.3	Flat_2.0_15.0m3
3	3.87	3.48	1.93	20.036	2700	54097.1	Flat_2.0_20.0m3
4	2.80	1.68	1.40	5.071	2700	13691.3	Long_2.0_5.1m3
5	3.53	2.11	1.76	10.064	2700	27172.1	Long_2.0_10.1m3
6	4.78	2.87	2.39	25.173	2700	67965.8	Long_2.0_25.2m3
7	3.46	2.86	2.18	10.077	2700	27208.0	Real_Flat_1.6_10.1m3
Analysis 4							
1	6.61	5.95	3.31	100.051	2700	270137.1	Flat_2.0_100.1m3
2	6.44	4.72	4.30	100.049	2700	270131.6	Long_1.5_100.0m3
3	7.58	4.55	3.79	100.048	2700	270129.9	Long_2.0_100.00m3
Analysis 5							
1	2.81	2.11	1.41	5.001	2700	13501.6	Equant_2.0_5.0m3
2	4.06	3.04	2.03	15.025	2700	40568.3	Equant_2.0_15.0m3
3	2.45	2.20	1.22	5.059	2700	13659.1	Flat_2.0_5.1m3
4	3.51	3.16	1.76	15.012	2700	40533.3	Flat_2.0_15.0m3
5	3.87	3.48	1.93	20.036	2700	54097.1	Flat_2.0_20.0m3
6	2.80	1.68	1.40	5.071	2700	13691.3	Long_2.0_5.1m3
7	3.53	2.11	1.76	10.064	2700	27172.1	Long_2.0_10.1m3
8	4.43	2.66	2.22	20.009	2700	54024.6	Long_2.0_20.0m3
9	4.78	2.87	2.39	25.173	2700	67965.8	Long_2.0_25.2m3
10	3.46	2.86	2.18	10.077	2700	27208.0	Real_Flat_1.6_10.1m3

Appendix D: APP6 – Methodology for Natural Hazard Risk Assessment

Risk Assessment Methodology

General

The natural hazards assessment has considered the acceptability, tolerability and significance of natural hazard risks in accordance with the relevant provisions in the QLDC Operative District Plan, the Proposed District Plan, and the Partially Operative Otago regional Council Regional Policy Statement[1] (RPS) (Objective 4.1 and supporting Policies). The policy recommends risk assessments are undertaken in accordance with the criteria set out within Appendix 6 (APP6) of the RPS, attached in Appendix D.

Likelihood

Three scenarios covering low, medium and high likelihood events have been identified for each hazard and are outlined in the risk assessment section for each hazard. Likelihood considered is dependent on the nature of the hazard and its impact to the site. The qualitative risk assessment for each hazard identifies and considers the likelihood with the greatest resultant risk from the three scenarios.

Consequence

The primary nature of activity proposed at the site is residential housing. For this assessment we consider that individual life risk to residents is the dominant subset of total risk due to the relatively high occupancy compared to transient population such as people in vehicles or pedestrians. We have used the proposed permanent residential population to evaluate consequence for natural hazards impacting the site.

Consequence is assessed for the residential population with and without proposed hazard mitigation measures. Changes to the natural hazard environment such as climate and geomorphic change are also considered.

Consequence level is qualitatively assessed using Table 7 of APP6 below.

Risk Assessment

Qualitative risk assessments of the identified hazards have been undertaken. The results of each natural hazard risk assessments are discussed in a summary section for each hazard type. This risk framework assesses the likelihood and consequence for each scenario with and without proposed mitigation methods. The scenario with the greatest risk is used to determine a final risk output category of acceptable, tolerable or significant as per table 8 of APP6.

[1] [1]Otago Regional Council (2021) Proposed Otago Regional Policy Statement. Integrating the management of Otago's natural and physical resources. Published June 2021

APP6 – Methodology for *natural hazard risk* assessment

Undertake the following four step process to determine the *natural hazard risk*.

Step 1 – Determine the likelihood

Using Table 6, assess the likelihood of three *natural hazard* scenarios occurring, representing a high likelihood, median likelihood, and the maximum credible event, using the best available information:

Table 6: Likelihood scale

Likelihood	Indicative frequency
Almost certain	Up to once every 50 years (2% AEP)
Likely	Once every 51 – 100 years (2 – 1% AEP)
Possible	Once every 101 – 1,000 years (1 – 0.11% AEP)
Unlikely	Once every 1,001 – 2,500 years (0.1 – 0.04% AEP)
Rare	2,501 years plus (<0.04% AEP)

Step 2 – *Natural hazard* consequence

Using Table 7 and the matters listed in (1) to (10) below, assess the consequence (catastrophic, major, moderate, minor, or insignificant) of the *natural hazard* scenarios identified in step 1 considering:

(1) the nature of activities in the area,

(2) individual and community vulnerability,

(3) impacts on individual and community health and safety,

(4) impacts on social, cultural and economic well-being,

(5) impacts on *infrastructure* and property, including access and services,

(6) available and viable *risk* reduction and hazard mitigation measures,

(7) *lifeline utilities*, essential and emergency services, and their co-dependence,

(8) implications for civil defence agencies and emergency services,

(9) the changing *natural hazard* environment,

(10) cumulative *effects* including *multiple* and *cascading hazards,* where present, and

(11) factors that may exacerbate a *natural hazard* event including the *effects* of *climate change*.

Table 7: Consequence table

Severity of Impact	Built				Health & Safety
	Social/Cultural	*Buildings*	Critical *Buildings*	Lifelines	
Catastrophic (V)	≥25% of *buildings* of social/cultural significance within hazard zone have functionality compromised	≥50% of affected *buildings* within hazard zone have functionality compromised	≥25% of critical facilities within hazard zone have functionality compromised	Out of service for > 1 month (affecting ≥20% of the town/city population) OR suburbs out of service for > 6 months (affecting < 20% of the town/city population)	> 101 dead and/or > 1001 injured
Major (IV)	11-24% of *buildings* of social/cultural significance within hazard zone have functionality compromised	21-49% of *buildings* within hazard zone have functionality compromised	11-24% of *buildings* within hazard zone have functionality compromised	Out of service for 1 week – 1 month (affecting ≥20% of the town/city population) OR suburbs out of service for 6 weeks to 6 months (affecting < 20% of the town/city population)	11 – 100 dead and/or 101 – 1000 injured
Moderate (III)	6-10% of *buildings* of social/cultural significance within hazard zone have functionality compromised	11-20% of *buildings* within hazard zone have functionality compromised	6-10% of *buildings* within hazard zone have functionality compromised	Out of service for 1 day to 1 week (affecting ≥20% of the town/city population) OR suburbs out of service for 1 week to 6 weeks (affecting < 20% of the town/city population)	2 – 20 dead and/or 11 – 100 injured
Minor (II)	1-5% of *buildings* of social/cultural significance within hazard zone have functionality compromised	2-10% of *buildings* within hazard zone have functionality compromised	1-5% of *buildings* within hazard zone have functionality compromised	Out of service for 2 hours to 1 day (affecting ≥20% of the town/city population) OR suburbs out of service for 1 day to 1 week (affecting < 20% of the town/city population	1 dead and/or 1 – 10 injured
Insignificant (I)	No *buildings* of social/cultural significance within hazard zone have functionality compromised	< 1% of affected *buildings* within hazard zone have functionality compromised	No damage within hazard zone, fully functional	Out of service for up to 2 hours (affecting ≥20% of the town/city population) OR suburbs out of service for up to 1 day (affecting < 20% of the town/city population	No dead No injured

When assessing consequences within this matrix, the final level of impact is assessed on the 'first past the post' principle, in that the consequence with the highest severity of impact applies. For example, if a *natural hazard* event resulted in moderate severity of impact across all of the categories, with the exception of critical *buildings* which had a 'major' severity of impact, the major impact is what the proposal would be assessed on. If a *natural hazard* event resulted in all of the consequences being at the same level (for example, all of the consequences are rated moderate), then the level of consequence is considered to be moderate.

When this assessment is being undertaken in accordance with HAZ-NH-M3(7)(a) or HAZ-NH-M4(7)(a) the text within Step 2 shall guide the assessment of *natural hazard* consequence.

Step 3 – Assessing activities for *natural hazard risk*

Using the information within steps 1 and 2 above, and Table 8, assess whether the *natural hazard* scenarios will have an acceptable, tolerable, or significant *risk* to people, property and communities, by considering:

(1) the *natural hazard risk* identified, including *residual risk*,

(2) any measures to avoid, remedy or mitigate those *risks*, including relocation and recovery methods,

(3) the long-term viability and affordability of those measures,

(4) flow on *effects* of the *risk* to other activities, individuals and communities, and

(5) the availability of, and ability to provide, *lifeline utilities*, and essential and emergency services, during and after a *natural hazard* event.

Table 8: Risk table

Likelihood	**Consequences**				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain					
Likely					
Possible					
Unlikely					
Rare					
Green, Acceptable *Risk*: Yellow, Tolerable *Risk*: Red, Significant *Risk*					

Notes:

Table 8 above has been included as a region-wide baseline. As set out in HAZ–NH–M2(1) *local authorities* are required to undertake a consultation process with communities, stakeholders and partners regarding *risk* levels thresholds and develop a *risk* table at a district or community scale. This region-wide baseline is to be used in the absence of a district or community scale *risk* table being developed.

When this assessment is being undertaken in accordance with HAZ-NH-M3(7)(a) or HAZ-NH-M4(7)(a) the text within Step 3 shall guide the assessment of *natural hazard risk*.

Step 4 – Undertake a quantitative *risk* assessment

While Steps 1-3 will qualitatively categorise *natural hazard risk* based on a community's understanding and acceptance level of *risk*, it will not provide quantitative understanding of the *risk* a *natural hazard* presents to the built environment, or health and safety.

If the assessment undertaken in Steps 1-3 determines that one of the three *natural hazard* scenarios generate *risk* that is significant, undertake a quantitative *risk* assessment utilising the following methodology:

(1) Based on the likelihood of a *natural hazard* event within the hazard zone (see Step 1), and including the potential impacts of *climate change* and sea level rise, select a representative range

of at least five hazard scenarios with varying likelihoods to model,[50] including the maximum credible event.

(2) Model the Annual Individual Fatality Risk (AIFR)[51] and Annual Property Risk (APR)[52] for the range of hazard scenarios across the hazard zone, and create loss exceedance distributions.

(3) Analyse loss exceedance distributions and determine losses.

(4) Implementing a first-past-the-post principle for the AIFR and APR:

  (a) for areas of new development where the greatest AIFR or APR is:

    (i) less than 1×10^{-6} per year, the *risk* is re-categorised as acceptable,

    (ii) between 1×10^{-6} and 1×10^{-5} per year, the *risk* is re-categorised as tolerable, or

    (iii) greater than 1×10^{-5} per year, the *risk* is re-categorised as significant.

  (b) for areas with existing development, where the greatest AIFR or APR is:

    (i) less than 1×10^{-5} per year, the *risk* is re-categorised as acceptable;

    (ii) between 1×10^{-5} and 1×10^{-4} per year, the *risk* is re-categorised as tolerable; or

    (iii) greater than 1×10^{-4} per year, the *risk* is re-categorised as significant.

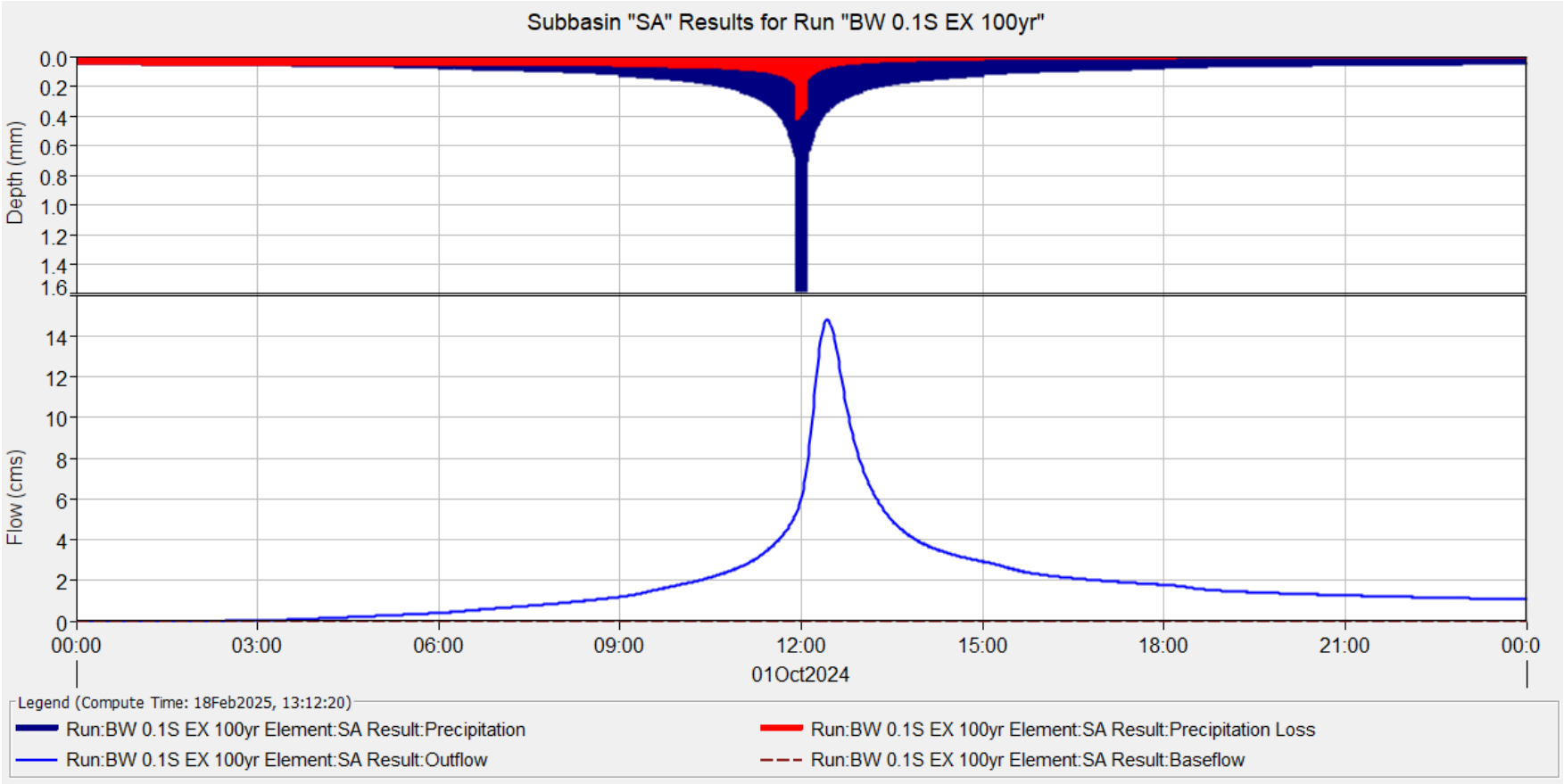
(5) Following the quantitative *risk* assessment, a *risk* level is assigned to the hazard area.

AIFR and APR are the selected *risk* metrics as they represent the likely consequences of a wide range of *natural hazards*. For example, some *natural hazards*, generally, do not have the capacity to cause fatalities, but may result in widespread damage to property, while other *natural hazards* have a high capacity to cause fatalities. A first-past-the-post principle to the re-categorisation of *risk* is applied to ensure that decisions are based on the greatest *risk* present between the two metrics.

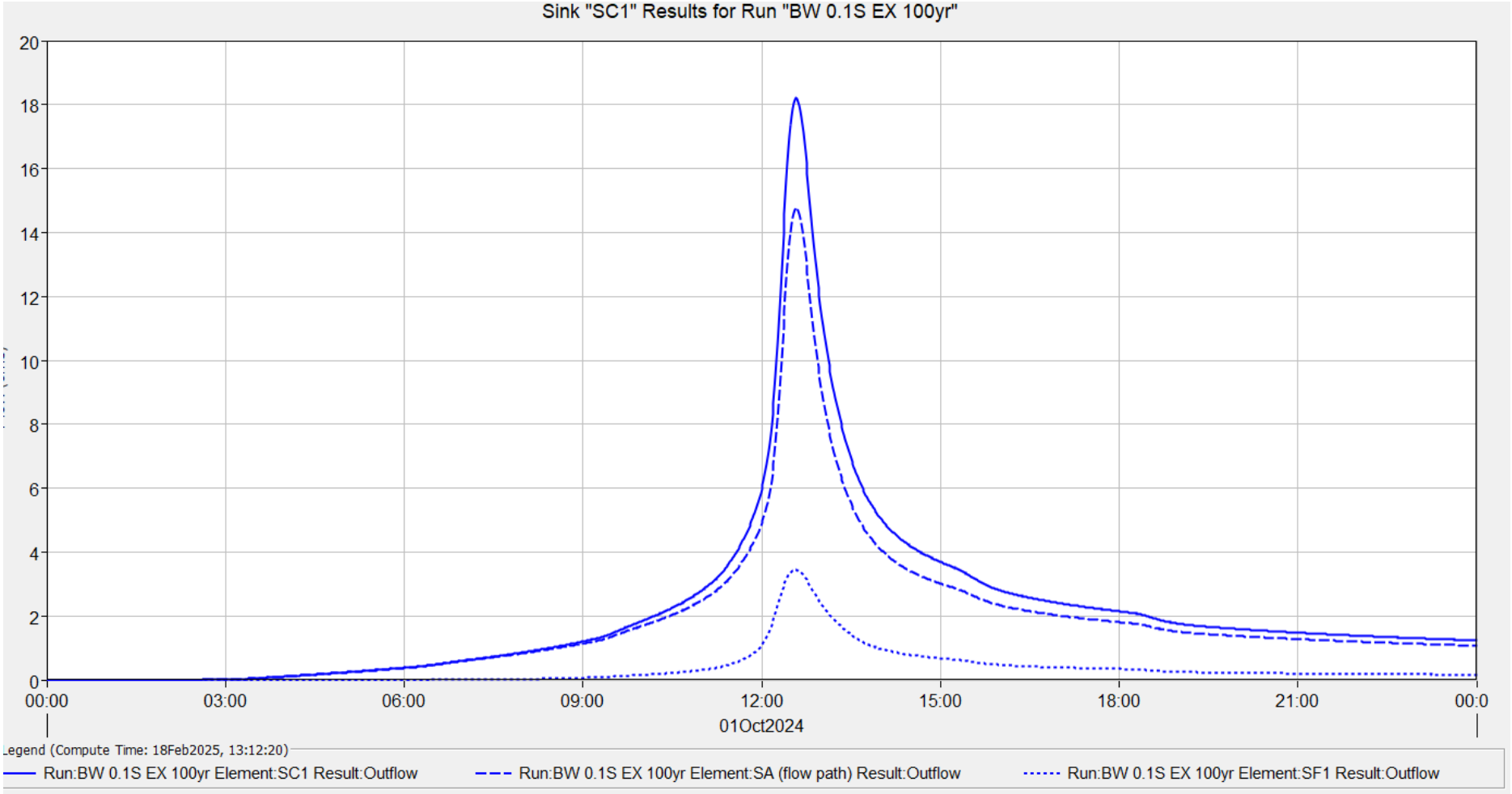
If the level of knowledge or uncertainty regarding the likelihood or consequences of a *natural hazard* event precludes the use of Step 4, then a precautionary approach to assessing and managing the *risk* should be applied, as set out in HAZ–NH–P5.

[50] The model should include an analysis of uncertainty
[51] Annual probability that an individual most at risk is killed in any one year as a result of the hazards occurring
[52] Annual probability of total property loss (relating to permanent structures) as a result of the hazards occurring

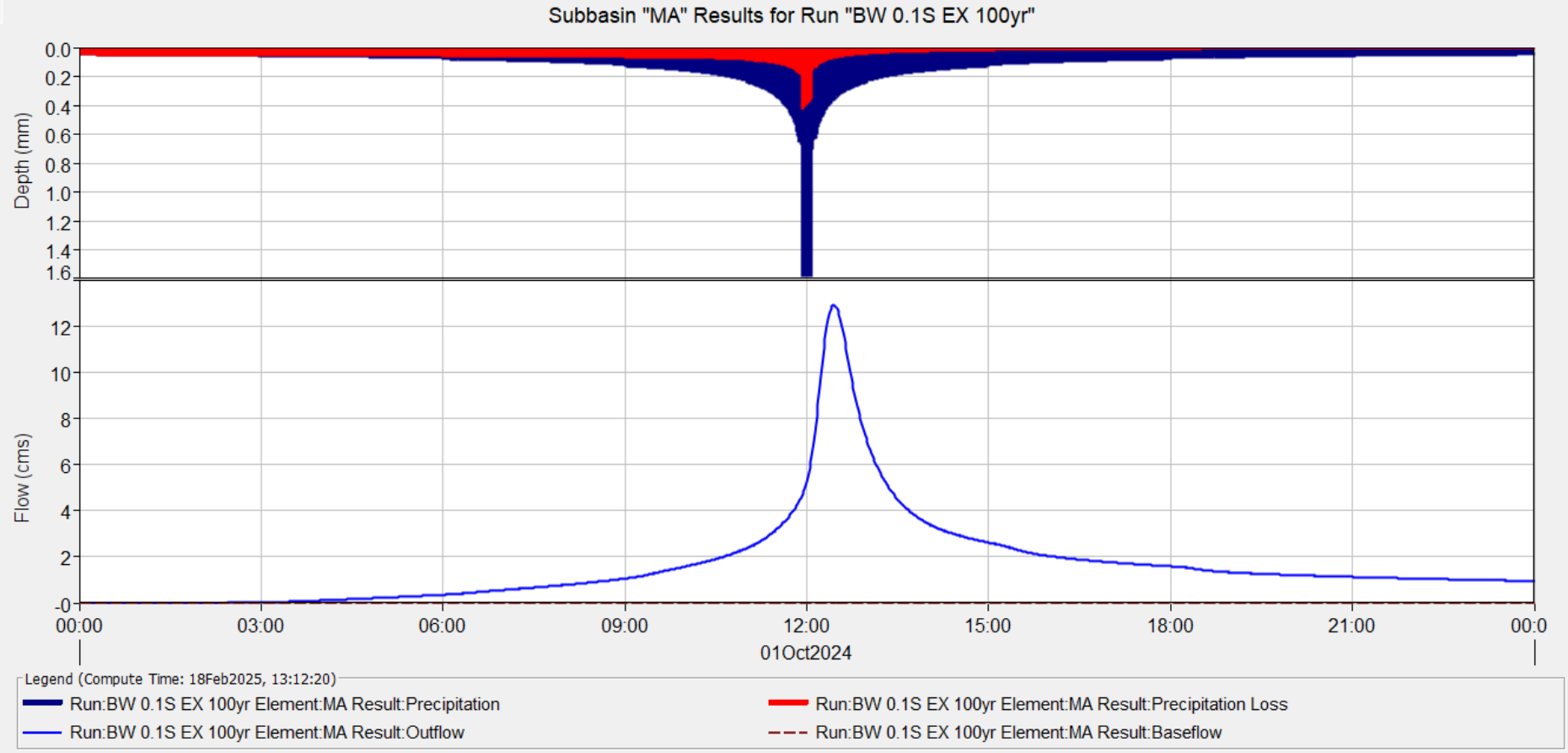
Appendix E: Additional HEC-HMS Hydrological model results



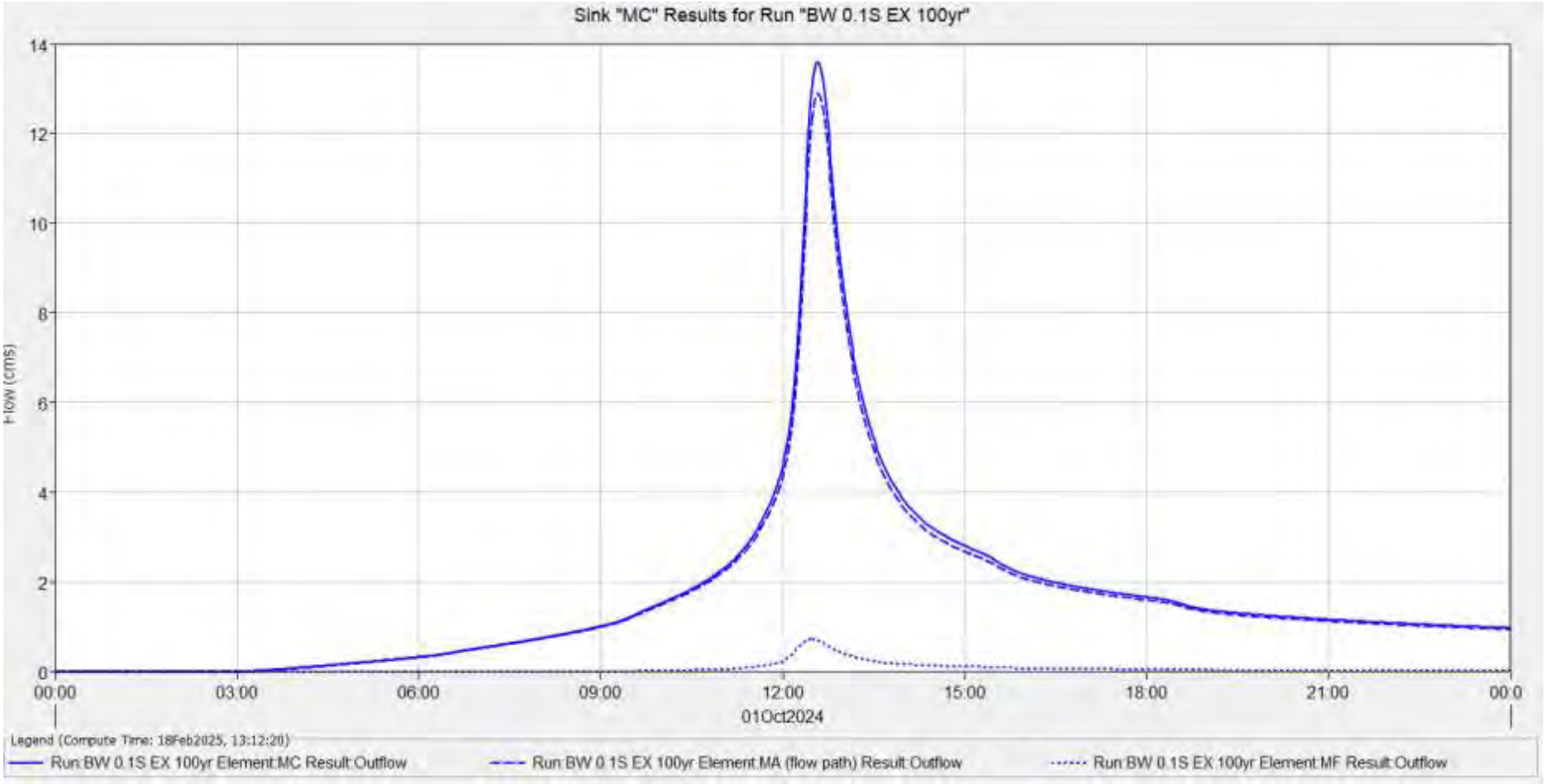
Design storm hytograph, losses and hydrograph for the southern catchment



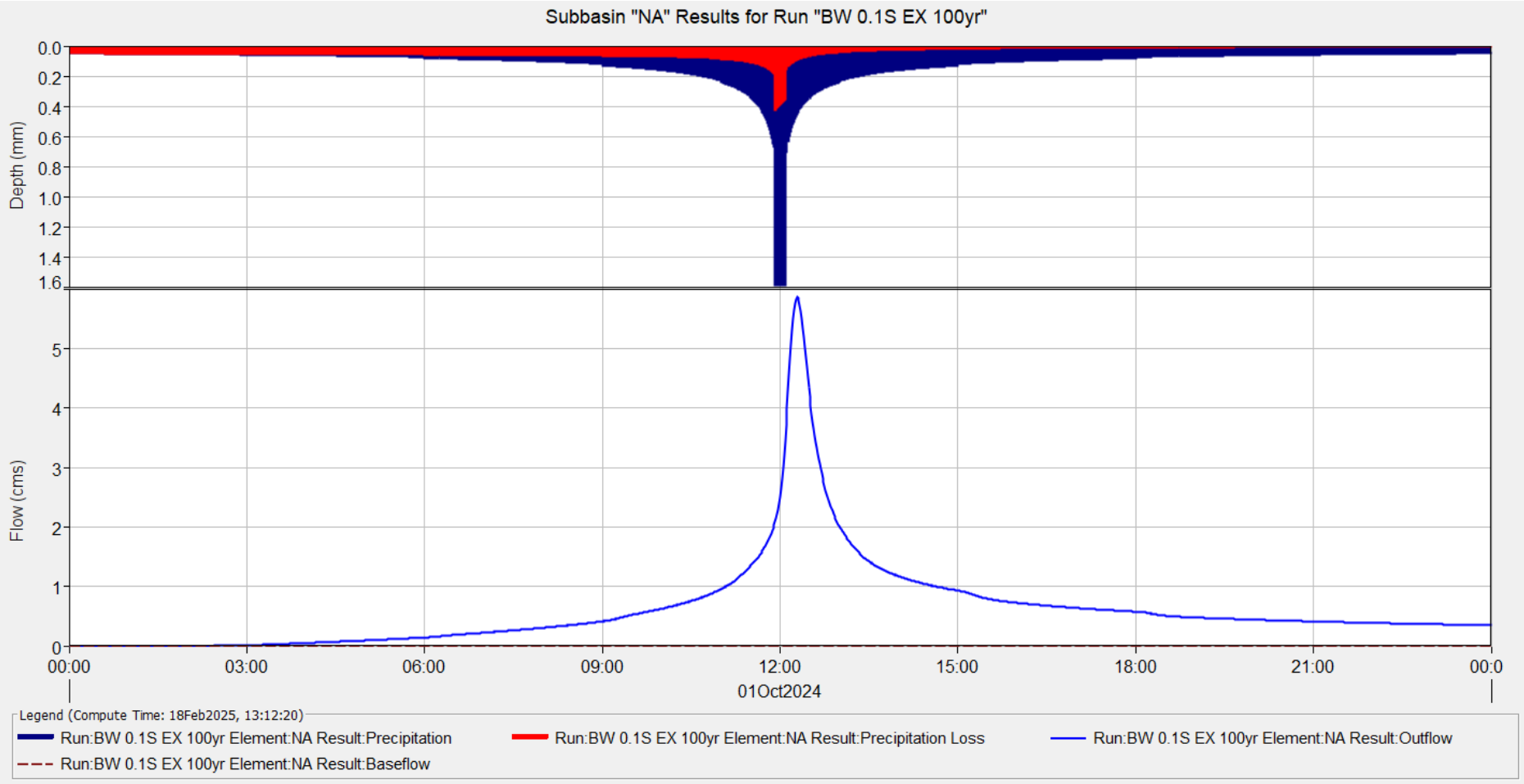
Combined inflows and outflow at the road for the southern catchments



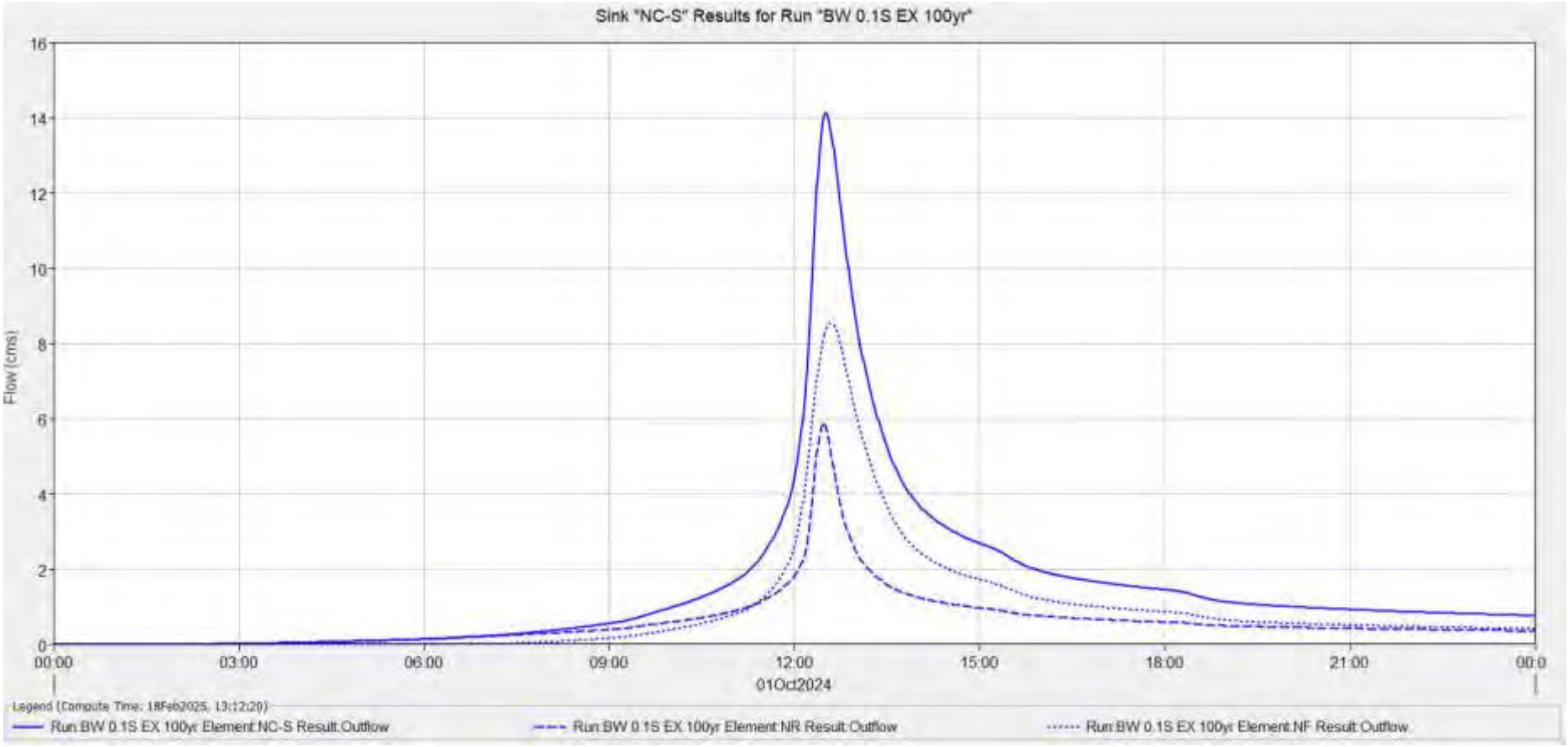
Design storm hytograph, losses and hydrograph for the middle catchment



Combined inflows and outflow at the road for the middle catchments

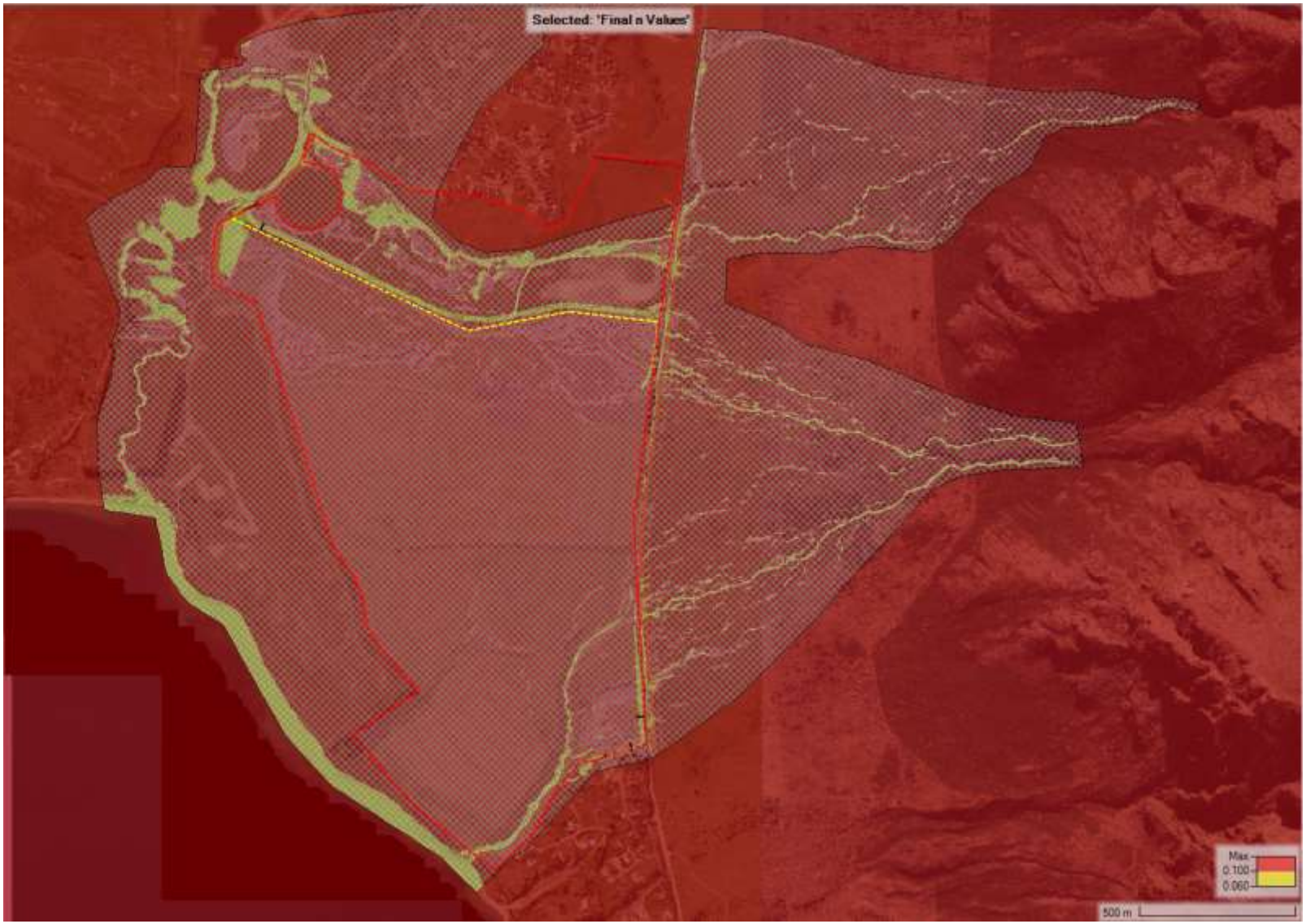


Design storm hytograph, losses and hydrograph for the northern catchment

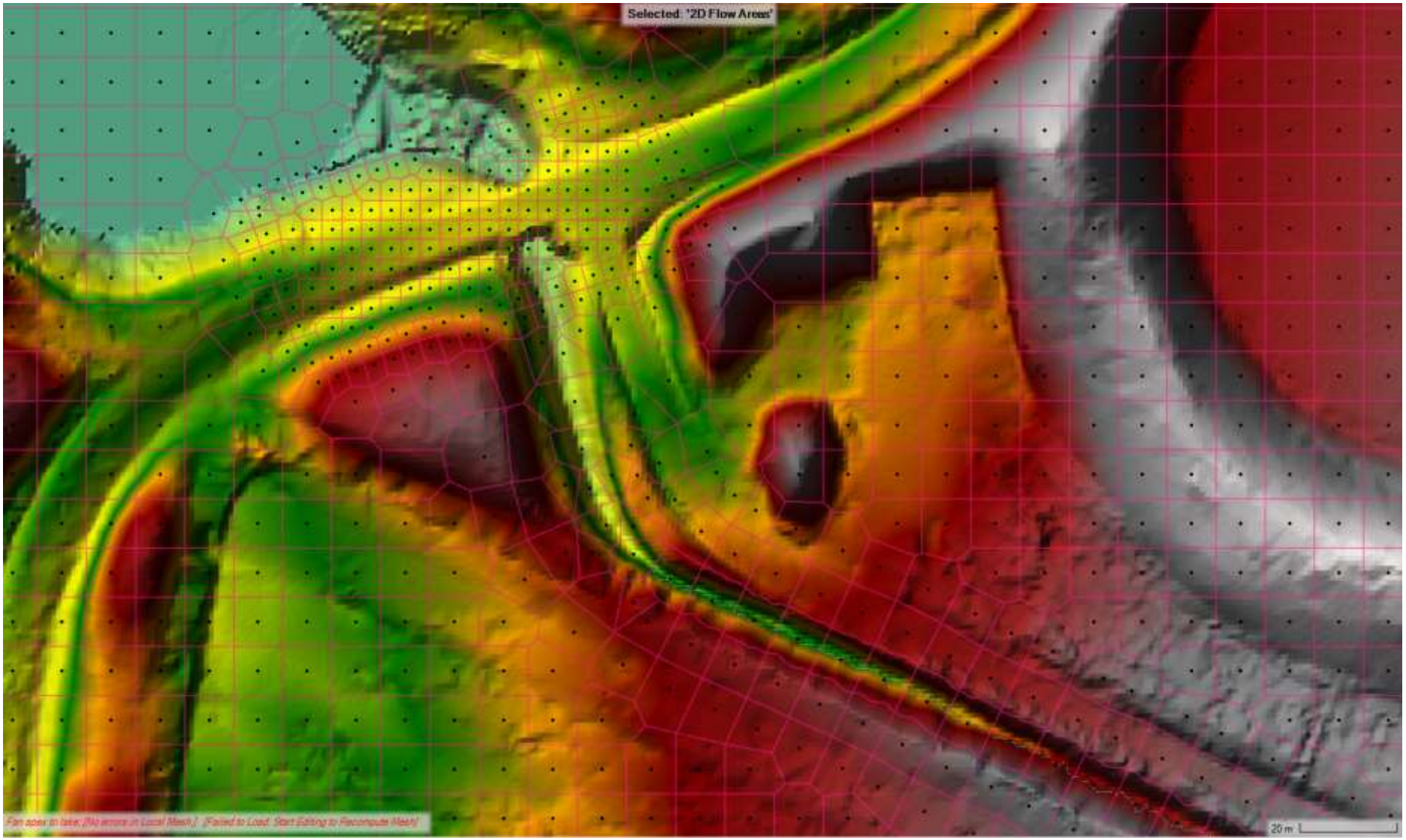


Combined inflows and outflow at the road for the northern catchments

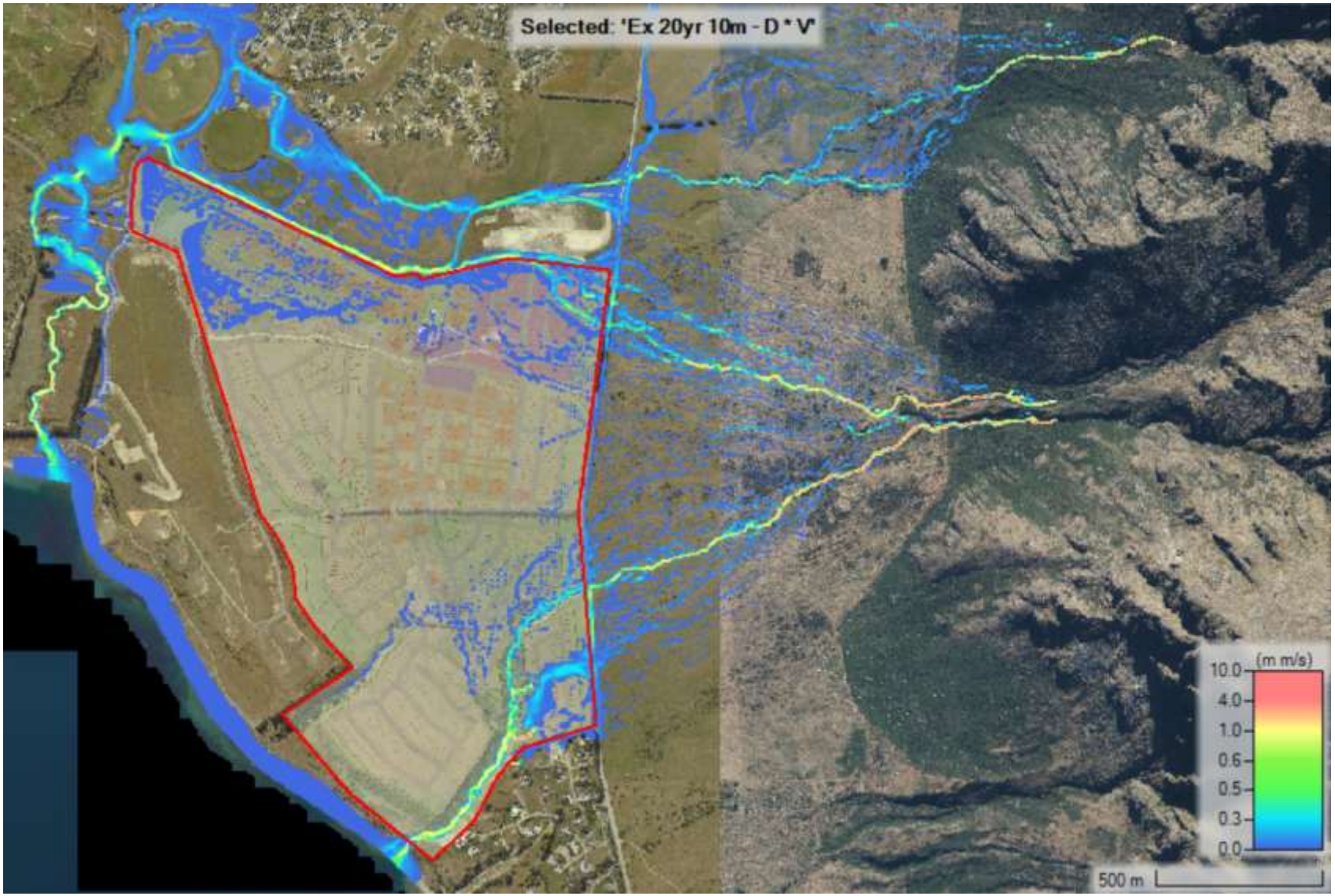
Appendix F: Additional HEC-RAS flooding model parameters & results



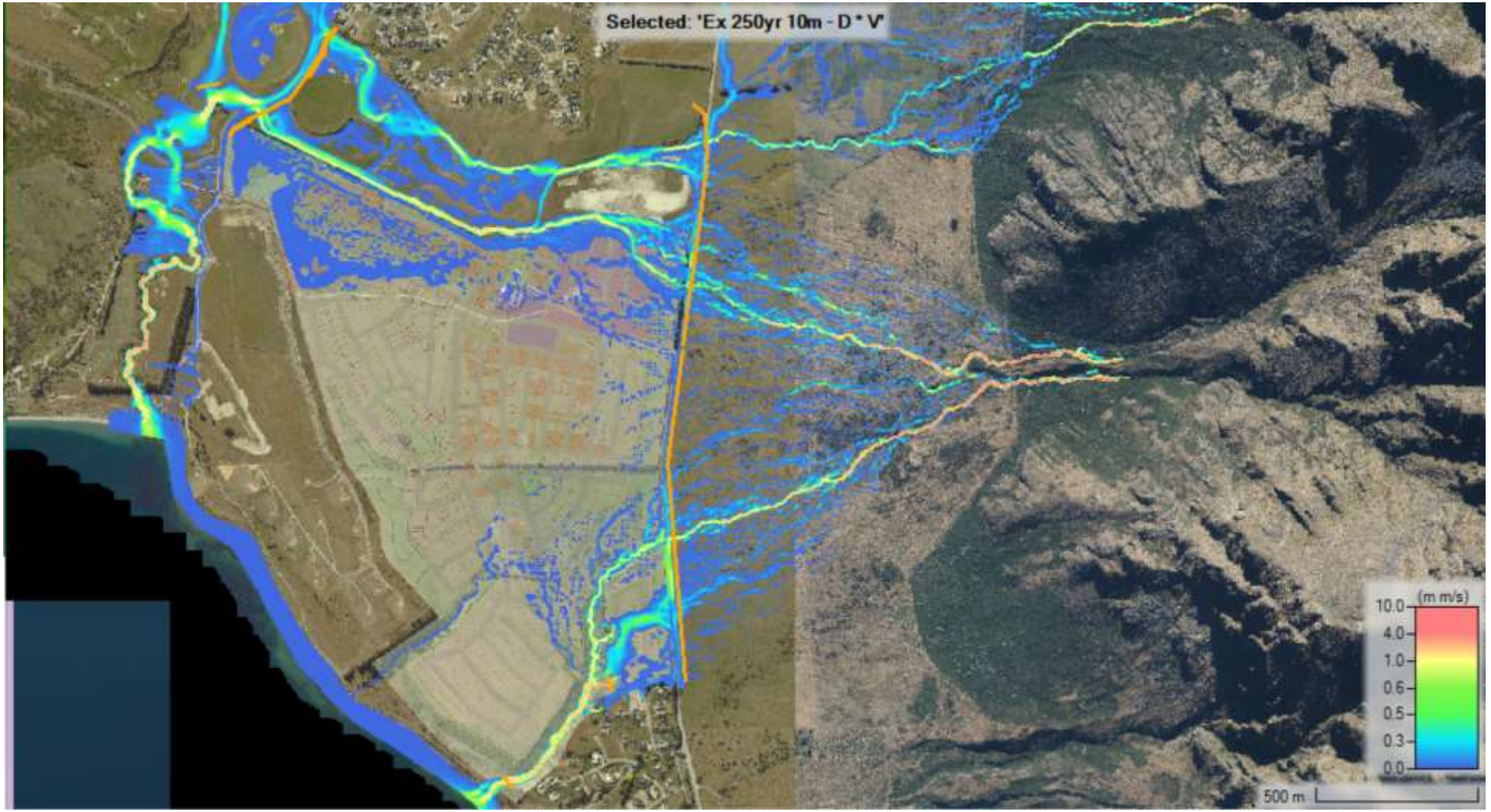
Post-development manning's-n value layer



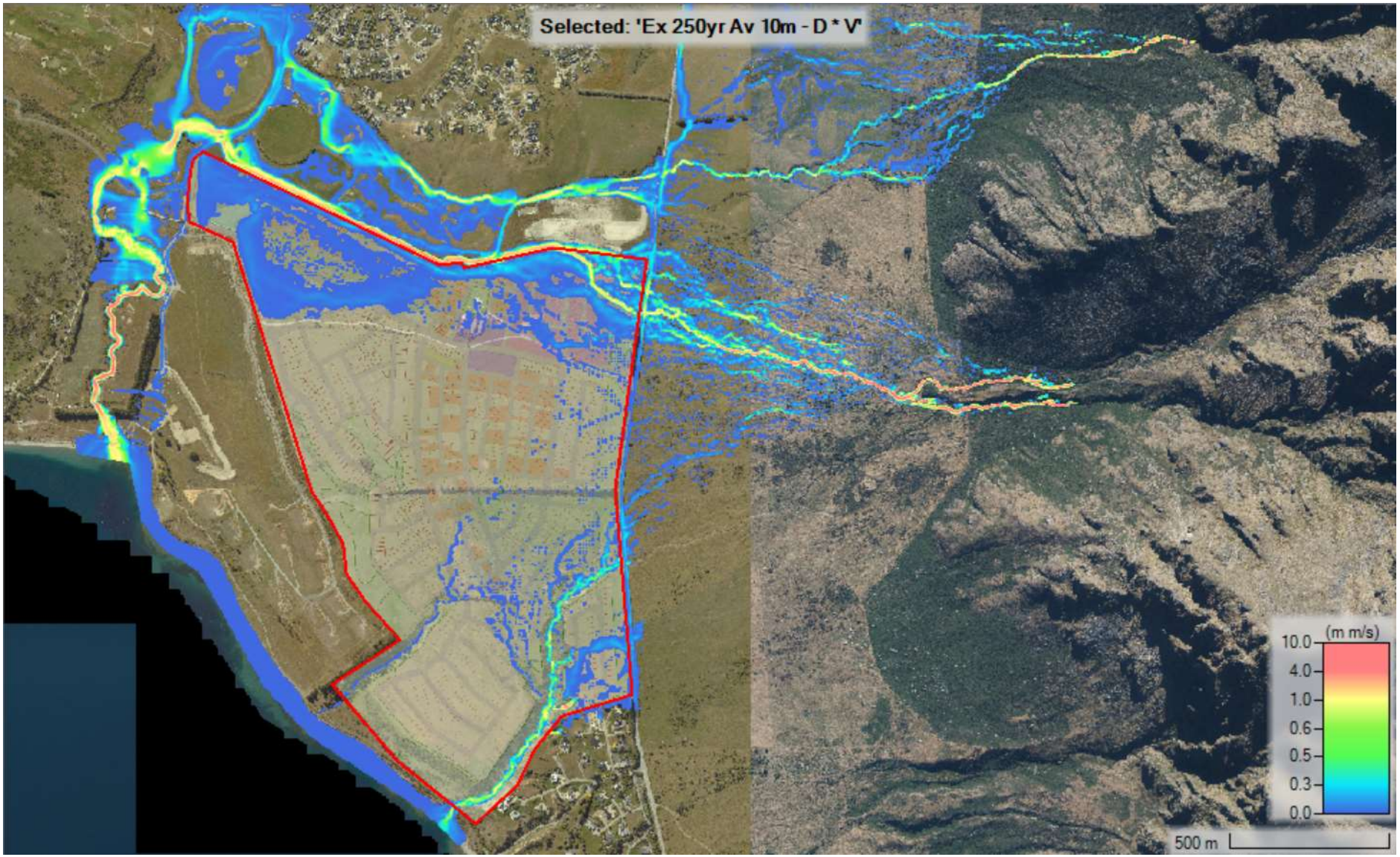
Example of 2d Flow area mesh showing refinement regions aligned with the pre-development diversion channel and road crossing downstream of the northwestern site boundary.



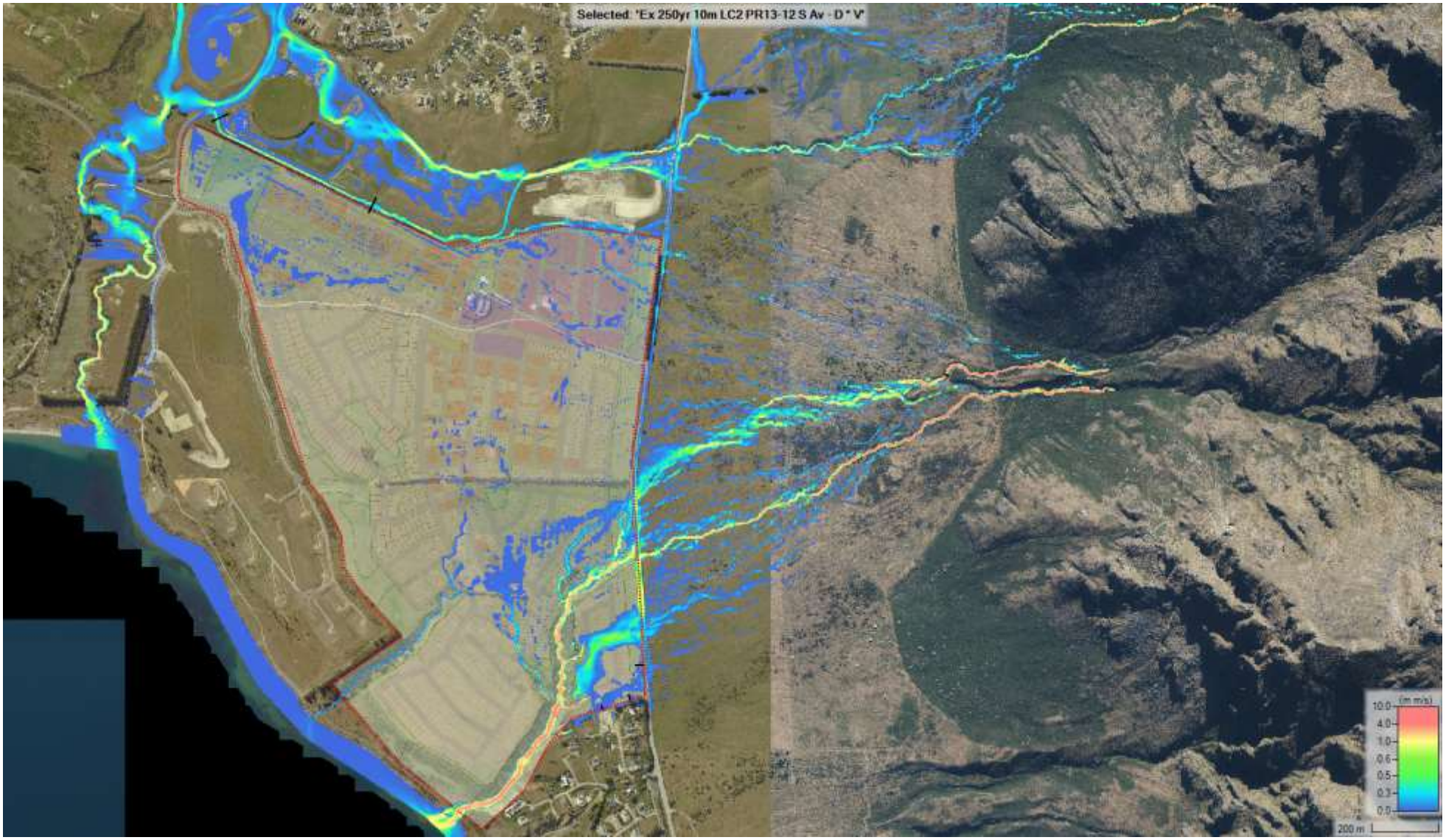
Pre-development debris flood hazard for a 20 yr return period rainfall event.



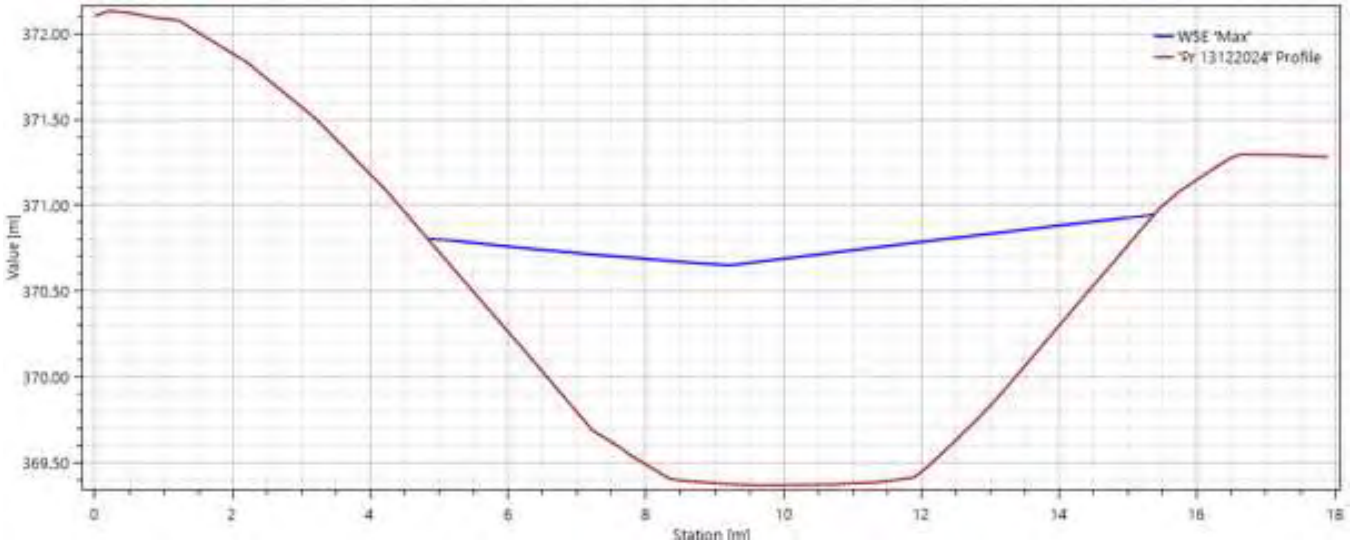
Pre-development debris flood hazard for a possible event, 250+ yr return period rainfall event.



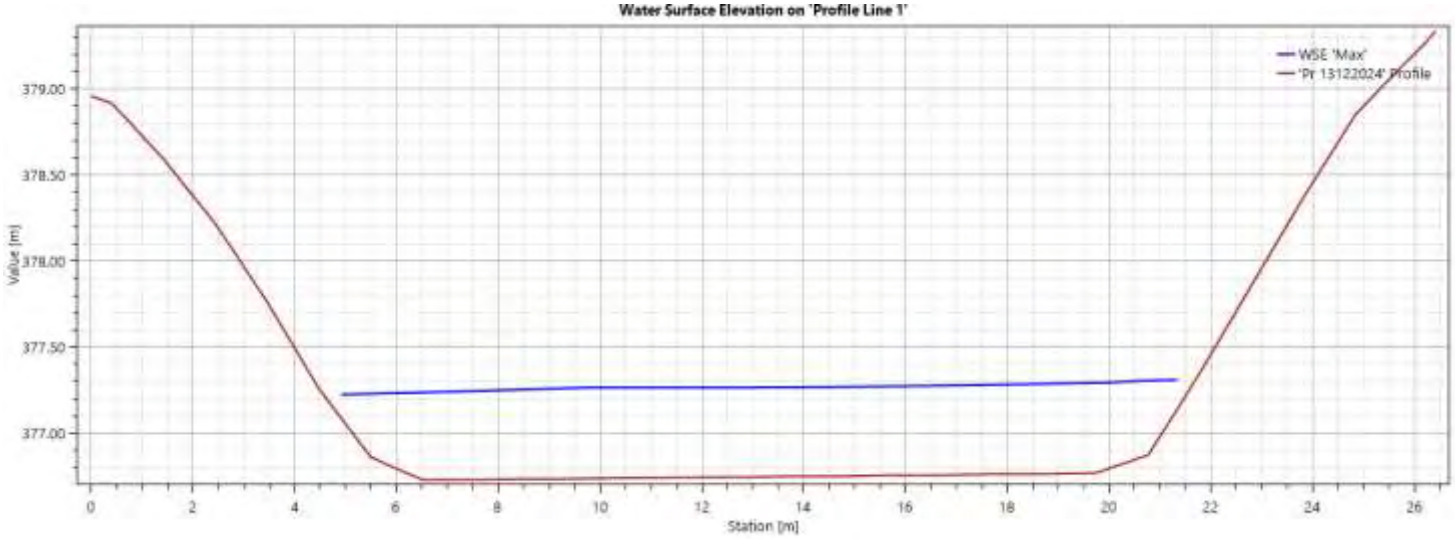
Pre-development debris flood hazard for a possible event, 250+ yr return period rainfall event with avulsion of the southern creek into the middle creek at the fan apex.



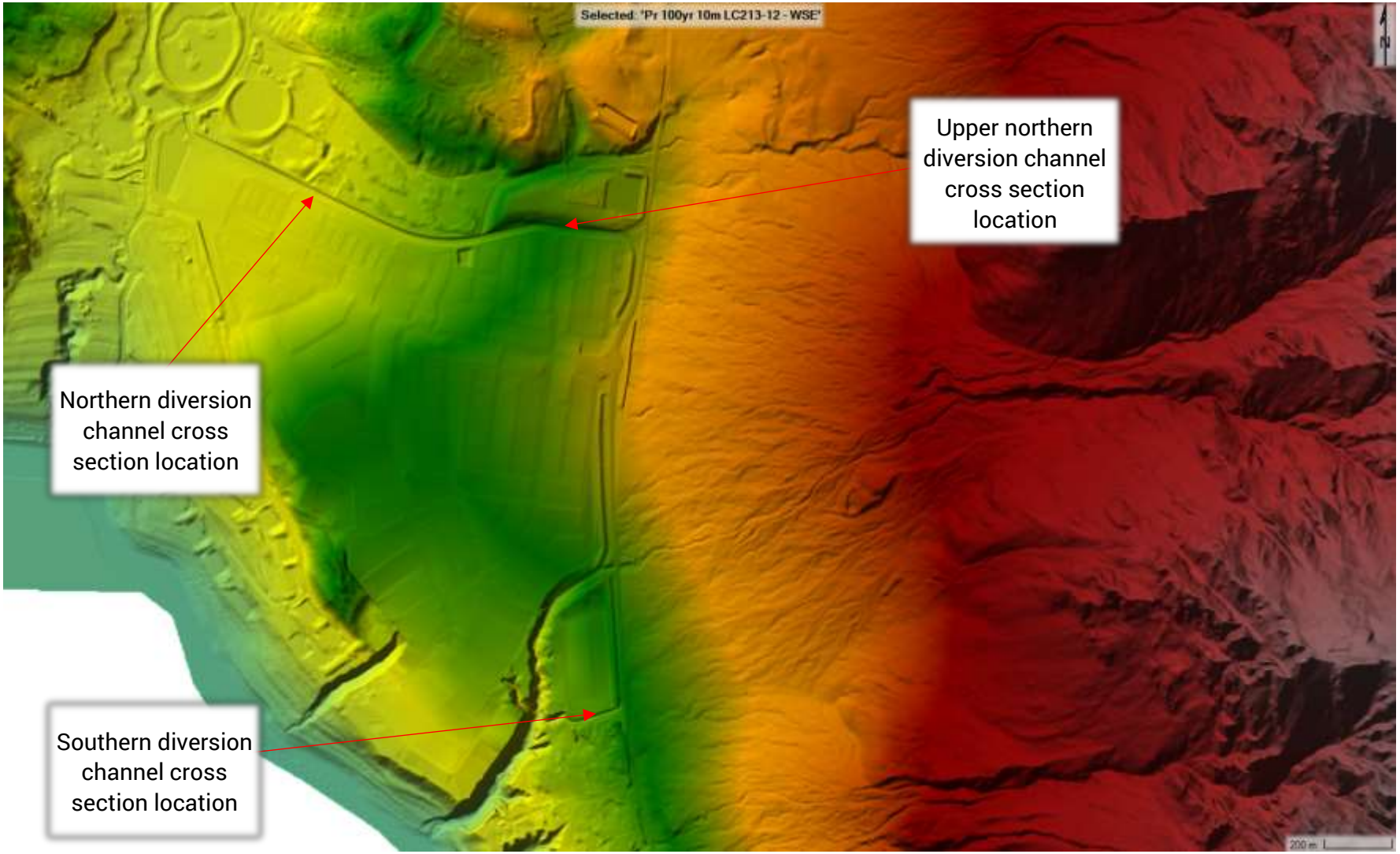
Pre-development debris flood hazard for a possible event, 250+ yr return period rainfall event with avulsion of the middle creek to the south at the fan apex.



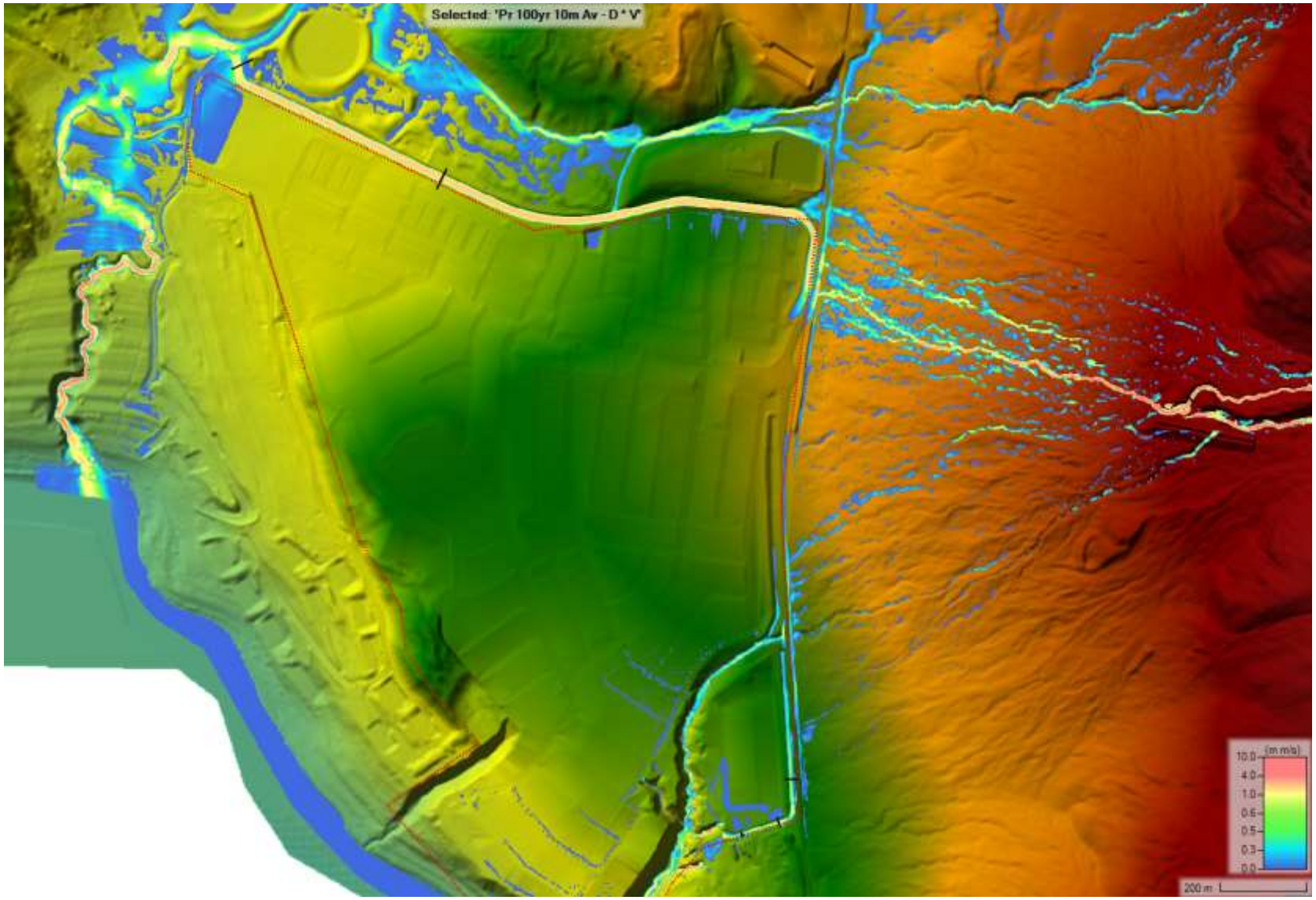
Maximum water surface elevation in the currently proposed southern diversion channel



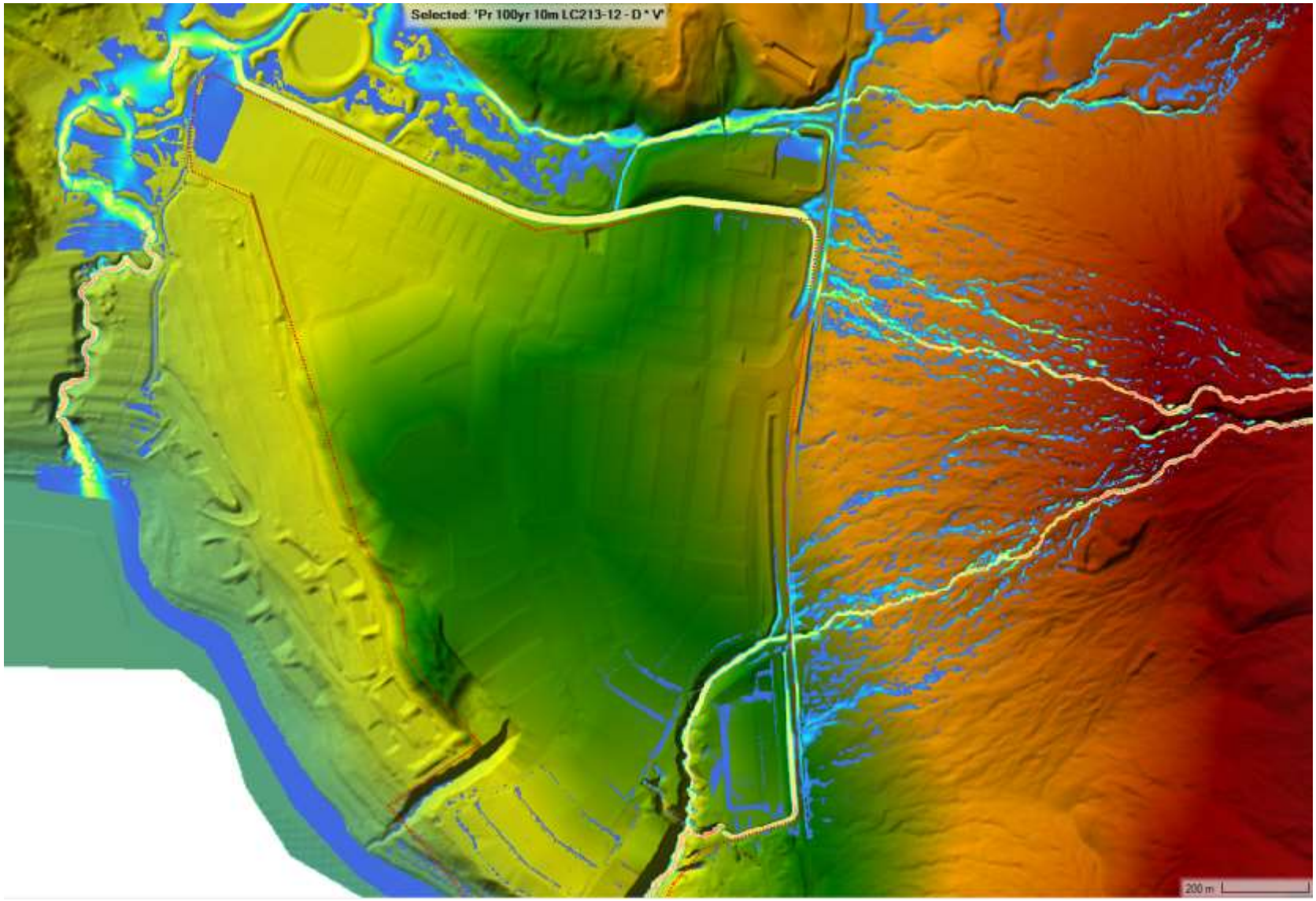
Maximum water surface elevation in the currently proposed upper northern diversion channel



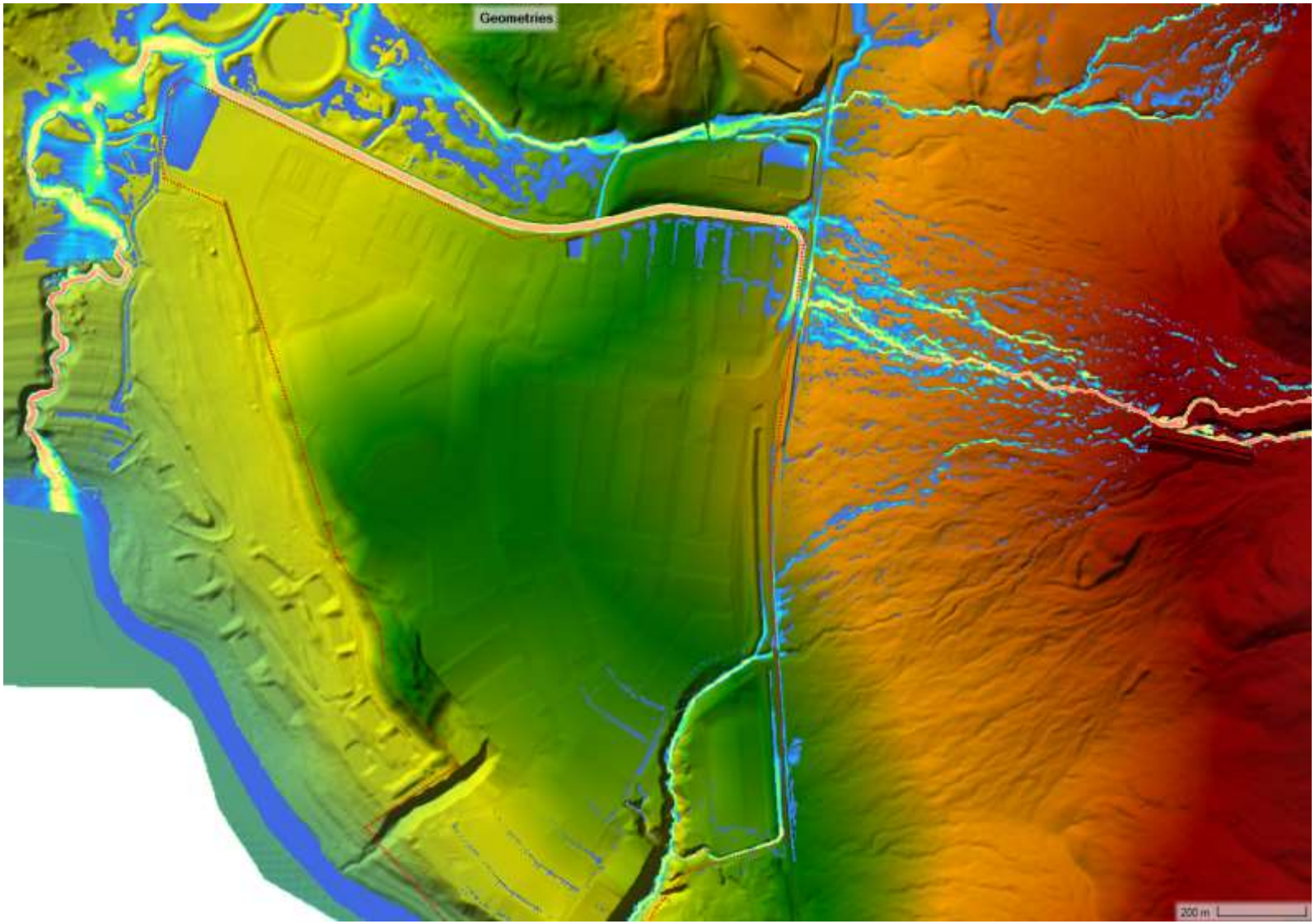
Locations of diversion channel cross sections



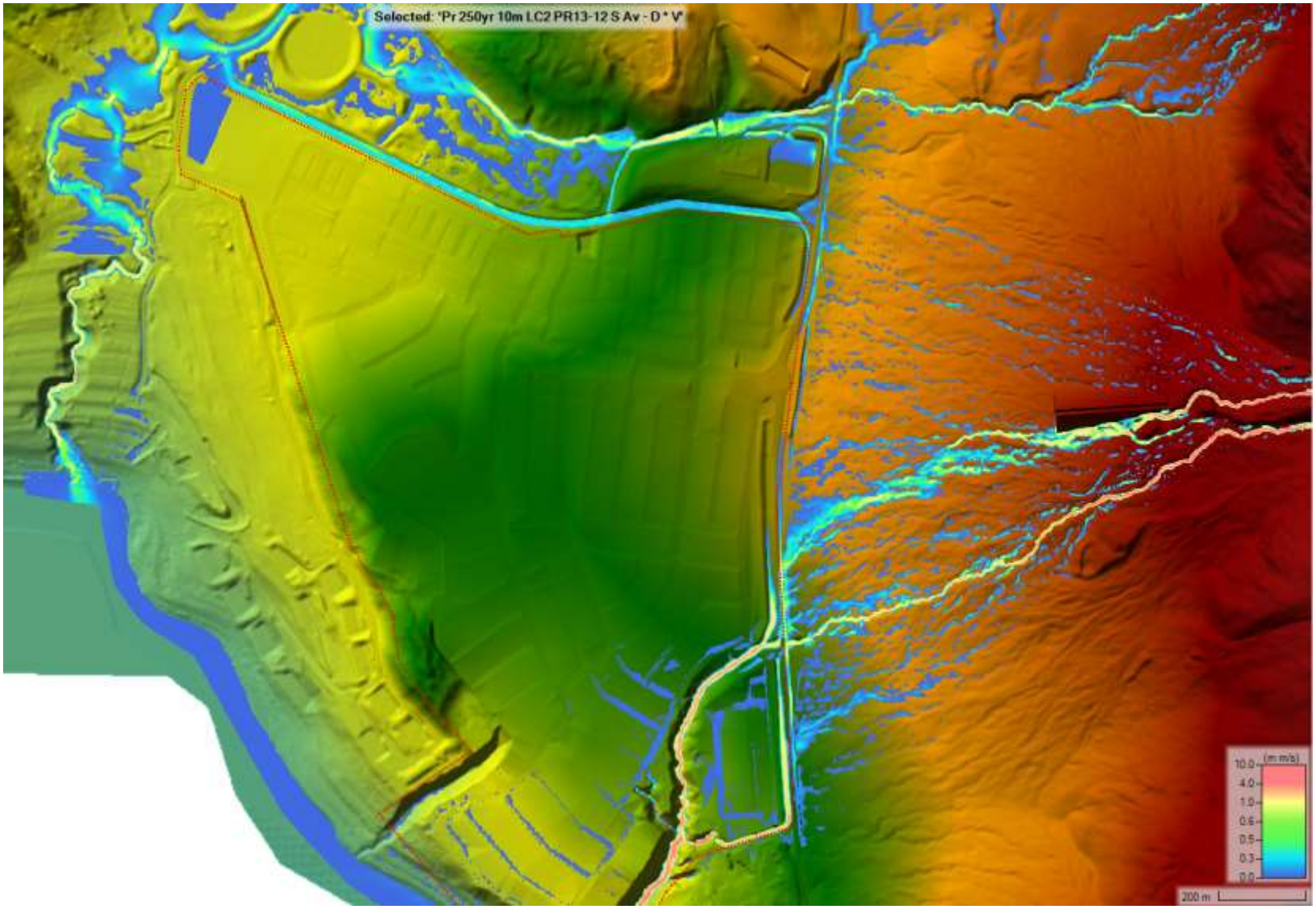
Post-development debris flood hazard for a 100 yr return period event with avulsion of the southern creek into the middle creek at the fan apex.



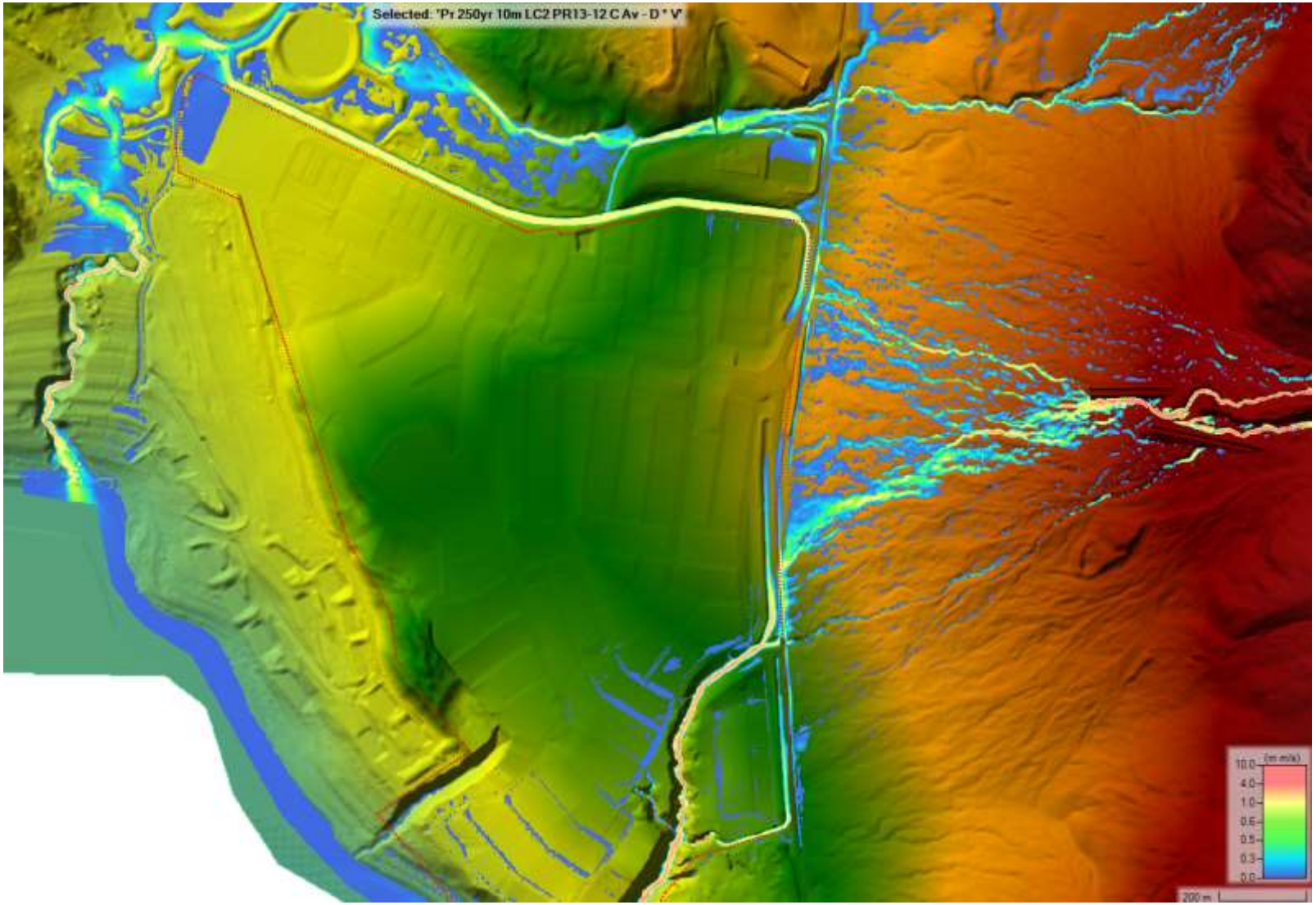
Post-development debris flood hazard for a 250+ yr return period design event.



Post-development debris flood hazard for a maximum credible event, 250+ yr return period event with avulsion of the southern creek into the middle creek at the fan apex.



Post-development debris flood hazard for a maximum credible event, 250+ yr return period event with avulsion of the middle creek to the south at the fan apex.



Post-development debris flood hazard for a maximum credible event, 250+ yr return period event with migration of both flow paths to the central area of the fan.

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Appendix F Hanley's Farm Routine Monitoring under Consent RM22.263.01

APPENDIX F

Overview

This summary provides an overview of the stormwater discharge monitoring completed to date for the Hanley's Farm Residential Development (Figure 1), and relevant receiving environment descriptions set out in the Land Water People report (LWP 2025[1]). These summaries provide a context and understanding of the stormwater discharges likely to be generated by the proposed Homestead Bay subdivision.

This summary includes an assessment of:

- Stormwater quality discharge monitoring results from Hanley's Farm Residential Development, acquired under consent RM22.263.01;
- Comparison of stormwater quality results for Hanley's Farm against available data from NIWA's Urban Runoff Quality Information System (URQIS)[2],
- Description of receiving environment quality and ecological values as summarised by LWP (2025), and Water Ways Consulting (Allibone, 2023[3]), as these pertain to the Homestead Bay development. LWP (2025) also provides a detailed overview of the quality of receiving waters, Lake Wakatipu, dry gullies, Māori Jack Stream, with is not repeated in detail here but their conclusions have been summarised here.

[1] Land Water People (LWP), 2025. Draft memorandum: Assessment of sensitivity and water quality criteria for Lake Wakatipu and its tributary streams, and of risks to manage for the treatment and discharge of wastewater from Homestead Bay housing development. 18 February 2025

[2] https://urqis.niwa.co.nz/ Noting no data is available for the Otago region, thus, data from Southland was used for comparisons.

[3] Allibone, R. 2023. Homestead Bay Aquatic Ecology Assessment. Report No. 127-23, prepared for RCL Group. November 2023.

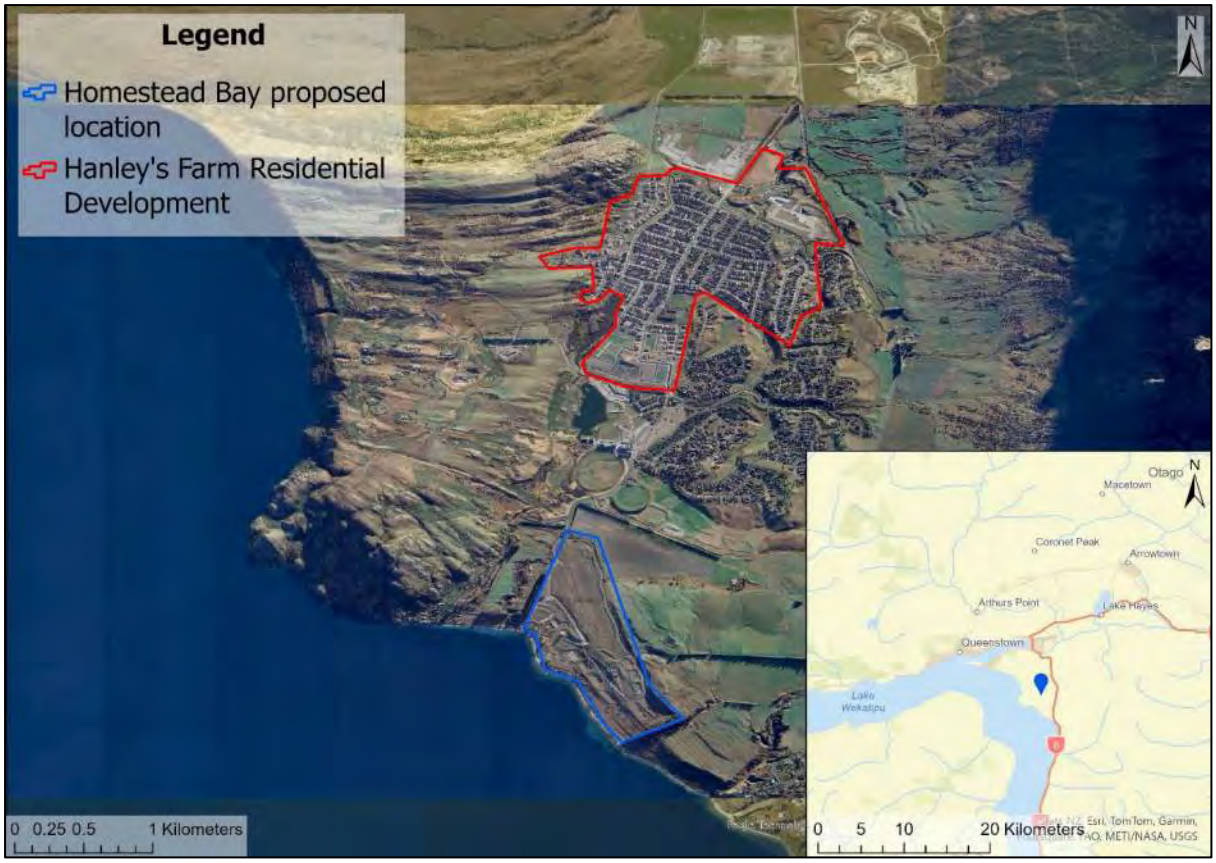

Figure 1 Location of the land use catchment and Hanley's Farm development in context of the proposed Homestead Bay development.

Guidelines and assessment framework

There are no New Zealand guidelines for end-of-pipe stormwater discharge quality (i.e. prior to mixing and dispersion in the receiving environment). It is widely accepted that stormwater quality is highly temporally and spatially variable. This variability is driven by site specific hydrological characteristics of the catchment, including (but not limited to) antecedent dry periods, rainfall intensity and duration.

Water quality guidelines (e.g. ANZG 2018[4]) are commonly applied for assessment of ecological risk to the receiving environment posed by point source discharges such as stormwater. More recently, acute receiving environment guidelines have also been published, with the intention that these may be applied to regulatory processes managing effects of point source discharges[5].

It is emphasised here, both the ANZG (2018) and recently published acute copper and zinc toxicity guidelines (Gadd et al. 2024[6]) apply for receiving environment assessment of effects, after reasonable mixing, and are not intended to assess compliance of the end-of pipe discharge itself. The available data acquired under Consent RM22.263.01, does not include receiving environment monitoring (only end of pipe samples).

The ANZG (2018) guidelines provide for long–term thresholds of water quality in the receiving environment (after reasonable mixing) and are applicable for the assessment of catchment wide

[4] Water Quality Guidelines Home.

[5] The ANZG defines **acute toxicity** as *a 'lethal or adverse sub-lethal effect that occurs as the result of a short exposure period to a chemical relative to the organism's life span';* **chronic toxicity** is define as '*a lethal or sublethal adverse effect that occurs after exposure to a chemical for a period of time that is a substantial portion of the organism's life span or an adverse effect on a sensitive early life stage*'. The current ANZG (2018) DGV's are chronic thresholds of species protection, whereas the Gadd et al. (2024) GVs list acute thresholds of species protection.

[6] Gadd J.B., Hickey, C.W., Snelder, A.H. (2024) Acute copper and zinc water quality guideline values for Aotearoa. Technical report of the derivation including bioavailability model evaluation. Report prepared for Ministry for the Environment. (260 pp).

effects of discharges to water bodies, rather than assessment of the direct or first-flush quality of stormwater discharges itself. Similarly, the recently published acute copper and zinc interim guideline values (GVs) (Gadd et al., 2024), like the ANZG (2018) DGVs, are applicable for receiving waters downstream of a discharge – rather than to the discharge quality itself.

For both sets of guidelines, DGV or interim GVs are typically applied to assess the risk of the dissolved (i.e. bioavailable) fraction of metals. For data where the total fraction of metals has been analysed (i.e. bioavailable and non-bioavailable fractions), if the concentration is below the DGV/GV, then the risk to the receiving environment is low. If the total fraction is higher than the DGV/GV, then the sample (and possibly future samples) would require to be analysed for the bioavailable fraction (i.e. dissolved component) to assess ecotoxicological risks. If there is ongoing evidence of elevated metal concentrations exceeding the DGV/GV, other factors that influence the toxicity (and hence risk to biota) would also be considered. These factors may include water quality modifiers such as pH, dissolved organic carbon, water hardness. This process would generally be undertaken as a tiered weigh of evidence process if the risks to receiving environment are required to be quantified, and would require significant targeted sampling campaigns that would likely not be accounted for in routine consent monitoring schedules.

The National Policy Statement for Freshwater Management[7] (NPSFM) lists National Bottom Lines (NBL) and D-band attribute states for important water quality attributes (in particular, nutrient analytes) for receiving waters in New Zealand. As with the ANZG and acute thresholds, the NPSFM NBLs (and other listed attribute band states) are intended for long term data sets, applicable to assessment of the state of receiving environment conditions. The reference to NBL or D state thresholds in this summary for Hanley's Farm is for information purposes only – not an assessment of breaches or non-compliance of monitoring results.

Given the above, direct comparison of stormwater results against the ANZG (2018), Gadd et al. (2024) interim tier 1 GVs, or NPSFM NBL is overly precautionary basis to inform potential risks to the receiving environment of the stormwater discharge quality itself. Rather, DGVs/GV/NBL are included as an additional line of information, and an exceedance of a DGV/GV/NBL (where provided) does not necessarily constitute an ecological risk. Rather, it serves as an indicator of potential contaminants of concern that are anticipated to be present in the stormwater discharge, and which may require mitigation to avoid and mitigate risks of the contaminant to the receiving environment.

Further, a qualitative assessment of potential risks posed by stormwater discharges to receiving environment water courses within the Homestead Bay subdivision is included on the basis of the assessment of receiving environment receptors summarised by LWP (2025) and Allibone (2023).

To gauge the relative quality of stormwater from the Hanley Farm development, summarised data was compared against available data held on NIWA's Urban Runoff Quality Information System (URQIS[2]) database. The URQIS database is a national data repository providing a useful resource of publicly available data for stormwater quality acquired across the country. It was noted there is no available data for the Otago region, therefore data from Southland was referred to. There were 11 data points available from Southland (noting no data was listed for the Otago region) based on a database search with the following parameters:

- Land use catchments: High-density and medium-density residential.
- Region: South Island regions – the only available data for South Island regions was from Southland.
- Water Types: Untreated stormwater[8]

Available water quality parameters held on URQIS included total phosphorus, suspended solids, pH, total zinc, total copper, total lead, total arsenic, and total chromium. A comparison of Hanley's Farm

[7] National Policy Statement for Freshwater Management | Ministry for the Environment

[8] Defined on URQIS as '*water contained within a reticulation network (generally a pipe network but may include some open channels such as swales) and is not subject to any form of quality treatment'*. It is noted the URQIS definitions do not identify specific treatment devices or efficacy of treatment devices. Thus, it is assumed the data for untreated stormwater is for a 'worst case' and may be improved with treatment.

stormwater discharge monitoring results against URQIS will provide a general context of what stormwater quality may be typically expected from medium-high density residential sites of similar land use catchments and environmental conditions.

Summary of Hanley's Farm monitoring 2023-2024

Hanley's Farm is a residential development located north of Homestead Bay within the same hydraulic catchment. Stormwater discharge monitoring is undertaken at Hanley's Farm as required by their resource consent (RM22.263.01, granted 26 July 2023). Stormwater monitoring has been undertaken at Hanley's Farm since September 2023, with ten monitoring events occurring between September 2023 and December 2024. Monitoring records under this consent provide relevant contextual information as to the anticipated quality of stormwater in the Homestead Bay subdivision.

The stormwater monitoring samples are collected from seven sampling locations across the Hanley's Farm development (Table 1). Consent conditions state that quarterly stormwater samples are to be collected during storm flow conditions, specifically following a rainfall event that exceeded 10 mm in 12 hours during the months of March, June, September, and December and following all major storm events (rainfall exceeding 20 mm in 12 hours). The consent does not specify samples are to be represent 'first flush' samples, which would require the installation and programming of water auto sampling units.

Stormwater discharge quality results have been collected from September 2023 to December 2024. During this period, the residential development across the lots ranged from was 50% to 95% stage of development (Table 1).

Table 1: Hanley's Farm sampling location details.

Sampling location ID	Description	Lot Development Date	Lot Development Date
DP1	Outlet	Civils – February 2019 Houses – 95% Complete around late 2021	Woolshed Creek
DP4	Outlet	Civils – February 2022 Houses – 95% complete late 2024	Woolshed Creek
DP5A	Outlet Willow Pond Channel WC	Civils – February 2021 Houses – 95 % Complete around late 2023	Western Channel then Woolshed Creek
DP5B	Outlet West Channel WC	Civils – May 2022 – Houses 95% late 2024	Western Channel then Woolshed Creek
DP7A	Willow Pond	Civils – November 2023 – Houses 50% are finished rest still under construction	Willow Pond
DP9	Outlet	Civils – April 2023 – Houses 75% are complete rest are still under construction	Willow Pond
DP9NW	Inlet to SW System in DP9 from farmland above	Civils – April 2023 – Houses 75% are complete rest are still under construction	Willow Pond

Hanley's Farm stormwater quality - Chemical and Physical Parameters

Hanley's Farm stormwater discharge monitoring results are listed in Table 3, and summarised as follows:

- Total Nitrogen, TKN (organic N), and TP are strongly positively correlated, with Pearson's R coefficients of 0.87, 0.91 and 0.96 for TN, TKN and TP, respectively;
- DRP, Nitrate-N and Ammoniacal-N are not correlated with TSS (Pearson's R coefficient -0.19, -0.11, -0.04, respectively);
- Nitrite-nitrogen levels were all generally lower than laboratory detection limits;
- Conductivity was not correlated with TSS. The range of median values (17-75 µs/cm) reflects the variable nature of surface water conductivity, which is rapidly influenced by fluxes in dissolved substances (i.e. salts from natural soils, as well as agricultural fertilisers) that may wash into the catchments during rainfall and runoff from the surrounding catchment[9].
- pH levels were within the ambient range of most natural waters in New Zealand[10] (range pH 6.5 to 8.0).

[9] For reference, as noted on LAWA, high quality deionized water (nearly pure) has a conductivity of about 0.05 µS/cm, whereas seawater has a conductivity of approximate 50,000 µS/cm.

[10] Land, Air, Water Aotearoa (LAWA) - pH

Table 1: Median concentrations of physical and chemical parameters (mg/L) in stormwater sampled from the Hanley's Farm subdivision between September 2023 – October 2024 (N=10) (results rounded to 2 decimal places).

	Total Nitrogen	Nitrate - nitrogen	Nitrite Nitrogen	Ammoniacal nitrogen	Total Kjeldahl Nitrogen	Total phosphorus	Dissolved Reactive Phosphorus	Total dissolved Solids	Suspended Solids	Turbidity	Conductivity	pH
Sampling location ID	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**NTU**	**µs/cm**	
DP1 (N=10)	0.37	0.07	0.01	0.04	0.80	0.08	0.02	7.50	17.40	15	17	6.90
DP4 (N=10)	**0.93**	0.15	0.01	0.06	0.90	0.13	0.02	18.50	51.80	55	35	7.20
DP5A (N=10)	**1.03**	0.34	0.01	0.06	0.85	0.12	0.06	17.50	25	23	40	7.10
DP5B (N=10)	**1.12**	0.23	0.01	0.04	0.85	0.13	0.02	24.50	44.20	50	50	7.40
DP7A (N=10)	**1.31**	0.08	0.01	0.04	1.20	0.26	0.04	28.50	**101**	120	63	7.30
DP9 (N=10)	**3.08**	0.38	0.01	0.04	1.90	0.27	0.02	33.50	**131**	200	75	7.30
DP9NW (N=1)	**3.4**	0.99	0.13	0.13	2.5	0.17	0.004	113	51	38	228	7.4
Median URQIS range	-	-	-	-	-	**0.3**	-	-	**97**	-	-	**6.8**
90th Percentile URQIS range	-	-	-	-	-	**0.9**	-	-	**280**	-	-	
NPSFM Annual median*	**0.75 (lakes)**	**2.4 (NBL)**		**0.24 (NBL)**			**0.018**					

Note: Shaded cells indicate values that are higher than the published URQIS ranges.

*ANZG (for Conductivity) and NPSFM Annual Median NBL, or D-band attribute state (for DRP) are listed for general context purposes, not an assessment of breaches of guideline values.

Heavy Metals

Hanley's Farm stormwater samples were not required to be tested for heavy metals under resource consent RM22.263.01. By request of the client, heavy metals were included in the analytical suite from September 2024. Results for heavy metals in stormwater were acquired over four monitoring events (September – October 2024), and a summary is listed in Table 3.

Median results were compared against the available URQIS median and 90th percentile values. It is noted here the Hanley's Farm analysis was for total metals only, not the dissolved (bioavailable) fraction. Thus any exceedance of the thresholds does not necessarily constitute an ecotoxicological risk. Rather, an assessment of the contribution of the dissolved fraction to total loads would be required to quantify the risks to the downstream receiving environment.

For the metalloid arsenic, five sampling locations exceeded the arsenic 90th percentile URQIS range, with one site (DP1) exceeding the URQIS median level. Arsenic is a naturally occurring element present in the surrounding catchment geology (comprised of schist rock formations from the Remarkables). When present in the naturally geology, levels are generally also elevated in surface water environments.

In general, across the Hanley's Farm discharge monitoring sites, the median concentrations at each site were within the range, or below the range, reported for available URQIS data. There were no results that appeared to be unusually elevated by comparison to the ranges reported on URQIS, noting the naturally elevated levels of arsenic.

Heavy metals were generally higher at site DP9 as compared with the other sites, and median concentrations at this site were elevated above the URQIS 90%ile concentrations for arsenic, chromium, copper and lead (noting arsenic was also elevated across all sites compared to the URQIS data).

To investigate the source of elevated contaminants at DP9, stormwater samples were collected from an additional sampling location upstream of DP9 at the northwestern boundary of the development (DP9NW). The DP9NW sampling results exceeded those at DP9 for all parameters aside from total phosphorus, dissolved reactive phosphorus, suspended solids, and turbidity. The upstream catchment to DP9 is predominately farmland. Therefore, it is likely that the contaminant source is located upgradient of the Hanley's Farm development, and not due to the development of the subdivision itself.

Noting the strong positive correlation between TSS and key nutrients (TN, TKN, DRP) discussed above, it is likely that concentrations of metals in stormwater discharges are also predominantly sediment associated. This would require specific analysis of the total and dissolved fraction of metals alongside TSS analysis. The current range of results for key stormwater indicator contaminants (Cu, Zn) suggest that even a 10-fold dilution in the receiving environment would be sufficient to ensure ecological risks from contaminants (including acute effects) are minimal. During high rainfall sufficient to generate flow in the ephemeral water courses, it is anticipated dilution would be in order of 100s or greater fold, sufficient to adequately dilute any point source concentration to levels well below receiving environment DGVs.

Table 3: Median concentrations of total recoverable metals/metalloid (mg/L) in stormwater sampled from the Hanley's Farm subdivision between September–October 20204 (N=4). Bold and grey shading indicates values exceeding URQIS median or 90th percentile data thresholds.

Site and sample number (N)	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
DP1 (N=4)	**0.003**	<0.001	0.002	0.003	0.002	0.003	0.026
DP4 (N=4)	**0.005**	<0.001	**0.006**	0.008	0.003	0.003	0.040
DP5A (N=4)	**0.008**	<0.001	**0.005**	0.006	0.003	0.003	0.023

DP5B (N=4)	**0.007**	<0.001	**0.007**	**0.011**	0.003	0.004	0.033
DP7A (N=4)	**0.008**	<0.001	**0.010**	**0.011**	0.006	0.004	0.045
DP9 (N=4)	**0.020**	<0.001	**0.023**	**0.047**	**0.016**	0.023	0.079
DP9NW (N=1)	0.005	<0.001	0.002	<0.002	0.002	0.003	0.008
Median URQIS range (total metals)	0.0027	-	0.0042	0.011	0.012	-	0.1
90th Percentile URQIS range (total metals)	0.0056	-	0.011	0.018	0.028	-	0.22
Acute Cu/Zn interim 95%ile GV (dissolved)*				0.0013			0.024
ANZG 95th percentile level of species protection DGV*	0.013	0.0002	0.001	0.00047**[11]	0.0034	0.011	0.0041**[12]

*Note – Acute Cu/Zn and ANZG DGV are listed for information purposes only (see earlier discussion regarding *Guidelines and Assessment Framework*)
**ANZG DGV for chronic copper and zinc were revised in 2023 and published in separate Technical Briefs, respectively (refer to footnotes below). The revised DGVs for both chronic Cu and Zn are lower than those published on the ANZG (2018) weblink portal.

For the Homestead Bay proposed subdivision, given the proximity to the Hanley's farm and influences of the wider upper catchments, and similarity in scale and projected landuse of the subdivision (including similar treatment devices), it is likely the stormwater quality discharging from the Homestead Bay subdivision will be of a similar quality.

Receiving environment considerations and sensitivities for Homestead Bay

Land Water People (2025) have provided an assessment of receiving environmental sensitivities and risks posed by wastewater discharge from the Homestead Bay housing development. The report identifies the following aquatic receiving environments (see Figure 3):

- Groundwater zones (Wakatipu Basin[13]);
- Two unnamed ephemeral watercourses that are aligned through the development block;
- Māori Jack Stream; and
- Lake Wakatipu.

Further information regarding quality of the receiving water can be found in the LWP (2025) report.

[11] copper-fresh-dgvs-draft-technical-brief.pdf
[12] Toxicant default guideline values for aquatic ecosystem protection: Zinc in freshwater
[13] water-plan-map-c-series-index.pdf

Figure 3 Locations of the receiving environments for the Homestead Bay development.

Groundwater

There are several groundwater bores within or nearby the Homestead Bay development block; one bore is identified as representing background reference quality for groundwater and another bore downgradient is used to monitor the wastewater discharge from Jacks Point land application area. This bore is considered indicative of the likely groundwater conditions at Homestead Bay. Both bores have been monitored for nitrate concentrations, with results in the order of 0.1 mg/L. LWP (2025) noted these results as very low and indicative of a natural state unimpacted by human activities. No other results from monitoring of the bores were referenced in the LWP report.

Surface water courses/streams

The two unnamed water courses are ephemeral, thus, contain surface water during and after heavy rainfall events before draining quickly. LWP (2025) notes that the watercourses function as flood conveyance that carry flood waters to Lake Wakatipu. The aquatic ecological value of the watercourses was identified as low due to no evidence of fish or stream macroinvertebrates (LWP 2025, Allibone 2023). While one watercourse was noted to have terrestrial grasses growing along the channel, the other water course had evidence of more frequent flow events that prevent terrestrial vegetation establishing at the lower 400 m of the channel within the Homestead Bay Block. The two water courses contribute eroded sediment from the Remarkables to the lake during flood flows. Therefore, these water courses are likely to convey stormwater discharges from the Homestead Bay subdivision to Lake Wakatipu in high flow conditions only. In lower flow conditions, the stormwater flow from the subdivision to these channels is likely to discharge through the ground to underlying groundwater or to the lake.

Māori Jack Stream is a perennial, partially subterranean stream located on the western side of Māori Jack Road, along the western edge of the Homestead Bay development. The stream connects to Lake Wakatipu through flows beneath the sand/cobble shoreline approximately 20 m from the lake edge at Homestead Bay. Only the lower reaches of the stream were noted to have visible, slow-flowing surface water, approximately 600 m upstream of the edge of Lake Wakatipu. The stream is noted as having an ecological health indices of 'fair' to 'poor' water quality based on macroinvertebrate sampling and water quality results as summarised in LWP (2025). This is based on the stream supporting a macroinvertebrate community with soft-bottomed MCI scores ranging from

68–92 and EPT% abundance from 0–11 %, meeting the definition of C to D band attribute state under the NPSFM. The stream also supports slight periphyton growth and very little macrophyte growth.

Lake Wakatipu
Lake Wakatipu is located southwest of the Homestead Bay development. The water quality at the lake is considered 'very good' based on several years of monitoring results available on Land Air Water Aotearoa (LAWA)[14], Limnotrack website[15], and a water quality report documented in the Otago Regional Council's latest "*State and Trends of Rivers, Lakes and Groundwater in Otago 2017-2022*" report. Specifically, the lake's water quality is in the NPS-FM's 'A Band' for total nitrogen, total phosphorus, ammoniacal nitrogen, chlorophyll *a*, Secchi disc depth (clarity), and *E. coli.* LAWA states that based on a suite of water quality measurements, Lake Wakatipu has a Trophic Level Index (TLI) score of 1.4 (microtrophic) or "Very Good".

It is noted that significant and rapid mixing of surface water and groundwater entering the lake from the Homestead Bay site is to be expected from the energy of the frequent wind-driven waves and southerly winds. No periphyton or macrophyte growth on the shores of the Lake was noted in the e3S 2022 report, noted as likely due to the high wave energy in the area. Similarly, no macrophytes were observed in shallow margins, expected given the exposure to wind-driven waves. Native fish species were recorded in the lake on the NZFFD and while no assessment in the e3S report was completed, a common bully was observed during field works. The RWP sets concentration limits for Lake Wakatipu.

Risks of stormwater quality to receiving environments

On the basis of the monitoring summary for Hanley's Farm, the key contaminants of concern discharged from stormwater for the Homestead Bay development are TSS and metals. The highly correlated nature of TSS with nutrients (TN, TKN, DRP) indicates that by managing for sediment discharges, then management of other key contaminants of concern will follow.

A high-level qualitative assessment of risk posed by stormwater quality to the ecological values of primary receiving environment has been undertaken that follows the framework in the Ecological Impact Assessment Guidelines (EcIA, Roper-Lynsay et al. 2018).

It is noted that the primary receiving environment, the ephemeral channel habitats, are intermittently rather than continuously exposed to the stormwater discharges (i.e. rain-driven events), and likely to be high intensity in order to generate sufficient surface flow in the channels. Any exposure to stormwater contaminants is likely to be restricted to a short length of the affected channel during wet weather discharges only, and contaminants present are likely to be diluted >100 fold from the 'end of pipe' concentration ranges noted in the Hanley's Farm summary of findings, thus well below receiving environment quality guidelines for adverse ecological effects.

Table 4 summarises the expected level of adverse effect based on what is known about the anticipated discharge and the receiving environment.

The overall level of adverse effect posed by stormwater quality from the Homestead Bay subdivision is assessed as Low for ecological sensitivities in both the primary receiving environment of the ephemeral channels, and further downstream in Lake Wakatipu.

Table 4: Determination of level of effect

Feature	Factors considered in determining the 'Magnitude of effect'		Factors considered in determining the 'Level of effect'		Level of effect
	Spatial scale	Duration	Magnitude	Ecological value	
Biota of primary receiving environment (ephemeral channels)	Small	Short	Negligible	Low	Low

[14] Land, Air, Water Aotearoa (LAWA) - Lake Whakatipu Open Water 10m
[15] LIMNOTRACK

Biota of downstream receiving environment (Lake	Medium	Short	Negligible	High	Low

Definition of terms

- Spatial scale of effect: Small (tens of metres), Medium (hundreds of metres), Large (>1km)
- Duration of effect: Short (days to weeks), Moderate (weeks to months), Persistent (years or more)
- Magnitude of effect: Negligible (no or very slight change from existing condition, Low (minor change from existing conditions, minor effect on population or range of feature), Moderate / Medium (loss or alternation to key elements of existing conditions, moderate effect on population or range of the feature), High / Severe (major or total loss of key elements of existing conditions, large effect on population or range of the feature).

The primary receiving environment for stormwater are the surface water courses described above. As noted in LWP (2025) and Allibone (2023), the ecological condition is described as not being able to 'support any fish, nor any stream macroinvertebrates' (Allibone 2023), thus ecological sensitivities are assessed as 'Low'. Lake Wakatipu is known to support Very Good water quality, and High ecological conditions[16] , thus ecological value (Table 4) is assessed as High.

Given the low ecological value of the ephemeral channel, and high likelihood of significant dilution and dispersion of any residual urban-derived stormwater contaminants (following treatment mitigations), the risk to receiving environment sensitivities in the ephemeral channels is regarded as *low*.

For Lake Wakatipu, the proposed stormwater treatment and mitigation will control the main stormwater contaminant of concern, being TSS. Following treatment and associated mitigation and dilution in the primary receiving environment, the risk to receiving environment sensitivities in Lake Wakatipu is regarded as *low*.

[16] Land, Air, Water Aotearoa (LAWA) - Lake Whakatipu/Wakatipu

Appendix G Geosolve Limited (GeoSolve) Geotechnical Assessment report

Geotechnical Assessment for Resource Consent

Homestead Bay, Queenstown

Report prepared for:

RCL Homestead Bay Limited

Report prepared by:

GeoSolve Limited

Distribution:

RCL Homestead Bay Ltd

GeoSolve Limited (File)

January 2025

GeoSolve Ref: 220556.01

Version	Issue Date	Purpose	Author	Reviewed
1	24/01/25	Issue for consent application	JMJ	PGF/TP

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1 Executive Summary

- The site is considered appropriate for the proposed mixed use development from a geotechnical perspective provided the recommendations of this report are followed. Further geotechnical consideration will be required for the detailed design, and completion reporting stages of the project.
- The site stratigraphy typically comprises alluvial fan deposits, beach deposits, lake sediments, uncontrolled fill, loess, colluvium, glacial pond sediment, glacial till and outwash deposits.
- The regional groundwater was observed in the piezometers installed in the boreholes at depth below the site. Perched groundwater was encountered at shallow depths along the elevated eastern site boundary.
- The liquefaction assessment has identified a risk in elevated eastern areas where shallow groundwater is present. . Engineering solutions will be available to allow development in this area. Further assessment can be completed and may remove, or reduce, the assessed liquefaction risk, which is considered conservative.
- A slope stability analysis has been for the slopes around the southern and southwestern creeks. The results show the slopes do not meet the required factors of safety and building setbacks are required.
- The soil materials present at shallow depths will vary with respect to foundation bearing. Good ground will not be present in some areas and specific engineering design will be required where this is the case.
- Geotechnical assessment of the proposed earthworks plans should be undertaken at the detailed design stage of the project.
- Recommendations for temporary and permanent batter slopes are provided in Table 5.1. Slopes that require to be steeper than those described should be subject to specific engineering design.
- Any engineered fill that is utilised as bearing for foundations or to form batter slopes should be placed and compacted in accordance with NZS 4431:2022 and certification provided to that effect by a chartered professional engineer. A suitably qualified person should inspect all excavations, batter slopes, lot areas prior to the placement of engineered fill.
- For detailed design purposes it is recommended that the site is classified “Class D – deep soil site” in accordance with NZS 1170.5:2004 seismic provisions.

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2 Introduction

2.1 General

This report presents the results of a geotechnical investigation and assessment completed by GeoSolve Limited for a proposed mixed use development at Homestead Bay, Queenstown.

Photograph 2.1: Looking west over central and northern areas of the proposed development area .

The investigation and assessment has been undertaken for RCL Homestead Bay Limited in accordance with GeoSolve proposal reference 220556.01, dated 9 October 2024, which outlines the scope of work and the conditions of engagement.

2.2 Development

The Paterson Pitts Group (PPG) preliminary subdivision plans depict the formation of a mixed use development comprising approximately 1839 low to medium density residential lots, 24 medium density residential superlots, 47 high density superlots and 2 commercial lots. A school development zone is proposed in the north west corner of the development area. A new reservoir infrastructure zone is proposed in the north east corner of the development area, in Lot 12.

No earthworks plans are available at this stage, however, GeoSolve understand that earthworks will be required to facilitate development.

3 Site Description

The site is located at Homestead Bay, approximately 6 km south of Frankton, Queenstown, between Homestead Bay Road, Chief Reko Road and Kingston Highway (SH6). The site forms part of an existing farm, as shown in Figure 3.1 below. The site is legally described as Lot 8 DP 443832 and Lot 12 DP 364700 and is approximately 205 hectares in size.

Figure 3.1: Site location plan showing the proposed development area is outlined in red. Aerial Image retrieved from QLDC GIS. Image not to scale.

The development proposal is mostly contained within Lot 8 which comprises pastural farmland, farm tracks and associated farming infrastructure. The NZone skydiving company occupy an area in the northern portion of the site where a grassed airstrip and associated buildings are present.

Lot 12 remains largely unmodified under the proposal, however a reservoir structure is proposed in the north eastern area. Associated pipework will head south to service the proposed development in Lot. 8.

Vegetation cover comprises grass, feed crop paddocks, tree shelter belts and scattered bushes. Dense matagouri scrub is found in the deeply incised creek channels towards the southern area of the site.

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3.1 Geomorphological Mapping and Surface Drainage

The subject site is located within the Homestead Bay area at the western foot of the Remarkables Range. Whakatipu Waimāori (Lake Wakatipu) is approximately 45 m west of the south-western corner, and 800 m to the south of the north-western corner of the site.

The site generally slopes from approximately 410 m RL in the northeast corner to approximately 320 m RL in the lower southwestern corner. A topographic contour plan for the site has been produced using LiDAR contour data at 10 m intervals (Wakatipu, 2021) sourced from QLDC GIS database as shown in Figure 1a, Appendix A. Geomorphological observations made across the site are also presented on Figures 1b-c, Appendix A.

No evidence of large scale historical earthworks were observed in Lot 8, however, it is expected that minor earthworks have been completed to construct the runway in the northwest of the site. Other minor earthworks undertaken as part of the operation of the farm are also expected. A clean fill site is present in the eastern area of Lot 12.

Three significant surface drainage channels are present across the site, named Northern, Middle, and Southern Creeks respectively. A smaller and ephemeral creek drains southwest from the centre of the site. Numerous other ephemeral or abandoned shallow stream channels are present. The Southern Creek flows across the site towards the south-west and Lake Wakatipu. The Middle and Northern creeks flow to the west into modified stream channels. The three channels are shown on Appendix A, Figure 1b.

The site topography can be generally separated into three distinct geomorphological environments. For the purposes of this report, we have separated the site into the following topographic zones.

- Zone A – Elevated eastern areas, alluvial fan geomorphology.
- Zone B – Lower lying north western area, alluvial fan and historic lake environment.
- Zone C – Elevated western area with Glacial materials and geomorphology.

The topographic zones are shown in Figure 3.2 with a generalised description provided in Sections 3.1.1 to 3.1.3 below. The zones have been defined by review of historic aerial photography, site inspection, and intrusive ground investigations. The intrusive ground investigations and the site stratigraphy are described in Sections 4 and 5 below.

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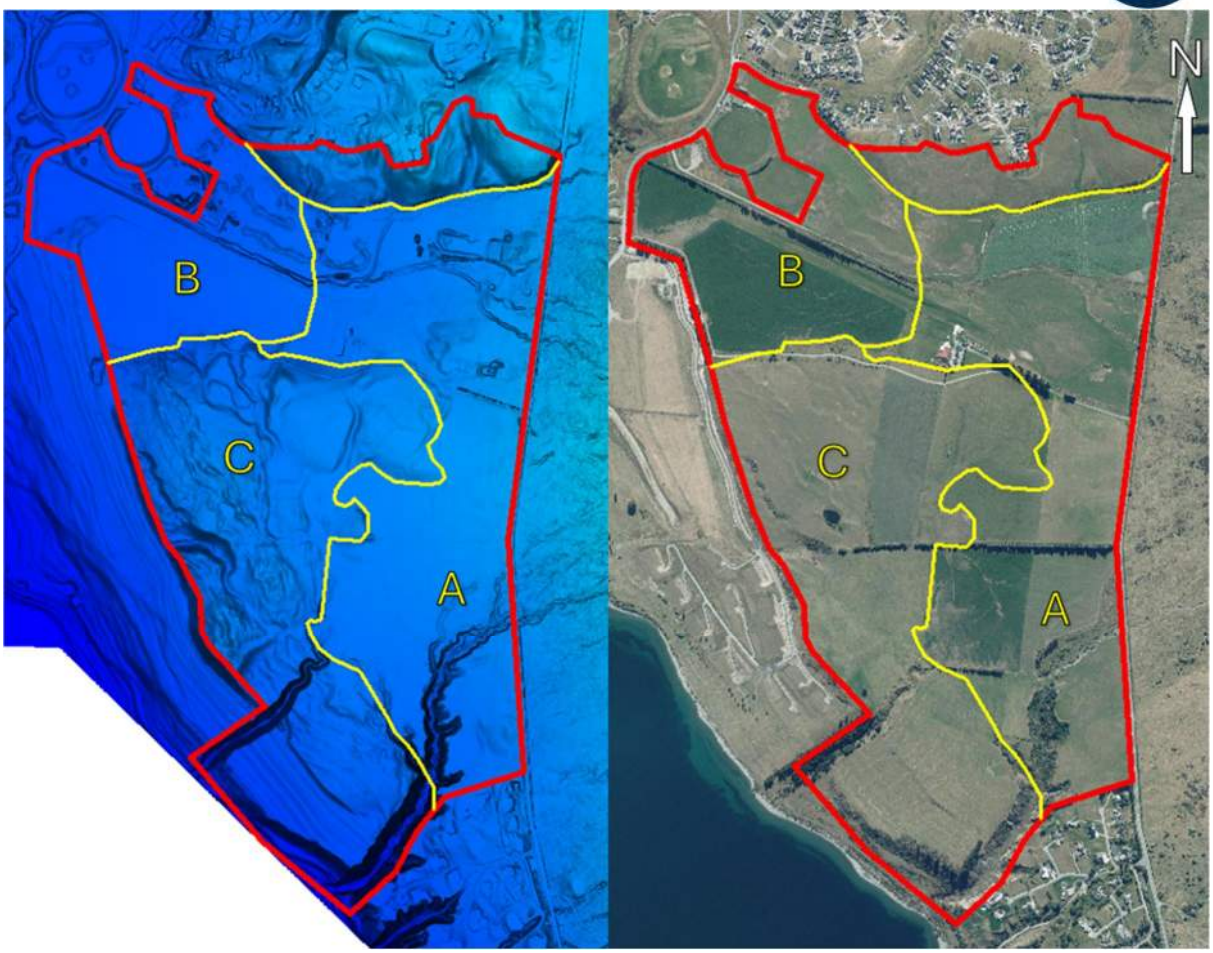

Figure 3.2: Generalised topographic/geomorphic zones (yellow) and site boundary (red). Basemap DEM produced from 1 m LiDAR. Image not to scale. A = Elevated Eastern Fan, B = Low laying fan and historic lake environment, C = Glacial geomorphology and glacial deposits

3.1.1 Zone A –Alluvial Fan

The eastern and southern portion of the site is located on an elevated, gently inclined slope comprising distal fan alluvium, see Photograph 3.1 below. The fan alluvium originates from the western slopes of the Remarkables, and immediate area.

In the southwestern corner of Zone A, the Southern and Southwestern creek channels have incised through the Fan Alluvium and Glacial deposits in response to the lowering of Lake Wakatipu. The Southwestern creek was dry during the assessment and is likely ephemeral in nature. The creek banks are moderately to steeply inclined, with grassed vegetation suggesting a less active environment. The Southern creek was flowing at the time of the assessment. The Southern creek banks are very steeply inclined and locally subvertical. Vegetation is often sparse, with colluvial wedges forming at the toe of slopes indicating shallow failure, erosion and regression of slope crests is ongoing in the present environment, see Photograph 3.2 below.

The northern creek flows along the northern boundary of Lot 8 in a modified channel.

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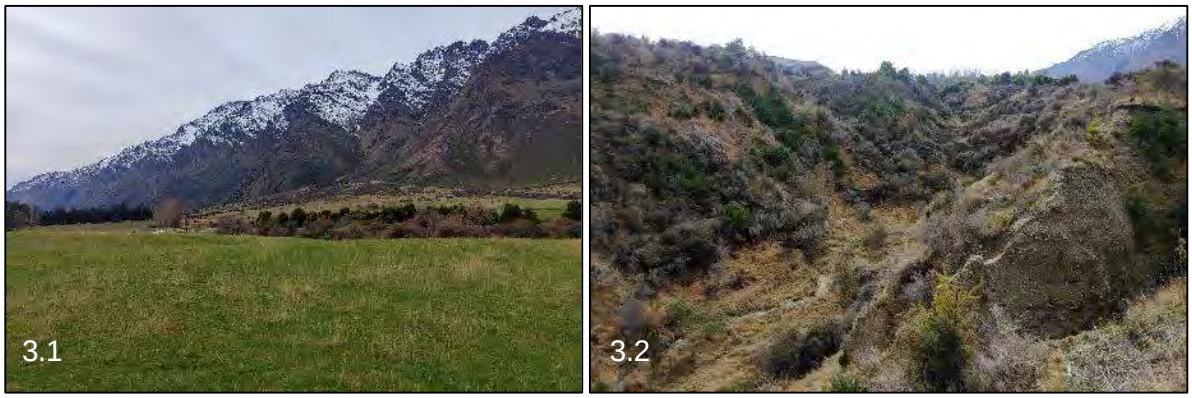

Photograph 3.1: Standing on the alluvial fan looking east towards the Remarkable Range and the head of the fan.
Photograph 3.2: The deeply incised southern flow channel through the alluvial fan then glacial till deposits.

3.1.2 Zone B – Low Lying North western Area

Zone B is located in the north-west portion of the site. The ground surface is near flat to sloping very gently towards the west. Investigations in this area encountered laminated silt (lake sediments) and beach deposits at shallow depths indicating the depositional environment has been influenced by the historically higher level of Lake Wakatipu.

3.1.3 Zone C – Glacial Till/Outwash Deposits

Zone C runs along the elevated western portion of the site with surface topography comprising of undulating, irregular hummocky features, see Photograph 3.3 below. The deposition environment and geomorphology is glacial in origin.

Numerous drainage channels are present. Ponding surface water (natural and man-made) is present and illustrates the dense relatively impermeable nature of the glacial till deposits.

Several glacial boulders (4+ m diameter) are present at surface level . Smaller boulders have been stockpiled by the farmer in places.

From the western crest of the zone the slope falls moderately towards Lake Wakatipu. A series of beach ridges running parallel to the western boundary of the site represent stranded shorelines associated with the lowering of Lake Wakatipu.

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Photograph 3.2: Site photo of Zone C characterised by locally elevated irregular and undulating hummocky topography.

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4 Geotechnical Investigations

An engineering geological site appraisal has been undertaken with confirmatory subsurface investigations. Inspection and investigations were undertaken between October and December 2024 and comprised the following:

- Desktop review of existing geotechnical data on the GeoSolve database, publicly available historical aerial photos and geological reporting;
- Geomorphological mapping of the proposed development and surrounding area;
- 3 boreholes with associated SPT testing and piezometer installation were advanced to a maximum depth of 19.85 m below ground level (bgl) (BH01-BH03).
- 47 test pits with associated Scala penetrometer testing were advanced to a maximum depth of 5.0 m bgl (TP01-TP47);
- 41 Cone Penetrometer tests (CPTs) were advanced to a maximum depth of 20.38 m bgl.

In addition to the above, two boreholes completed by GeoSolve in 2022 (BH1-22 and BH2-22) and have been included in this assessment.

Test pits and boreholes were not undertaken in the northwestern portion of the site due to the land currently either in crop or comprising an active runway.

The investigation locations are shown on Figure 1, Appendix A, and the logs are included in Appendix B.

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5 Subsurface Conditions

5.1 Geological Setting

The site is located within the Wakatipu basin, a feature formed by successive glaciations throughout the late-Quaternary culminating approximately 18 ka[1]. Ice retreat left deposits of moraine, till, outwash gravels and pond sediments over ice–scoured schist bedrock.

The lake sediments and beach gravels which underly the north western area of the site were deposited during higher lake levels in post glacial period. The Lake deposits are overlain by younger alluvial fan materials derived from the adjacent Remarkables Mountains or re-worked glacial outwash material. The alluvial fan deposits blanket eastern and northern areas of the site, whilst older glacial deposits in elevated western areas remain exposed.

5.1.1 Active Faulting

No active fault traces are known to exist in the immediate vicinity of the site. However, numerous active faults have been identified within the region (Motutapu, NW Cardrona, Nevis, Pisa, Moonlight Faults). The nearest known active fault, the Nevis Fault, is located 19 km east of the site. The recurrence intervals for active faults in the region are assessed to be in the order of 5,500 to 120,000 years[4].

Significant seismic risk exists in the Lakes District Region from a rupture of the Alpine Fault[5] which is located approximately 85 km NW of the site. Strong ground shaking in the Lakes District region is expected during a rupture of the Alpine Fault. Recent research[6] suggests there is a 75% probability of an Alpine Fault earthquake occurring within the next 50 years and an 82% probability that the next earthquake on the Alpine Fault will be of M_w8 or greater.

[1]Turnbull, I.M. (2000) Geology of the Wakatipu area. Lower Hutt: Institute of Geological & Nuclear Sciences. *Institute of Geological & Nuclear Sciences 1:250,000 geological map 18* 72 p.
[4] Barrell, D.J., (2019). General distribution and characteristics of active faults and folds in the Queenstown Lakes and Central Otago districts, Otago. GNS Science Consultancy Report 2018/207. Published: March 2019
[5] Orchiston, C., Davies, T., et al. (2016) Alpine Fault Magnitude 8 Hazard Scenario. https://af8.org.nz/
[6] Howarth, J.D., *et al.* (2021). Spatiotemporal clustering of great earthquakes on a transform fault controlled by geometry. Nature Geoscience; doi: 10.1038/s41561-021-00721-4

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5.2 Site Stratigraphy

The subsurface stratigraphy observed in the test pits and boreholes comprises:

- 0.1-0.7 m of Topsoil (all test pits and boreholes), overlying;
- 0.2-1.0 m of Uncontrolled Fill (TP4, 36, and 41), overlying;
- 0.1-1.2 m of Loess (TP1, 2, 16, 20, 21, 24, 27, 29, 32, 33, 34, 37, 38, 39, 44, 46 only), overlying;
- 0.6-4.8 m + of Alluvial Fan Deposits (TP3, 5, 9, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 35, 40, 41, 42, 43, 45 and 46, and BH1, 2, and 3), interbedded with;
- 0.9-2.3 m + of Beach Deposits (TP34, 35, and 36), interbedded with;
- 0.2-0.5 m of Colluvium (TP22, 25, 26, 27, 28, 29, 31, 32, 33, 37 and 39), overlying;
- 0.9-3.0 m + of Glacial Pond Sediment (TP10, 11, 12, 22 and 23, and BH2), overlying;
- 0.3-1.0 m of Weathered Glacial Till (TP1, 2, 30, and 44), overlying;
- 0.7-9.85 m + of Outwash Deposits (TP4, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 27, 28, 29, 31, 32, 43, and 45, and BH2 and 3), overlying and interbedded within;
- 0.3-9.75 m+ of Glacial Till (TP1, 2, 3, 4, 9, 14, 15, 21, 24, 25, 26, 28, 30, 33, 37, 38, 39, 43, 44, 46, and 47, and BH1, 2 and 3).

Topsoil was observed at the surface of all test pits and boreholes and covers the bulk of the site. The topsoil typically comprised organic silty SAND with trace rootlets.

Uncontrolled Fill was observed below the topsoil in TP4, 36, and 41 to a maximum depth of 1.3 m bgl and typically comprised medium dense silty sandy fine to coarse GRAVEL, sandy fine to medium GRAVEL with a trace of silt and medium to coarse GRAVEL with a trace of sand and silt. Small fragments of steel pipe were observed within the uncontrolled fill in TP4. The uncontrolled fill encountered is inferred to be from historic farm related landscaping.

Loess typically comprising loose to medium dense silty fine SAND with trace rootlets and organics, fine to medium SAND with minor to trace silt and trace to no gravel, rootlets and organics and firm sandy SILT with trace gravel and organics was observed in 16 of the test pits to a maximum depth of 1.5 m bgl.

Alluvial Fan Deposits were observed in 20 of the test pits and all 3 boreholes to a maximum depth of 7.35 m however the base of the deposits was not encountered in several of the test pits. The depths of the alluvial fan deposits generally decreased towards the west away from the source area of the Remarkables. The alluvial fan deposits typically comprised varying fractions of interbedded SILT, SAND and GRAVEL. A 500 mm thick deposit of medium dense 600 mm diameter BOULDERS was encountered in TP41.

Beach Deposits were observed in TP34, 35 and 36, in the northwest corner of the site, underlying the alluvial fan deposits. The base of the beach deposits was not encountered in TP34 and 35. The beach deposits typically comprised medium dense to dense, sandy fine to coarse GRAVEL with trace to no cobbles.

Up to 0.5 m of Colluvium was observed in TP22, 25, 26, 27, 28, 29, 31, 32, 33, 37 and 39 generally underlying the topsoil and/or loess to a maximum depth of 1.0 m bgl. The colluvium typically comprised varying fractions of SILT, SAND and GRAVEL.

Glacial Pond Sediments were encountered in TP10, 11, 12, 22 and 23, and BH2 and typically comprised stiff SILT, medium dense to hard SAND in varying interbedded fractions of the silt and sand. Gravel deposits were also present.

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Over 9.85 m of Outwash Deposits were observed in 18 of the test pits and 2 of the boreholes, predominantly in the western and southwestern portions of the site. The outwash deposits encountered typically comprised medium dense to dense, SAND and GRAVEL with a cobble and boulder fraction in some locations.

Over 9.75 m of Glacial Till was observed in 21 of the test pits and 2 of the boreholes, generally underlying the alluvial fan deposits in the eastern area of the site and interbedded within and by the outwash deposits in the western and southwestern area of the site. The glacial till was typically observed to comprised medium dense to dense SAND and very stiff to hard SILT, with varying fractions of cobbles and boulders.

Lake Sediments were encountered in BH2-22 between 22.4 and 27.2 m bgl underlying alluvial fan deposits and overlying glacial till and comprised stiff SILT .

Full descriptions of the observed subsurface stratigraphy can be found in the test pit and borehole logs contained in Appendix B. Inferred ground models for the site can be found in the cross-sections provided in Appendix A. Figure 1a, Appendix A, shows the general distribution of surface geology across the site.

5.3 Groundwater

The regional groundwater table was measured in standpipe piezometers constructed in the boreholes (BH1 - BH3 and BH1-22 – BH2-22). Boreholes locations are shown on the Investigation Site Plan, Appendix A Figure 1a. Table 5.1 below summarizes the measured ground water levels.

Table 5.1: Site groundwater levels as observed in borehole piezometers.

Piezometer	Date Measured	Groundwater Depth m BGL	Groundwater m RL (NZVD2016)
BH1-22	2nd September 2022	14.8	339.2
	16th December 2024	13.4	340.6
	17th January 2024	15.4	338.6
BH2-22	2nd September 2022	5.1	386.9
	17th January 2024	4.3	387.7
BH1	16th December 2024	13.1	360.9
	17th January 2024	14.4	360.5
BH2	17th January 2024	10.5	380.5
BH3	17th January 2024	Dry	-

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Groundwater seepages were encountered in several of the test pits in the eastern area of the site. All the test pits which encountered ground water seepages are location in elevated areas of the alluvial fan adjacent to the eastern site boundary. Seepage depths are summarised in Table 5.2 below. A preliminary zone of shallow seepage is identified on Figure 1b Appendix A. BH2-22 is present in this area and also encountered relatively shallow groundwater.

Table 5.2: Groundwater seepages as observed in test pits.

Test Pit	Geology at Seepage Level	Groundwater Depth (m BGL)
TP7	Alluvial Fan Deposits	4.2
TP9	Alluvial Fan Deposits	3.1
TP14	Outwash Deposits	4.0
TP40	Alluvial Fan Deposits	1.3
TP41	Alluvial Fan Deposits	2.6
TP42	Alluvial Fan Deposits	1.9
TP47	Contact between Alluvial Fan Deposits and Glacial Till	0.9*
*Test pit was located immediately adjacent to flowing creek		

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6 Natural Hazards Assessment

The subject site is shown to be within or nearby to mapped natural hazard areas as shown on QLDC Hazard mapping. Further, interpretation of the geomorphological mapping and aerial photography has concluded that the following natural hazards may affect the proposed development area:

- Slope stability
- Liquefaction
- Alluvial fan, debris flow and flooding
- Rock fall
- Rock avalanche
- Strong ground motion associated with a seismic event.
- Lake seiche

The alluvial fan, debris flow, flooding, rock fall, rock avalanche and lake seiche hazards have been specifically assessed in the GeoSolve report referenced 220556.02 dated 17th January 2025, and are not covered in this report. Internal natural hazards including liquefaction and slope stability are addressed below.

6.1 Seismic

A severe seismic risk is present in the region as discussed in Sections 5.1 and 5.1.1. Appropriate allowance should be made for seismic loading during detailed design of subdivision earthworks and any associated structures.

6.2 Liquefaction

6.2.1 General

The majority of the site, in particular Topographic Zones A and C are mapped as LIC 1 (P) [7] / Classification A[8] on the QLDC hazard maps, indicating a probably low risk of liquefaction. The north-western extent of the site (Topographic Zone B) is mapped as LIC 2 (P) / Class B indicating a possibly moderate risk of liquefaction. The QLDC hazard mapping is shown below in Figure 6.1.

For assessing liquefaction susceptibility there are three key parameters:

- Level of shaking – Queenstown is located in an area of high seismic risk relatively to other parts of New Zealand. Therefore, a detailed assessment of liquefaction is required.
- Composition and density of the soil – the soils are variable across the site. Significant areas of soil could liquefy from a composition and density perspective.
- Soil saturation – Soils require to be fully saturated to liquefy. Two areas of differing soil saturation have been. Elevated eastern areas have a perched groundwater level approximately between 2 and 6 m depth. The remainder of the site does not have a perched groundwater level. Regional groundwater levels have been measured to be at least 10 to 15 m depth.

[7] Tonkin and Taylor (2012) Queenstown Lakes District - Liquefaction Hazard Assessment
[8] GNS (2019) Liquefaction Susceptibility - Regional Analysis

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Figure 1b, Appendix A, identifies the approximate extent of the eastern perched water zone. Therefore most of the site, where there is no perched groundwater level, will have at least 10 m of dry non liquefiable crust. In these areas the liquefaction risk will be low for a standard shallow foundation structure (i.e. MBIE TC1 equivalent). The perched groundwater level is highly variable with seepages running through more permeable deposits in the alluvial fan. Further geotechnical investigations and assessment can be undertaken to better define the seepage behaviour, however, for this assessment we have undertaken a detailed assessment using the CPTs and assuming different shallow groundwater levels.

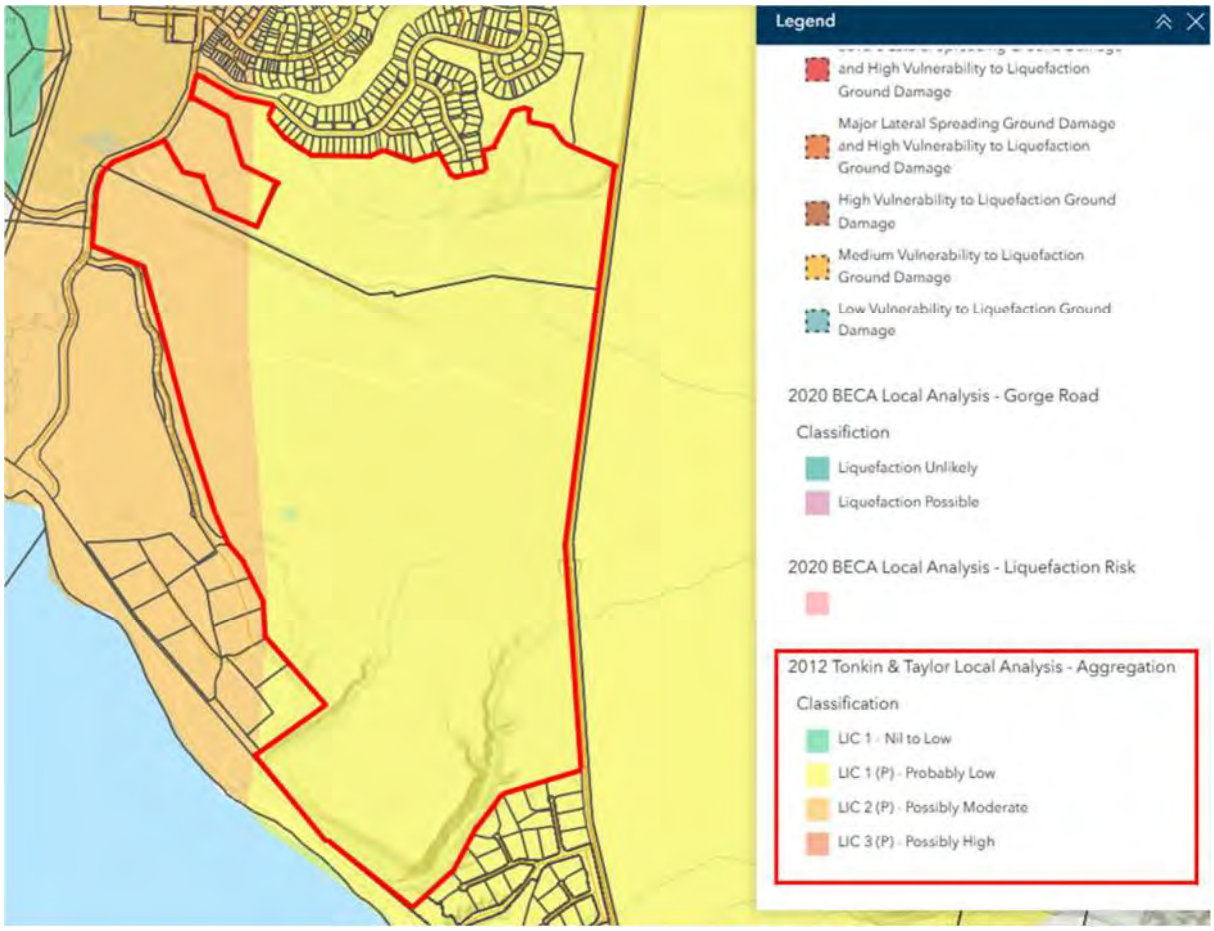

Figure 6.1: Liquefaction hazard mapping. Image retrieved from QLDC GIS Natural Hazards Map on 17t^{h} January 2024. The site boundary is shown in red.

6.2.2 Design Earthquakes

As it is proposed to form a mixed use development including a school, five earthquakes scenarios have been assessed in accordance with NZS 1170 – Structural Design Actions[9] for an Importance Level 2 and 3 structures with a 50-year design life.

[9] NZS 1170-5 (2004) Structural Design Actions, Part 5: Earthquake Actions – New Zealand.

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Peak horizontal ground accelerations and effective magnitudes were calculated using the procedure from Module 1 of the Earthquake Geotechnical Engineering Practice in New Zealand[10]. Table 6.1 below summarises the scenarios considered.

Table 6.1: Earthquake accelerations and effective magnitudes for liquefaction assessment

Scenario	Performance Requirements	Annual Probability of Exceedance	Peak Horizontal Ground Acceleration (PGA)	Effective Magnitude
Serviceability Limit State (SLS)	*Avoid damage that would prevent the structure being used as originally intended without repair.*	1/25	0.10 g	6.5
Intermediate Event – IL2	*No requirements but assists in considering affects as per liquefaction planning guidelines*	1/100	0.20 g	6.5
Intermediate Event – IL3	*No requirements but assists in considering affects as per liquefaction planning guidelines*	1/250	0.31 g	6.5
Ultimate Limit State (ULS) – IL2	*Avoid collapse of the structural system.*	1/500	0.41 g	6.5
Ultimate Limit State (ULS) – IL3	*Avoid collapse of the structural system.*	1/1000	0.53 g	6.5

6.2.3 Liquefaction Analysis

Analysis was undertaken on the CPT soundings using the Boulanger & Idriss (2014)[11] method to calculate the factor of safety against liquefaction and Zhang et al (2002)[12] to calculate liquefaction-induced reconsolidation settlement. As no laboratory testing has been undertaken in this analysis, a soil classification index (I_c) cut off of 2.6 and a fines correction coefficient (C_{fc}) of 0 has been adopted. No thin layer correction has been applied.

As discussed above only the CPTs in the upper platform where shallow groundwater is present have been analysed which include CPT8, 12-16, 20-24 and 26, which achieved variable depths of between 2.3 and 13.9 m. The deeper CPTs are considered more representative.

Groundwater in this zone is variable and at the time of writing this report the extent of full saturation of the soil profile has not been fully defined. Therefore, we have undertaken a

[10] NZGS and MBIE (2021) Earthquake Geotechnical Engineering Practice, Module 1
[11] Boulanger, R.W. & Idriss, I.M. (2014). CPT and SPT Based Liquefaction Triggering Procedures. Department of Civil & Environmental Engineering, University of California.
[12] Zhang, G., Robertson, P.K., Brachman, R.W.I. (2002). Estimating liquefaction-induced ground settlements from CPT for level ground.

sensitivity assessment for different saturation depths to highlight potential risk. Further assessment will be required for future stages of work.

For this assessment we have compared calculated indexed liquefaction induced consolidation settlement and the liquefaction severity number (LSN) for different groundwater depths. The different groundwater depths consider the above five events. As part of this we have considered three of the most credible groundwater levels at this area of the site of 2 m, 4 m and 6 m. These results are summarised in Appendix C.

The results show that:

- Limited liquefaction occurs in the SLS and the IL2 intermediate design event in all groundwater cases. Therefore, for standard structures the risk for these events is low.
- If the groundwater/point of full saturation is at 2 m depth the IL3 intermediate design event does show that liquefaction is occurring but LSN and indexed settlement infer that moderate damage is expected. If the groundwater/point of saturation is one of the deeper cases limited/minor liquefaction risk is expected. An IL3 structure would require specific engineering design, so a development perspective in all cases there would be numerous design options to accommodate this risk.
- If the groundwater/point of full saturation is at 2 m depth liquefaction is calculated to occur in the ULS design event which could be moderate to major. However, if the groundwater was at lower depths minor to moderate liquefaction risk would be expected.
- Based on the variability of the groundwater levels and lack of free faces in close proximity to the site we consider that lateral spreading will not govern any liquefaction design. However, this should be re-assessed when the extent of earthworks, and presence of any proposed channels/basins, is understood.

6.2.4 Further Work

Soil laboratory testing has not been undertaken to confirm the soil classification index cut off and the fines correction factor. GeoSolve have undertaken testing in other areas in the greater Queenstown area which did show reduction in liquefaction risk if testing was undertaken. Therefore, soil laboratory testing could be undertaken to better define these parameters.

The alluvial fan deposits are highly interbedded. Research and experience in the eastern suburbs of Christchurch show that standard assessments with no correction provide relatively conservative results. GeoSolve have undertaken shear wave velocity testing in some greater Queenstown sites in similar interbedded soils which also have shown reduction of liquefaction risk and justification for using a thin layer correction for the CPT based assessment. Therefore, the current assessment is considered conservative and further assessment could be undertaken to better define these effects.

6.2.5 Liquefaction Analysis Summary

- The site has been divided into two zones, the upper terrace where there is a perched groundwater table, and the remainder of the site where there is no perched groundwater table and a minimum non-liquefiable crust of 10 m is expected.
- Given the relatively deep regional groundwater level, where there is no perched groundwater, the liquefaction risk has been assessed to be low to very low or MBIE TC1 equivalent for most of the site.

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- In the elevated eastern area of the site, where perched groundwater is present, the liquefaction risk has been assessed as medium vulnerability.
  As there is no SLS liquefaction risk and no to minor intermediate risk, it is likely that common specifically designed foundation solutions could be developed to mitigate any liquefaction effects, such as robust foundation slabs similar to MBIE TC2 slabs.
- The above assessment is appropriate for Resource Consent and has shown that development is possible and the liquefaction risk over most the site is relatively low. However, further assessment is recommended for further stages of the development to better refine the liquefaction risk and zoning. These further assessments would incorporate proposed development plans including any proposed earthworks, channels, basins or other areas which could increase liquefaction induced lateral spreading risk.
- We have identified some aspects of potential conservatism in the liquefaction risk given the soil types observed. Further refinement of these could be considered in further assessment stages.

6.3 Slope Stability

6.3.1 General

A slope stability assessment has been undertaken based on site observations and review of the test pit and borehole data. No signs of shallow or deep-seated slope instability are evident within the site with the exception of the southern creek channels where localised shallow instability, stream bank erosion and slope crest regression is evident.

No proposed earthworks plan have been provided to date and the assessment has therefore considered the existing topography only.

6.3.2 Slope Crest Stability

Crest slope regression is likely to be ongoing for the southwestern terrace slope and the southern creek channels. Accordingly, a detailed slope stability assessment has been undertaken on several representative cross sections using the software programme Slope/W.

Cross sections H, I, J, K, L, M, N, O, P Q, R, S have been analysed, the locations of which are shown on Figure 1a, Appendix A. Proposed development around the margins of the channels comprises individual house residential building lots.

The following slope stability cases have been analysed:

- Static Case – No seismic loading;
- Serviceability Limit State (SLS) – (equivalent to a 1 in 25-year event).
- Ultimate Limit State (ULS) – major regional earthquake (equivalent to a 1 in 500-year event). Stability should be sufficient to prevent loss of life following an event of this magnitude.

Building surcharge loads have been applied where applicable. The analysis assumes dry conditions based on the groundwater levels measured in the piezometers. The soil parameters used in the analysis are provided in Table 7.1 below. The target Factors of Safety used for the analysis are shown in Table 6.2 below.

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Table 6.2: Target Factors of Safety

Stability Case	Target Factor of Safety
Static	>1.5
Seismic SLS	>1.2
Seismic ULS	No target, magnitude of ground displacements to be estimated

The analysis results indicate the analysed slopes do not meet the required Factors of Safety with respect to all three cases. Building setbacks will be required to achieve the required factors of safety for residential development. Preliminary building setback distances are provided in Table 6.3 below and are shown on Appendix A Figure 1a.

Table 6.3: Building setback dimensions to achieve required Factors of Safety.

Cross Section	Side of Creek	Stability Case		
		Static (Min FoS 1.5)	Seismic SLS (Min FoS 1.2)	Seismic ULS (<5-10 mm ground displacement)
		Minimum setback from crest of slope (m)		
H	NW	5	5	5
	SE	5	5	5
I	NW	7	7	7
	SE	5	5	5
J	NW	5	5	5
	SE	5	5	5
K		5	5	5
L		13	13	14
M		17	17	17
N		20	20	21
0	NW	5	5	5
	SE	5	5	5
p	NW	6	6	7
	SE	5	5	5
Q	E	5	5	5
	W	11	11	11
R	SW	4	5.0	6
	NE	7	8	9
S		15	15	16

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Several results returned values of less than 5 m, however, a minimum set-back of 5 m is provided in Table 6.5.

The setbacks provided for the ULS case may need to increase if 0 mm displacement is required. The setbacks provided have been rounded up to the nearest metre.

The setbacks do not preclude development nearer the slope crest, however, any future building development inside the building setback will require specific engineering design and standard foundations may not be applicable.

As noted above, the stability assessment is for the current ground surface. If future proposed earthworks result in modification of the ground surface in the assessed areas slope stability results may differ from those presented in Table 6.5. The need for further assessment should be reviewed once earthworks plans are available during the detailed design stage. The Geotechnical Completion Report, typically issued upon completion of the earthworks, will also need to incorporate the results and setback recommendations.

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7 Engineering Considerations

7.1 General

The recommendations and opinions contained in this report are based upon ground investigation data and mapping obtained at discrete locations and historical information held on the GeoSolve database. The nature and continuity of subsoil conditions away from the investigation locations is inferred and cannot be guaranteed.

7.2 Geotechnical Parameters

Table 7.1 provides a summary of the recommended geotechnical design parameters for the soil materials expected to be encountered during earthworks and future building platforms.

Table 7.1: Recommended geotechnical design parameters

Unit	Thickness as encountered in 2024 investigation (m)	Bulk density γ (kN/m^3)	Effective cohesion c´ (kPa)	Effective friction ϕ´ (deg)	Elastic modulus **E** (kPa)	Poissons ratio ν
Topsoil	0.1-0.7	To be removed from engineered fill subgrade and proposed lots unless specifically designed.				
Uncontrolled Fill	0.2-1.0					
Loess	0.1-1.2	17	0	32	5,000	0.3
Alluvial Fan Deposits	0.6-4.8+	18	0	30-32 (30 when silty)	5,000-10,000	0.3
Beach Deposits	0.9-2.3+	18	0	33	5,000-10,000	0.3
Colluvium	0.2-0.5	18	0	32	5,000	0.3
Lake Sediment	-	18	0	28	5,000	0.3
Glacial Pond Sediment	0.9-3.0+	17	0	32	5,000	0.3
Outwash Deposits	0.7-9.85+	19	0	34-38	20,000	0.3
Glacial Till	0.3-9.75+	18	0	35-39	20,000	0.3

7.3 Site Preparation

During the earthworks operations all topsoil, organic matter, uncontrolled fill, and other unsuitable materials should be removed from the construction areas in accordance with the recommendations of NZS 4431 and NZS 3604.

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Owing to the moderately erodible nature of some of the soils present across the site, sediment control measures should be instigated during earthworks construction. QLDC Guidelines for environmental management plans should be consulted by a suitably qualified person for site management.

7.4 Engineered Fill

All fill that is utilised as bearing for foundations or to form batter slopes should be placed and compacted in accordance with the recommendations of NZS 4431:2022 and certification provided to that effect. The alluvial fan deposits, outwash deposits and glacial till are suitable for used as engineered fill on site (during good weather and in accordance with an earth fill specification). Boulders and cobbles over 100 mm in size will need to be screened from engineered fill sources. An earth fill specification should be provided prior to the commencement of earthworks.

We recommend topsoil stripping and subsequent earthworks be undertaken only when a suitable interval of fair weather is expected.

7.5 Excavations

No proposed contours have been provided to date however it is understood that a cut and fill earthworks will be required to form the proposed development.

Preliminary recommended slope batters are provided in Table 7.2 below. The recommendations should be reviewed by GeoSolve following provision of proposed earthwork plans during the detailed design stage.

All proposed batter slopes higher than 4 m or required to be steeper than the recommended angles will require specific engineering assessment by GeoSolve during the detailed design stage.

Table 7.2: Recommended maximum slope batters for temporary and permanent slopes

Material type	Recommended maximum batter for temporary slopes	Recommended maximum batter for permanent slopes up to 4 m high
Topsoil, Uncontrolled Fill, Beach Deposits	1(v):1.5(h)	1(v):3(h)
Loess, Alluvial Fan Deposits, Colluvium, Glacial Pond Sediment, Weathered Glacial Till	1(v):1.5(h)	1(v):2.5(h)
Glacial Till, Outwash Deposits	1(v):1(h)	1(v):2(h)

Remediation options such as soil nails, retaining or geogrid reinforcement can be considered to ensure appropriate Factors of Safety are met. Development setbacks from slope crests can also be considered. The requirement for stabilisation measures can be reviewed during the detailed design stage of the development.

Steeper batters than those outlined above may be appropriate in specific areas. Case-by case assessment will need to be undertaken to confirm the use of steeper batters.

7.6 Groundwater Issues

The regional groundwater table is expected to lie well below the finished development. Dewatering or other groundwater-related construction issues are therefore unlikely to be extensively required. Perched seepages have been identified in some eastern areas of the site at depths of 1-5 m, see Table 1 above and Figure 1b, Appendix A. Groundwater is expected to be encountered in excavations completed in this area. Seepage volumes and locations are expected to reflect precipitation and snow melt, and will therefore vary on a seasonal basis.

Seepages observed during construction will require to be captured by subsoil drains and outlet to an appropriate location such as landscaping areas or into the reticulated stormwater system. Consideration should be given to subsoil drainage if excavation is proposed in eastern areas of the site.

7.7 Foundations

Following the removal of topsoil and uncontrolled fill, it is expected that predominantly alluvial fan deposits will be encountered in Zone A, beach deposits, lake sediments or alluvial fan deposits within Zone C, and colluvium, weathered glacial till, glacial pond sediment, glacial till or outwash deposits within Zone C.

7.7.1 Zones A & B

Zones A and B are expected to be underlain by beach deposits, lake sediments and/or alluvial fan deposits. These deposits will provide a reduced bearing capacity and do not meet the 'good ground' bearing capacity requirements as outlines in NZS3604. Specific engineering design will be required for lots containing these soils to provide appropriate foundations solutions.

Preliminary assessment indicates robust foundation slabs similar to MBIE TC2 slabs may be required, depending on further detailed assessment of the liquefaction risk.

7.7.2 Zone C

Zone C is expected to be underlain by colluvium, glacial pond sediment, glacial till or outwash deposits. These materials provide a mix of 'good ground' and not 'good ground' with respect to bearing capacity as outlined in NZS3604. Specific engineering design will be required for lots containing these soils to provide appropriate foundations solutions.

7.8 Site Subsoil Category

For detailed design purposes it is recommended that the magnitude of seismic acceleration be estimated in accordance with the recommendations provided in NZS1170.5:2004.

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Based on the ground conditions observed during the site investigations and existing data from the surrounding area, we consider the site subsoil class in terms of NZS1170.5:2004 Clause 3.1.3 to be Class D (deep soil site).

7.9 QLDC Land Development and Subdivision Code of Practice

Section 2.4.4 of the QLDC Land Development and Subdivision Code of Practice (QLDC CoP) requires the developer of any subdivision to appoint a geo-professional to carry out the following functions from the planning to construction phases of the subdivision:

a) Check regional and district plans, records, and requirements prior to commencement of geotechnical assessment;

b) Prior to the detailed planning of any development, to undertake a site inspection and such investigations of subsurface conditions as may be required, and to identify geotechnical hazards affecting the land, including any special conditions that may affect the design of any pipelines, underground structures, or other utility services;

c) Before construction commences, to review the drawings and specifications defining any earthworks or other construction and to submit a written report to the TA on the foundation and stability aspects of the project (if required);

d) Before and during construction, to determine the extent of further geo-professional services required (including geological investigation);

e) Any work necessary to manage the risk of geotechnical instability during the construction process;

f) Before and during construction, to determine the methods, location, and frequency of construction control tests to be carried out, determine the reliability of the testing, and to evaluate the significance of test results and field inspection reports in assessing the quality of the finished work;

g) During construction, to undertake regular inspection consistent with the extent and geotechnical issues associated with the project;

h) On completion, to submit a written report (i.e. Geotechnical Completion Report) to the Territorial Authority (TA) attesting to the compliance of the earthworks with the specifications and to the suitability of the development for its proposed use including natural ground within the development area. Where NZS 4431 is applicable, the reporting requirements of that Standard shall be used as a minimum requirement.

This resource consent level report can be considered to have completed items a) and b) from the above list. Once resource consent for the subdivision has been granted a geo-professional will need to be appointed by the developer to review the earthworks drawings and specifications prior to finalising the documentation for tendering and/or construction, and to oversee the construction phase of the project including certification of fill and provide a Geotechnical Completion Report (GCR) and Schedule 2A in accordance with the QLDC CoP.

The GCR and Schedule 2A should detail the results of site observations, testing and monitoring during earthworks construction, confirm the stability of the finished earthworks, and identify any specific geotechnical design requirements that must be addressed in order to construct a building on site. Any identified specific design requirements will then be registered on the subject lots' 'certificate of title' and will need to be addressed during the building consent process.

The geo-professional completing the GCR and Schedule 2A which includes the certification of fill should in all cases be engaged by the developer not the contractor. It is also advisable that the geo-professional review the earthworks contract to assist in managing the developers risk and ensuring that the contract is clear with respect to geotechnical risks and responsibilities during construction.

The use of this report and any of its findings or recommendations as part of the GCR and Schedule 2A may only be used with our prior review and written agreement.

7.10 Further Works

It is recommended that the recommendations of this report are reviewed following provision of earthworks drawings.

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8 Neighbouring Structures

Neighbouring Properties: No adverse geotechnical implications apply for neighbouring properties during construction.

Aquifers: No aquifer resource will be adversely affected by the development.

Erosion and Sediment Control: The site presents some potential to generate silt runoff, and this would naturally drain downslope.

We recommend advice be sought from a qualified specialist where compliance with local and regional erosion and sediment control regulations is uncertain. Compliance with QLDC environmental management guidelines will be required.

Noise: Rock-breaking and/or blasting is unlikely to be required.

Dust: Regular dampening of soil materials with sprinklers should be effective if required.

Vibration: No vibration induced settlement is expected in these soil types.

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9 Applicability

This report has been prepared for the sole use of our client, RCL Henley Downs Limited with respect to the particular brief and on the terms and conditions agreed with our client. It may not be used or relied on (in whole or part) by anyone else, or for any other purpose or in any other contexts, without our prior review and written agreement.

Investigations have been undertaken at discrete locations in accordance with the brief provided. It must be appreciated that the nature and continuity of subsoil conditions away from the investigation locations cannot be guaranteed.

During construction, all earthworks should be examined by an inspector or engineer competent to confirm that subsurface conditions encountered throughout are compatible with the findings of this report. It is important that we be contacted if there is any variation in subsoil conditions from those described in this report.

Report prepared by:	Reviewed for GeoSolve Ltd by:
.....	.....
Jack Mynett-Johnson Engineering Geologist	Paul Faulkner Principal Engineering Geologist

Appendices:

Appendix A – GeoSolve Drawings
Appendix B – Investigation Logs
Appendix C – Liquefaction Results

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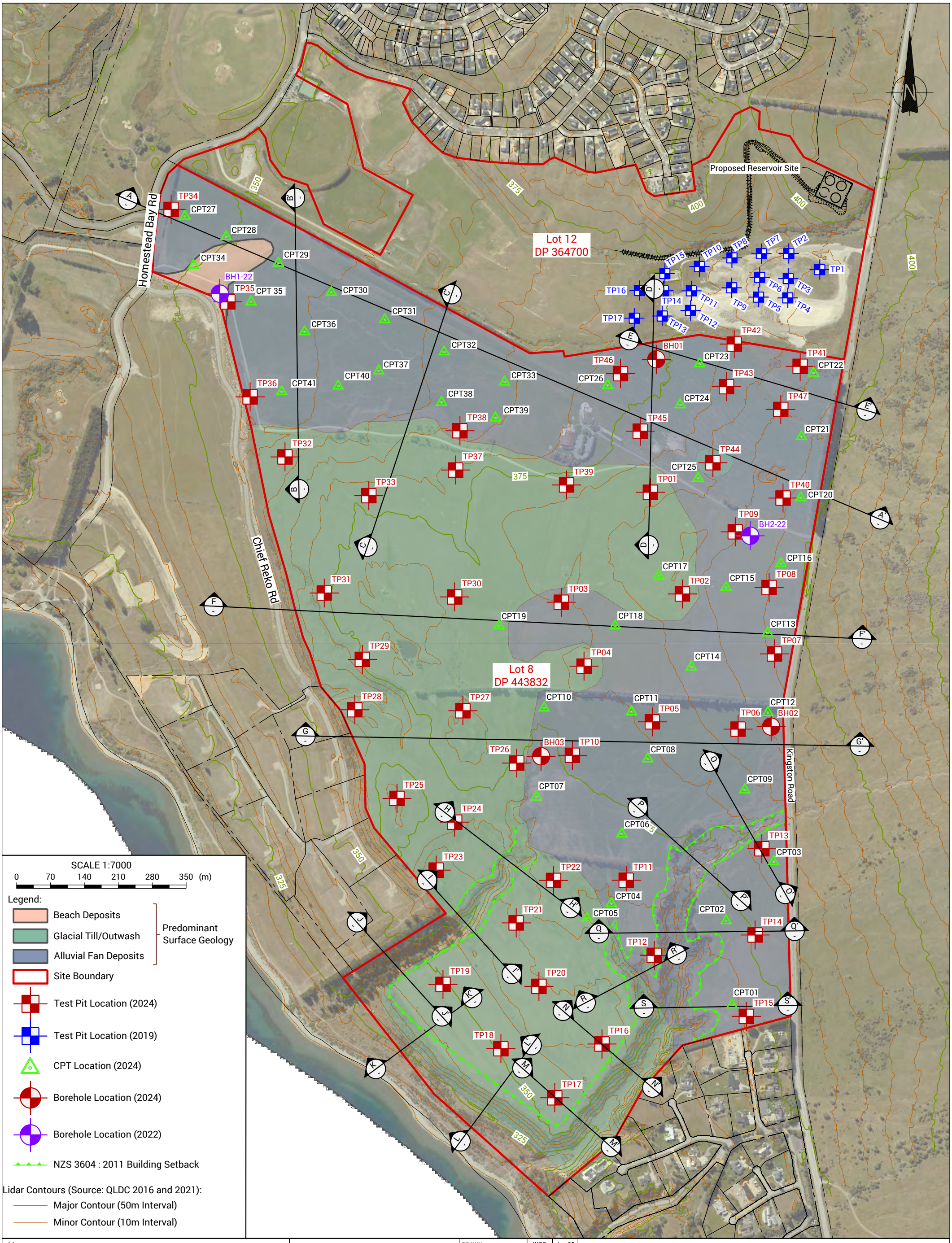
Appendix A: GeoSolve Drawings



SCALE 1:7000

0 70 140 210 280 350 (m)

Legend:

- Predominant Surface Geology
  - Beach Deposits
  - Glacial Till/Outwash
  - Alluvial Fan Deposits
- Site Boundary
- Test Pit Location (2024)
- Test Pit Location (2019)
- CPT Location (2024)
- Borehole Location (2024)
- Borehole Location (2022)
- NZS 3604 : 2011 Building Setback

Lidar Contours (Source: QLDC 2016 and 2021):

- Major Contour (50m Interval)
- Minor Contour (10m Interval)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Limited with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

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CADFILE: 220556.01-I.dwg		
SCALES (AT A3 SIZE): 1:7000		
PROJECT No: 220556.01		

RCL Homestead Bay Ltd

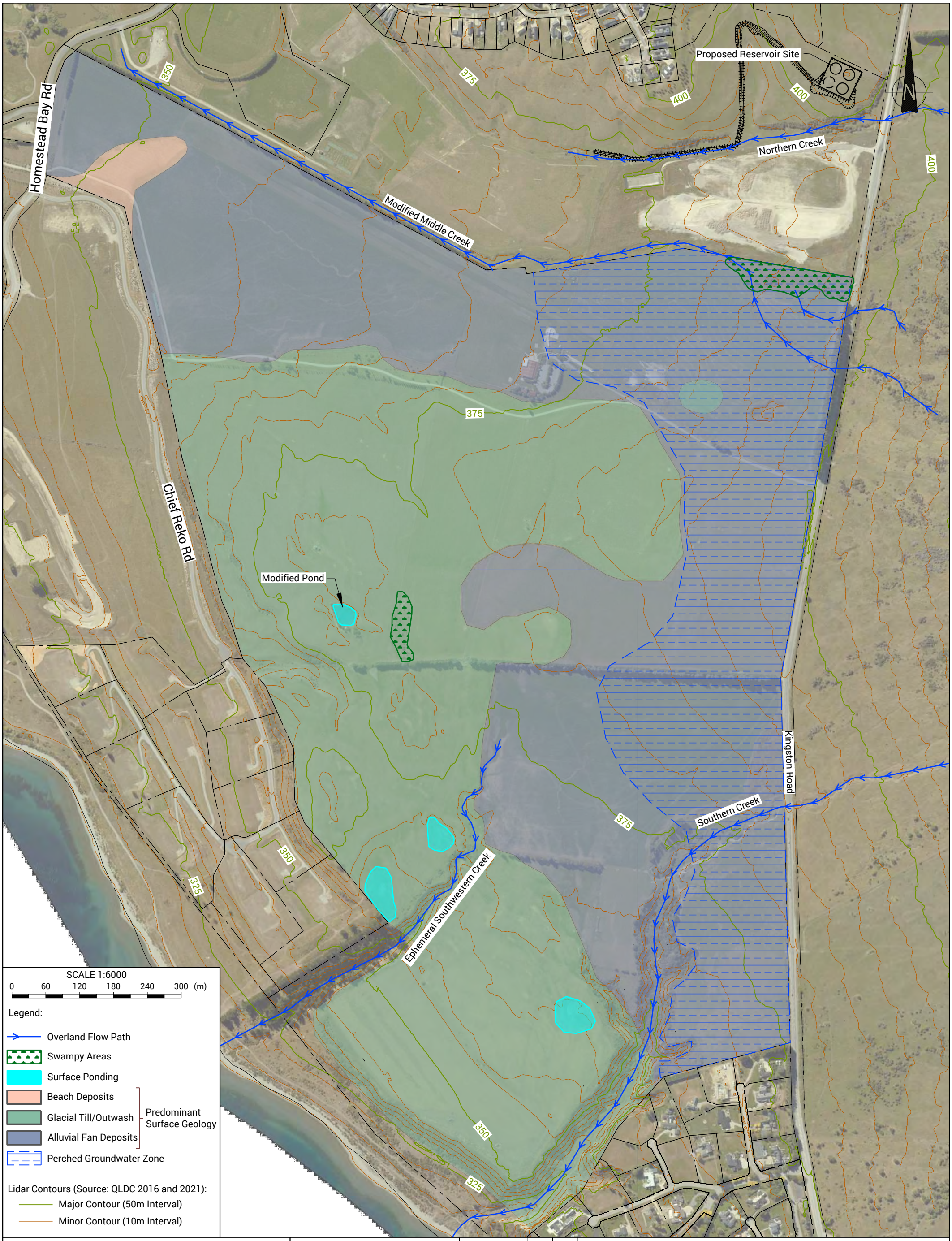
Homestead Bay

Geotechnical Assessment (GI)

Investigation Site Plan

FIG No: Appendix A, Figure 1a

Rev: A



Notes:
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CADFILE: 220556.01-I.dwg		
SCALES (AT A3 SIZE): 1:6000		
PROJECT No: 220556.01		

RCL Homestead Bay Ltd

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Geotechnical Assessment (GI)

Geomorphology Plan

FIG No: Appendix A, Figure 1b

Rev: A

Notes:
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APPROVED	PF	Jan.25
CADFILE: 220556.01-l.dwg		
SCALES (AT A3 SIZE): 1:8000		
PROJECT No: 220556.01		

RCL Homestead Bay Ltd

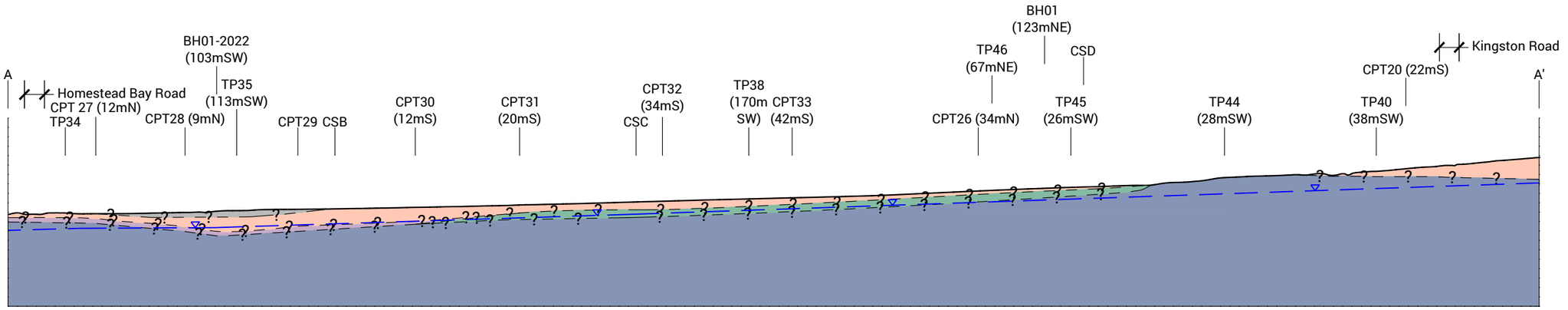
Homestead Bay

Geotechnical Assessment (GI)

ORC Borehole Plan

FIG No: Appendix A, Figure 1c

Rev: A



SCALE 1:5000

0 50 100 150 200 250 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:

- Alluvial Fan Deposit
- Beach Deposits
- Lake Sediment
- Outwash Deposits
- Glacial Till
- Indicative Groundwater Level

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DRAWN	WCG	Jan.25
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CADFILE: 220556.01-I (WF).dwg

SCALES (AT A3 SIZE): 1:5000

PROJECT No: 220556.01

FIG No: Appendix A, Figure 2a

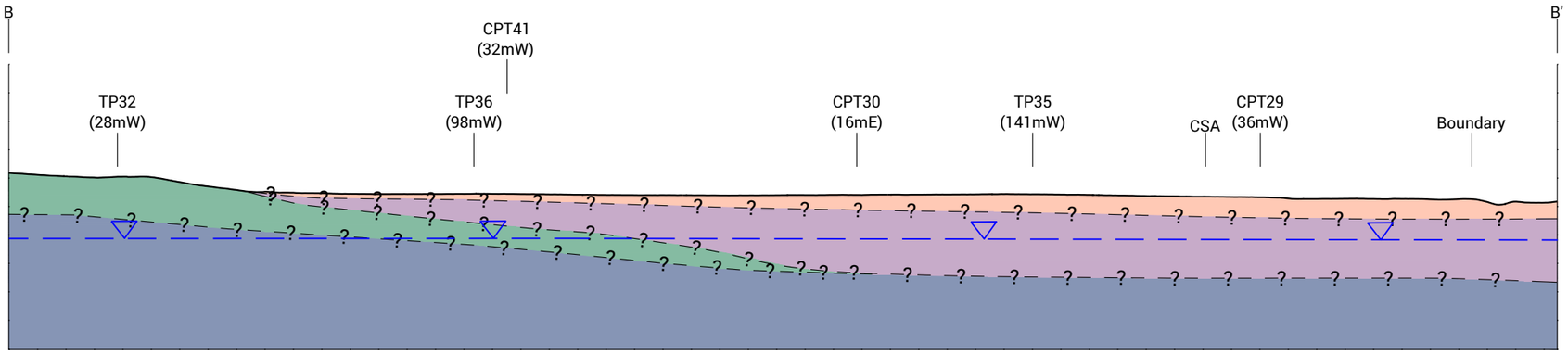
REV. A

RCL Homestead Bay Limited

Homestead Bay

Geotechnical Assessment

Cross Section A



SCALE 1:2000

0 20 40 60 80 100 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:

- Alluvial Fan Deposit
- Lake Sediment
- Outwash Deposits
- Glacial Till
- Indicative Groundwater Level

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APPROVED	PF	Jan.25

CADFILE: 220556.01-I (WF).dwg

SCALES (AT A3 SIZE): 1:2000

PROJECT No: 220556.01

FIG No: Appendix A, Figure 2b

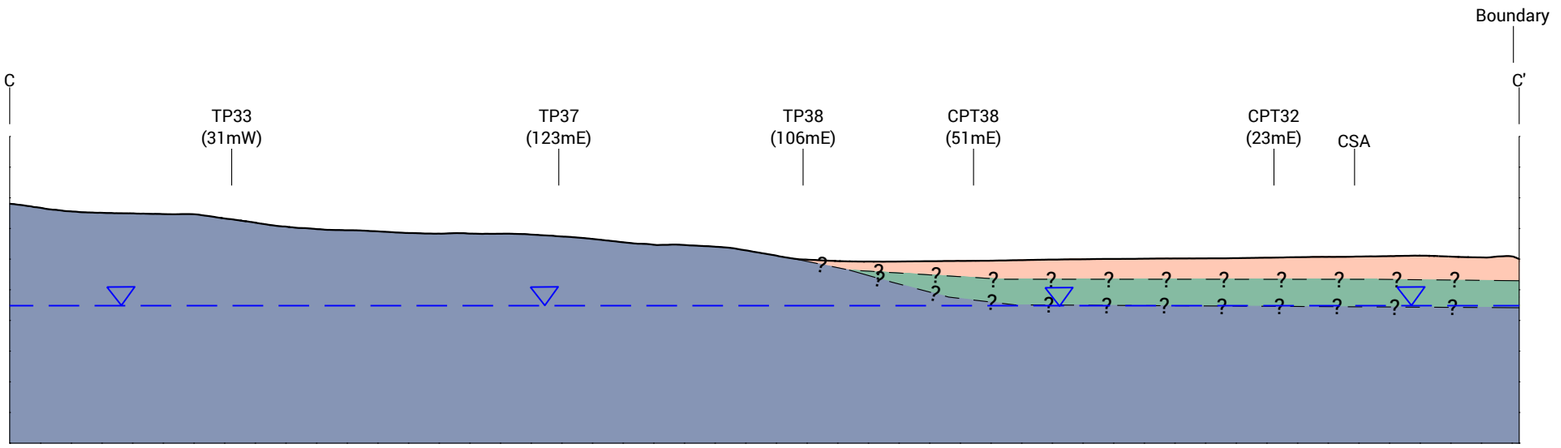
REV. A

RCL Homestead Bay Limited

Homestead Bay

Geotechnical Assessment

Cross Section B



SCALE 1:2000

0 20 40 60 80 100 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:
- Alluvial Fan Deposit
- Outwash Deposits
- Glacial Till
- Indicative Groundwater Level

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CADFILE: 220556.01-I (WF).dwg		
SCALES (AT A3 SIZE): 1:2000		
PROJECT No: 220556.01		

RCL Homestead Bay Limited

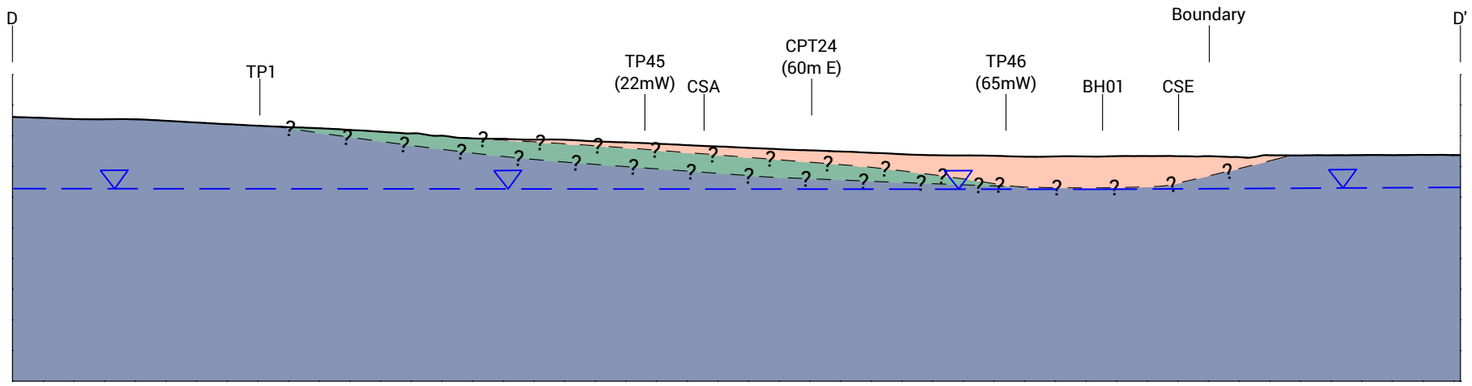
Homestead Bay

Geotechnical Assessment

Cross Section C

FIG No: Appendix A, Figure 2c

REV. A



SCALE 1:2000

0 20 40 60 80 100 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:
- Alluvial Fan Deposit
- Outwash Deposits
- Glacial Till
- Indicative Groundwater Level

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CADFILE: 220556.01-I (WF).dwg

SCALES (AT A3 SIZE): 1:2000

PROJECT No: 220556.01

FIG No: Appendix A, Figure 2d

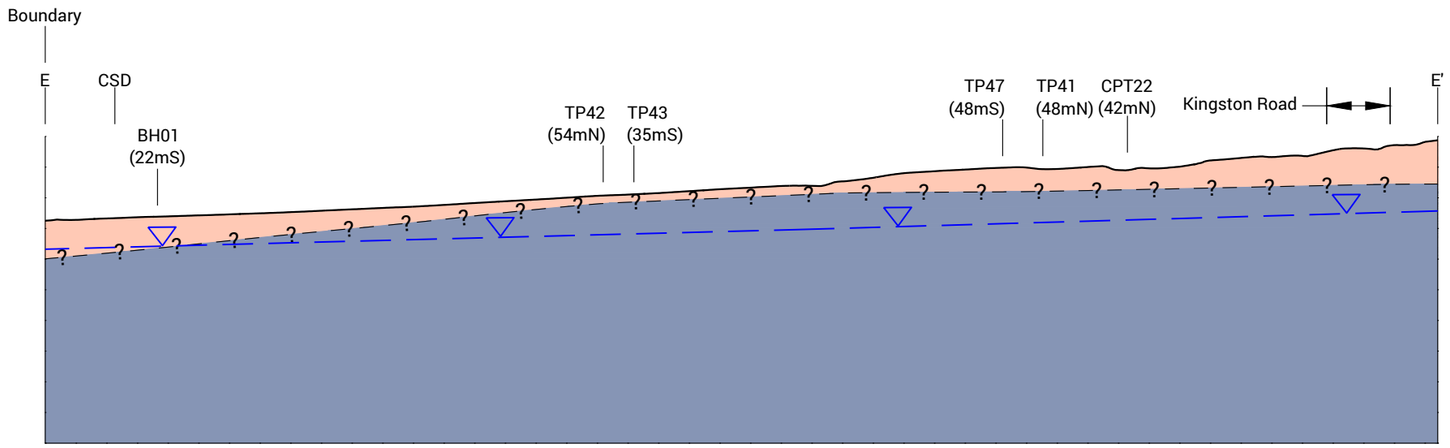
REV. A

RCL Homestead Bay Limited

Homestead Bay

Geotechnical Assessment

Cross Section D



SCALE 1:2000

0 20 40 60 80 100 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:
- Alluvial Fan Deposit
- Glacial Till

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CADFILE: 220556.01-I (WF).dwg

SCALES (AT A3 SIZE): 1:2000

PROJECT No: 220556.01

FIG No: Appendix A, Figure 2e

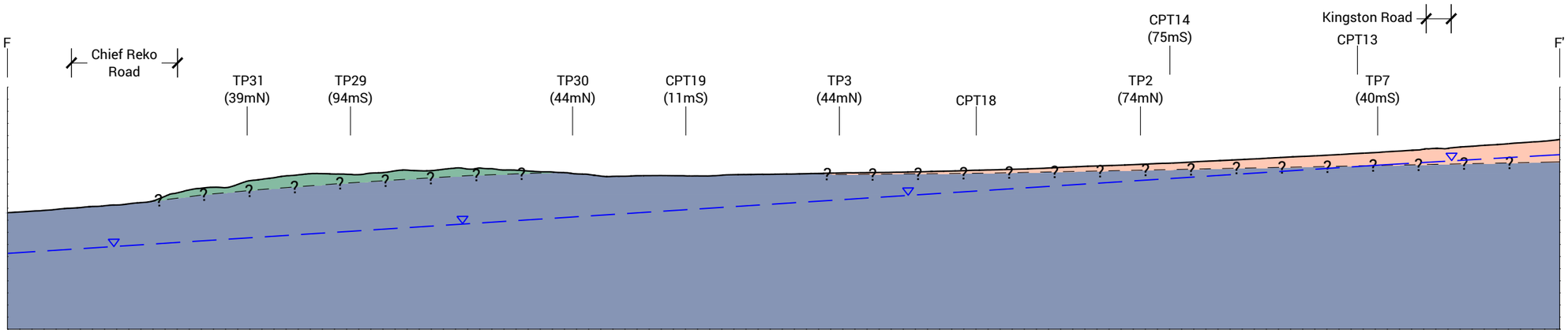
REV. A

RCL Homestead Bay Limited

Homestead Bay

Geotechnical Assessment

Cross Section E



SCALE 1:4000

0 40 80 120 160 200 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:
- Alluvial Fan Deposit
- Outwash Deposits
- Glacial Till
- Indicative Groundwater Level

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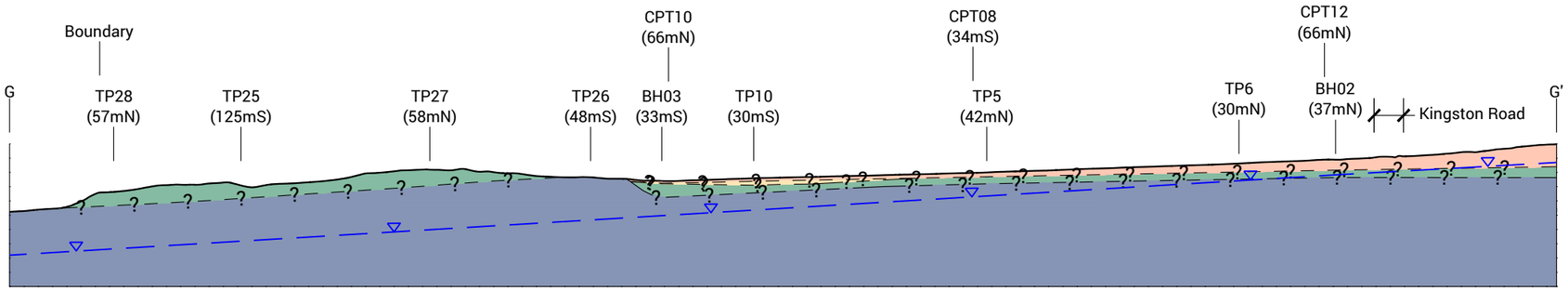
CADFILE: 220556.01-I (WF).dwg
SCALES (AT A3 SIZE): 1:4000
PROJECT No: 220556.01
FIG No: Appendix A, Figure 2f
REV. A

RCL Homestead Bay Limited

Homestead Bay

Geotechnical Assessment

Cross Section F



SCALE 1:4000

0 40 80 120 160 200 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:

- Alluvial Fan Deposit
- Glacial Pond Sediment
- Outwash Deposits
- Glacial Till
- Indicative Groundwater Level

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APPROVED	PF	Jan.25
CADFILE: 220556.01-I (WF).dwg		
SCALES (AT A3 SIZE): 1:4000		
PROJECT No: 220556.01		

RCL Homestead Bay Limited

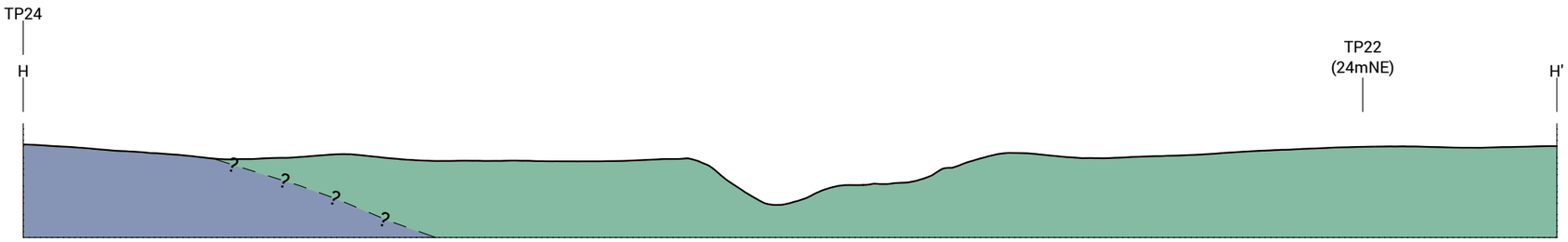
Homestead Bay

Geotechnical Assessment

Cross Section G

FIG No: Appendix A, Figure 2g

REV. A



SCALE 1:1000

0 10 20 30 40 50 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:
- Outwash Deposits
- Glacial Till

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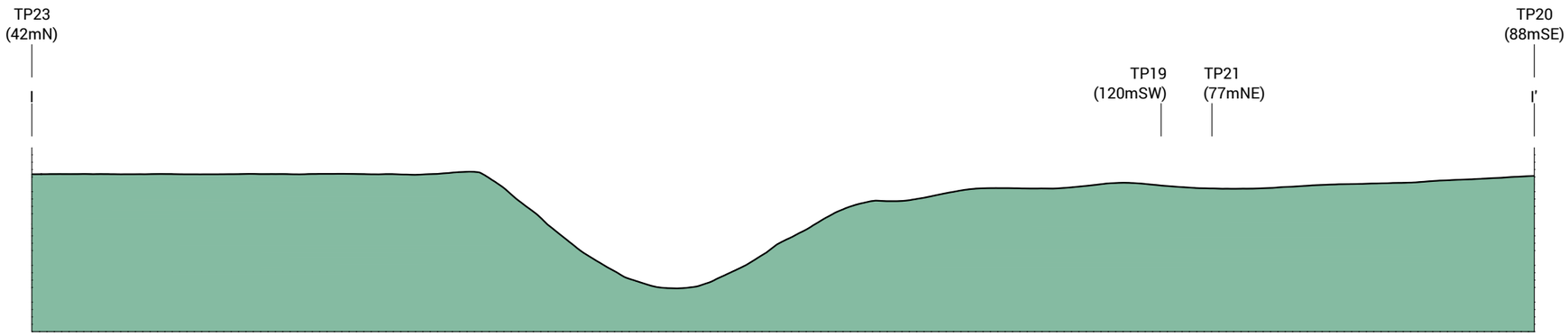
CADFILE: 220556.01-I (WF).dwg
SCALES (AT A3 SIZE): 1:1000
PROJECT No: 220556.01
FIG No: Appendix A, Figure 2h
REV. A

RCL Homestead Bay Limited

Homestead Bay

Geotechnical Assessment

Cross Section H



SCALE 1:750

0 7.5 15.0 22.5 30.0 37.5 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:

Outwash Deposits

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SCALES (AT A3 SIZE): 1:750

PROJECT No: 220556.01

FIG No: Appendix A, Figure 2i

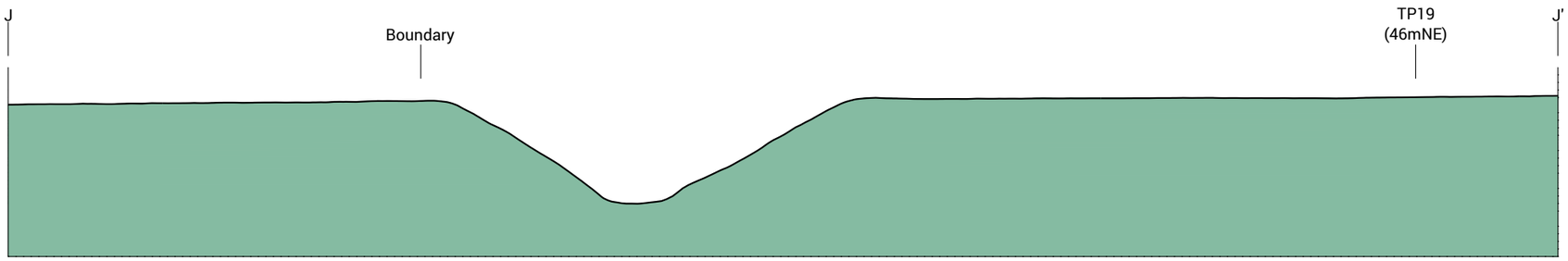
REV. A

RCL Homestead Bay Limited

Homestead Bay

Geotechnical Assessment

Cross Section I



SCALE 1:750

0 7.5 15.0 22.5 30.0 37.5 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:

Outwash Deposits

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CADFILE: 220556.01-I (WF).dwg		
SCALES (AT A3 SIZE): 1:750		
PROJECT No: 220556.01		

RCL Homestead Bay Limited

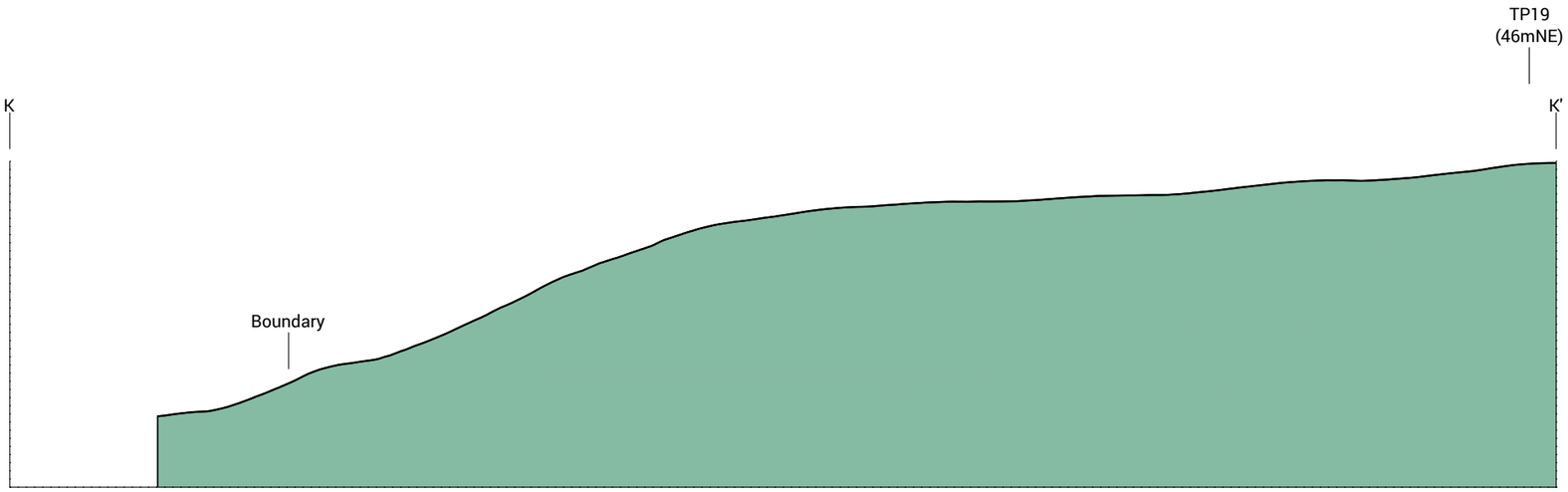
Homestead Bay

Geotechnical Assessment

Cross Section J

FIG No: Appendix A, Figure 2j

REV. A



SCALE 1:750

0 7.5 15.0 22.5 30.0 37.5 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:

Outwash Deposits

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DRAFTING CHECKED	WF/JMJ	Jan.25
APPROVED	PF	Jan.25
CADFILE: 220556.01-I (WF).dwg		
SCALES (AT A3 SIZE): 1:750		
PROJECT No: 220556.01		

RCL Homestead Bay Limited

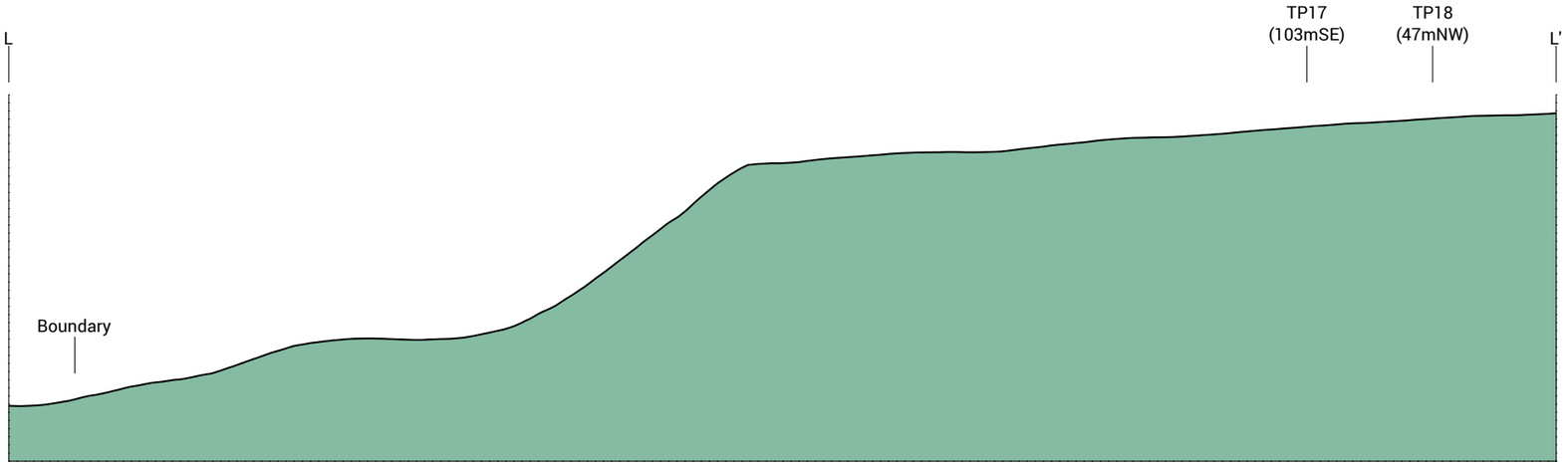
Homestead Bay

Geotechnical Assessment

Cross Section K

FIG No: Appendix A, Figure 2k

REV. A



SCALE 1:750

0 7.5 15.0 22.5 30.0 37.5 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:

Outwash Deposits

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CADFILE: 220556.01-I (WF).dwg

SCALES (AT A3 SIZE): 1:750

PROJECT No: 220556.01

FIG No: Appendix A, Figure 2l

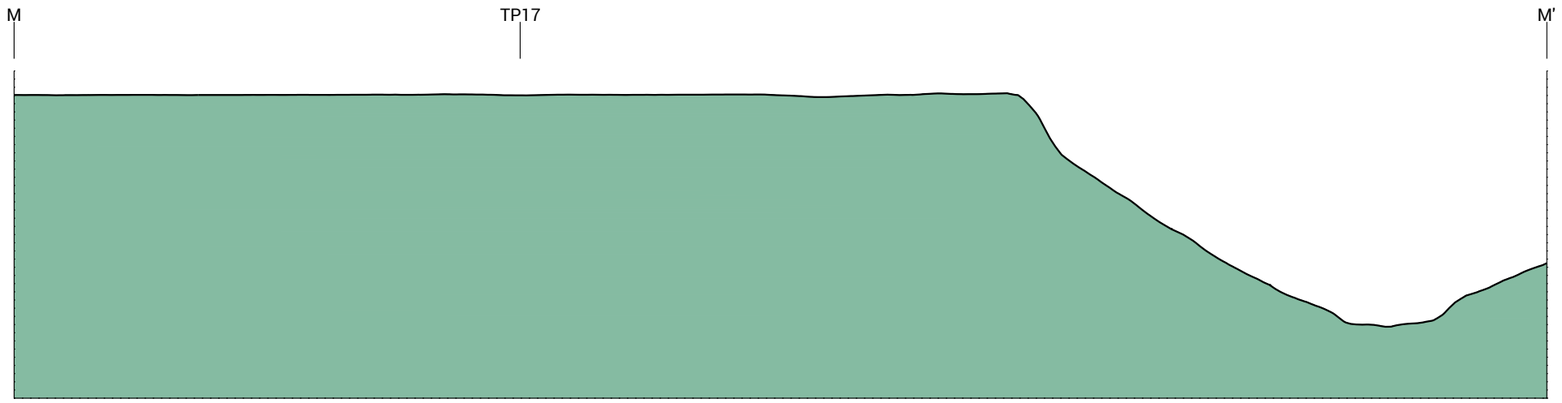
REV. A

RCL Homestead Bay Limited

Homestead Bay

Geotechnical Assessment

Cross Section L



SCALE 1:750

0 7.5 15.0 22.5 30.0 37.5 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:

Outwash Deposits

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DRAWN	WCG	Jan.25
DRAFTING CHECKED	WF/JMJ	Jan.25
APPROVED	PF	Jan.25

CADFILE: 220556.01-I (WF).dwg

SCALES (AT A3 SIZE): 1:750

PROJECT No: 220556.01

RCL Homestead Bay Limited

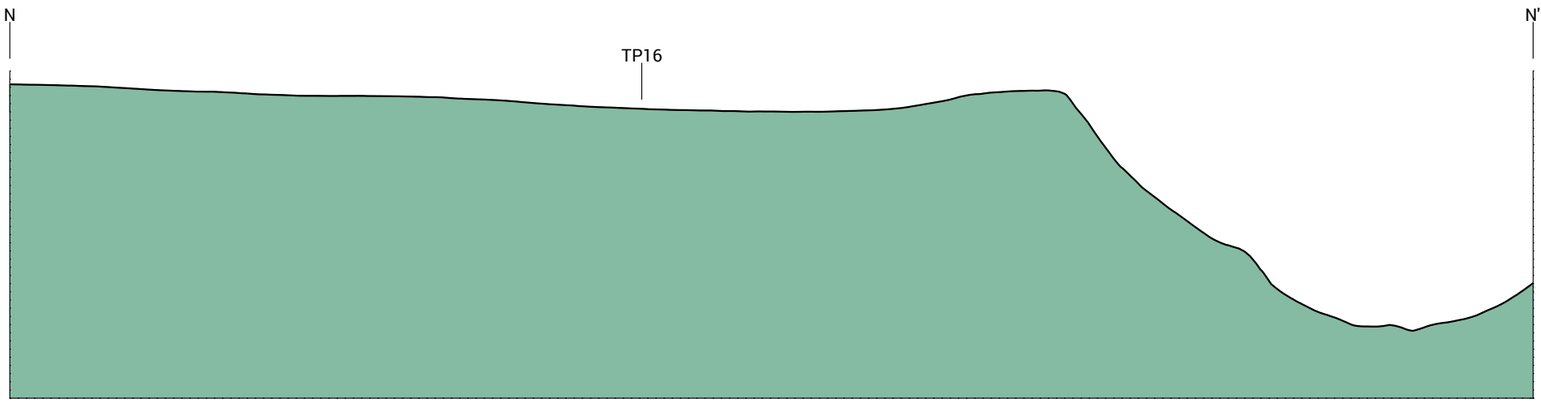
Homestead Bay

Geotechnical Assessment

Cross Section M

FIG No: Appendix A, Figure 2m

REV. A



SCALE 1:750

0 7.5 15.0 22.5 30.0 37.5 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:

Outwash Deposits

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DRAFTING CHECKED	WF/JMJ	Jan.25
APPROVED	PF	Jan.25
CADFILE: 220556.01-I (WF).dwg		
SCALES (AT A3 SIZE): 1:750		
PROJECT No: 220556.01		

RCL Homestead Bay Limited

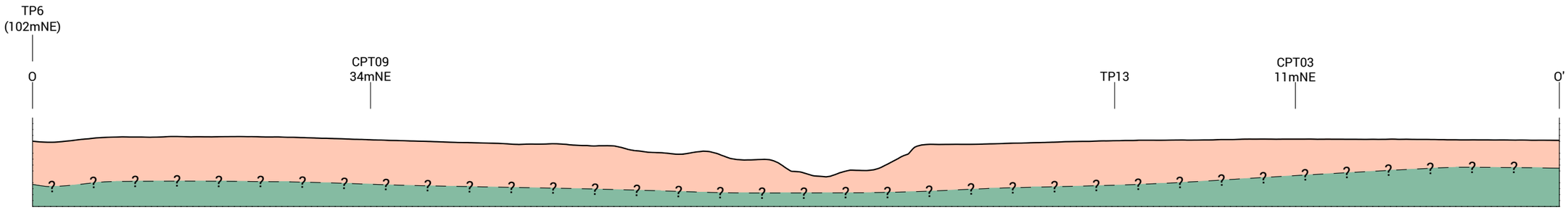
Homestead Bay

Geotechnical Assessment

Cross Section N

FIG No: Appendix A, Figure 2n

REV. A



SCALE 1:750

0 7.5 15.0 22.5 30.0 37.5 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:
- Alluvial Fan Deposit
- Outwash Deposits

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DRAFTING CHECKED	WF/JMJ	Jan.25
APPROVED	PF	Jan.25
CADFILE: 220556.01-I (WF).dwg		
SCALES (AT A3 SIZE): 1:750		
PROJECT No: 220556.01		

RCL Homestead Bay Limited

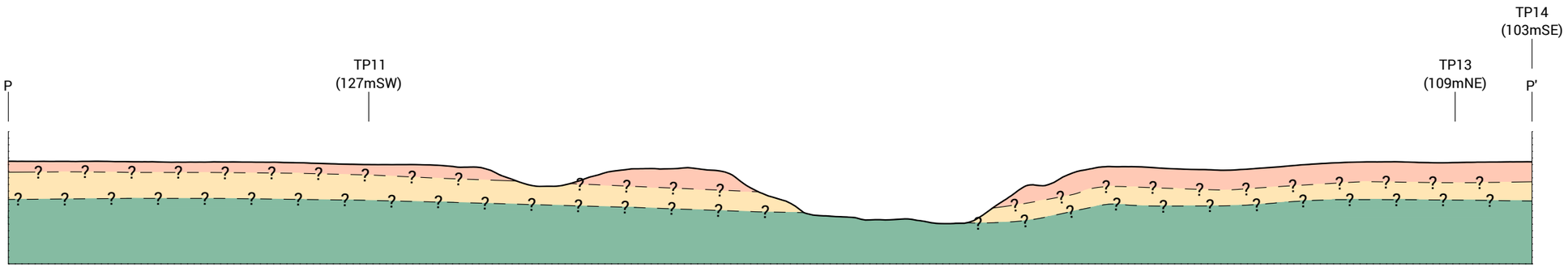
Homestead Bay

Geotechnical Assessment

Cross Section O

FIG No: Appendix A, Figure 2o

REV. A



SCALE 1:750

0 7.5 15.0 22.5 30.0 37.5 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:
- Alluvial Fan Deposit
- Outwash Deposits
- Glacial Till

GEOSOLVE
Level 1, 70 MacAndrew Road, South Dunedin
www.geosolve.co.nz

DRAWN	WCG	Jan.25
DRAFTING CHECKED	WF/JMJ	Jan.25
APPROVED	PF	Jan.25

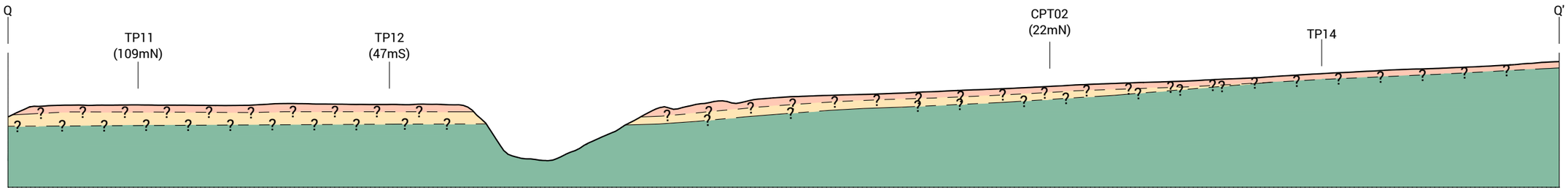
CADFILE: 220556.01-I (WF).dwg
SCALES (AT A3 SIZE): 1:750
PROJECT No: 220556.01
FIG No: Appendix A, Figure 2p
REV. A

RCL Henley Downs Limited

Homestead Bay

Geotechnical Assessment

Cross Section P



SCALE 1:1000

0 10 20 30 40 50 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:

- Alluvial Fan Deposit
- Glacial Pond Sediment
- Outwash Deposits

GEOSOLVE
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DRAWN	WCG	Jan.25
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APPROVED	PF	Jan.25

CADFILE: 220556.01-I (WF).dwg

SCALES (AT A3 SIZE): 1:1000

PROJECT No: 220556.01

FIG No: Appendix A, Figure 2q

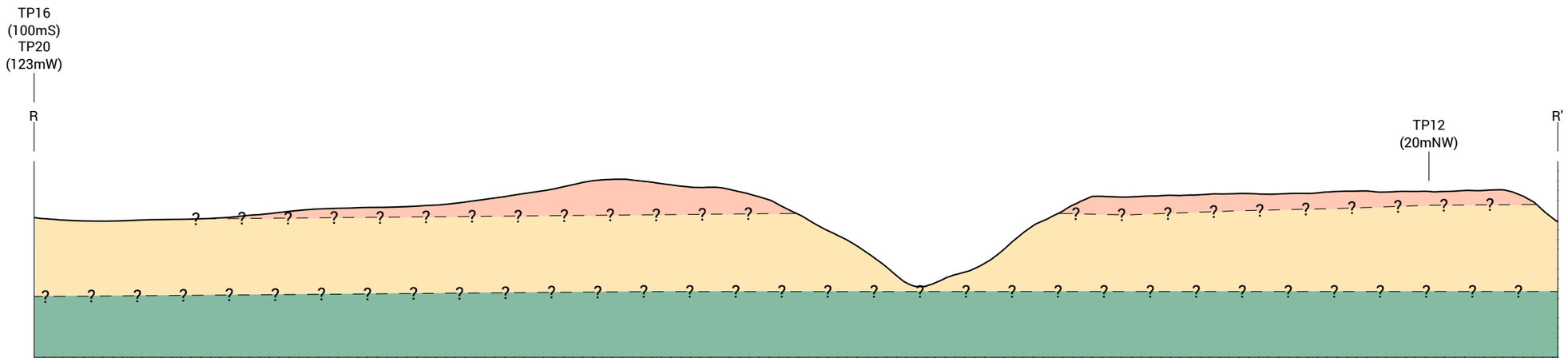
REV. A

RCL Homestead Bay Limited

Homestead Bay

Geotechnical Assessment

Cross Section Q



SCALE 1:500

0 5 10 15 20 25 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:
- Alluvial Fan Deposit
- Glacial Pond Sediment
- Outwash Deposits

GEOSOLVE
Level 1, 70 MacAndrew Road, South Dunedin
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DRAWN	WCG	Jan.25
DRAFTING CHECKED	WF/JMJ	Jan.25
APPROVED	PF	Jan.25

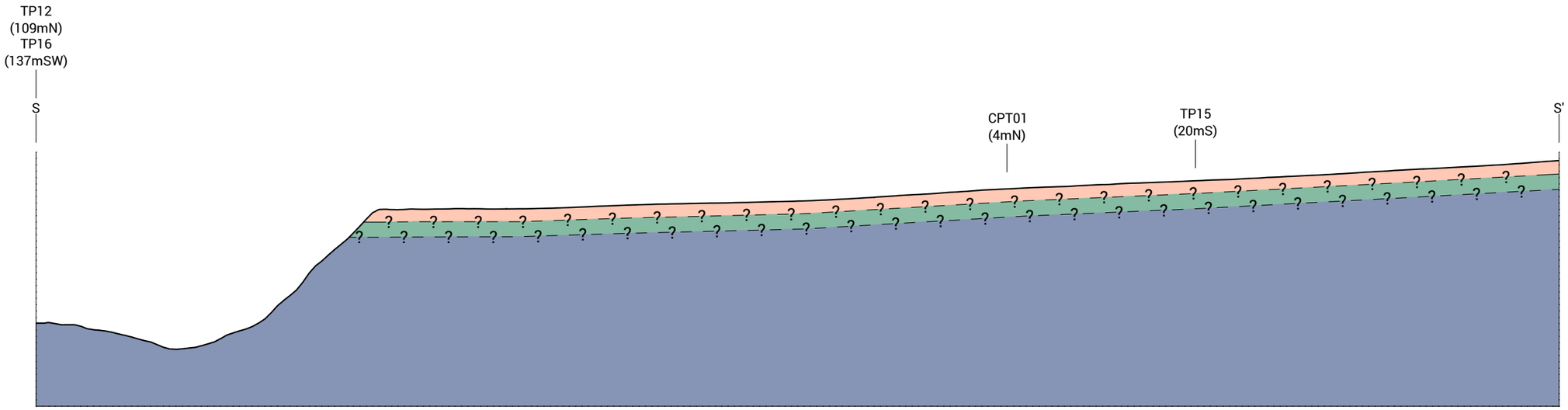
CADFILE: 220556.01-I (WF).dwg
SCALES (AT A3 SIZE): 1:500
PROJECT No: 220556.01
FIG No: Appendix A, Figure 2r
REV. A

RCL Homestead Bay Limited

Homestead Bay

Geotechnical Assessment

Cross Section R



SCALE 1:750

0 7.5 15.0 22.5 30.0 37.5 (m)

Notes:
1. These drawings have been prepared for the benefit of RCL Henley Downs Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Legend:

- Alluvial Fan Deposit
- Outwash Deposits
- Glacial Till

GEOSOLVE
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DRAWN	WCG	Jan.25
DRAFTING CHECKED	WF/JMJ	Jan.25
APPROVED	PF	Jan.25

CADFILE: 220556.01-I (WF).dwg

SCALES (AT A3 SIZE): 1:750

PROJECT No: 220556.01

FIG No: Appendix A, Figure 2s

REV. A

RCL Homestead Bay Limited

Homestead Bay

Geotechnical Assessment

Cross Section S

Appendix B: Investigation Data

GEOTECHNICAL WATER RESOURCES PAVEMENTS

TEST PIT LOG

HOLE NO.: TP01

CLIENT: RCL Homestead Bay Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 22/10/2024

COORDINATES: 1265689.0 mE, 4998600.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 22/10/2024

LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ

ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)
TOPSOIL	Organic silty SAND, trace rootlets, brown. 0.20 m
LOESS	Silty fine SAND, with rootlets and organic inclusions, brownish orange, massive. Loose, moist. 0.50 m
WEATHERED GLACIAL TILL	Sandy fine to coarse GRAVEL, with minor to some silt and trace cobbles, orange, massive. Medium dense, moist, gravels are subrounded to rounded. Sand is fine to coarse. 0.70 m Fine SAND, with trace to minor gravel and trace silt, 500 mm diameter boulder at 1.20 m, orange and grey, massive. Loose to medium dense, moist to wet. 1.30 m
GLACIAL TILL	Fine to medium SAND, with minor gravel and trace cobbles and boulders up to 500 mm in diameter, light grey, massive. Dry to moist, gravels are fine to coarse, subrounded to rounded. 3.80 m
	End Of Hole: 3.80 m

SAMPLES | DEPTH / RL | LEGEND

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.0		2												
0.1		2												
0.2		2												
0.3		1												
0.4		2												
0.5							7							
0.6							7							
0.7		2												
0.8		1												
0.9				4										
1.0														20 >>

SHEAR STRENGTH (kPa) Vane: 50 | 100 | 150 | 200 | Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

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TEST PIT LOG

HOLE NO.: TP02

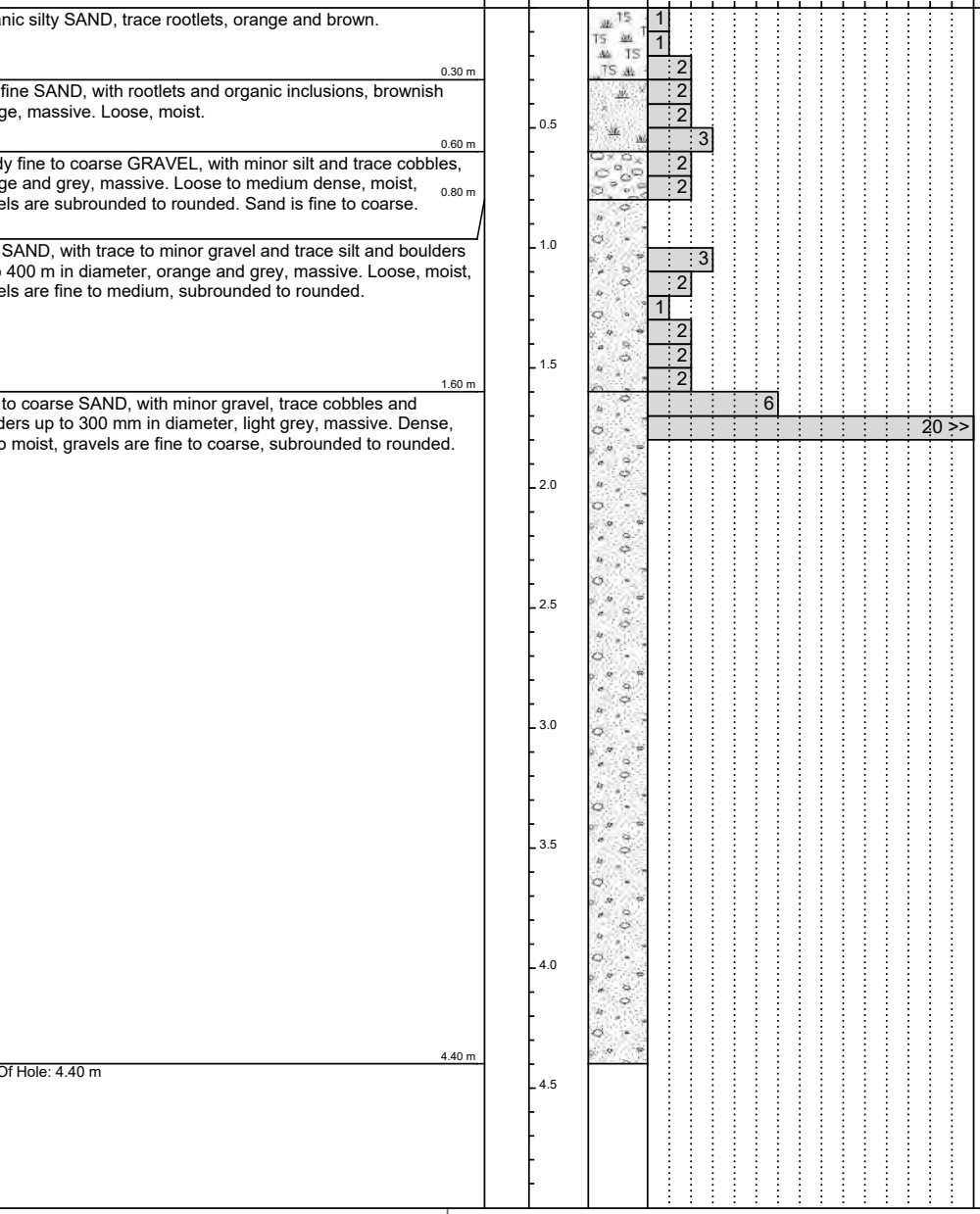
CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
COORDINATES: 1265764.0 mE, 4998393.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 22/10/2024
END DATE: 22/10/2024
LOGGED BY: JMJ
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic silty SAND, trace rootlets, orange and brown. 0.30 m		
LOESS	Silty fine SAND, with rootlets and organic inclusions, brownish orange, massive. Loose, moist. 0.60 m		
WEATHERED GLACIAL TILL	Sandy fine to coarse GRAVEL, with minor silt and trace cobbles, orange and grey, massive. Loose to medium dense, moist, gravels are subrounded to rounded. Sand is fine to coarse. 0.80 m Fine SAND, with trace to minor gravel and trace silt and boulders up to 400 m in diameter, orange and grey, massive. Loose, moist, gravels are fine to medium, subrounded to rounded. 1.60 m		
GLACIAL TILL	Fine to coarse SAND, with minor gravel, trace cobbles and boulders up to 300 mm in diameter, light grey, massive. Dense, dry to moist, gravels are fine to coarse, subrounded to rounded. 4.40 m		
	End Of Hole: 4.40 m		



PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

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TEST PIT LOG

HOLE NO.: TP03

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 22/10/2024
COORDINATES: 1265515.0 mE, 4998365.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)
TOPSOIL	Organic silty SAND, trace rootlets, brown. 0.30 m
ALLUVIAL FAN DEPOSITS	SILT, with trace organic inclusions, grey. Firm, moist. 0.70 m
	Sandy, silty fine to coarse GRAVEL, brown and grey, chaotic. Medium dense, moist to wet, gradual top and bottom contacts, gravels are subrounded to rounded. Sand is coarse. 1.00 m
	Sandy fine to coarse GRAVEL, orange, chaotic. Medium dense, moist, immediate contact at base, gravels are subrounded to rounded. Sand is coarse. 1.30 m
GLACIAL TILL	Fine to coarse SAND, with minor gravel and trace cobbles and boulders, grey, massive, with orange banding decreasing with depth. Dense, moist, gravels are fine to coarse, subrounded to rounded. 3.80 m
	End Of Hole: 3.80 m

SAMPLES | DEPTH / RL | LEGEND

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	Blows
0.30	1
0.40	2
0.50	2
0.60	1
0.70	1
0.80	2
0.90	1
1.00	6
1.10	6
1.20	4
1.30	7
1.40	18 >>
1.50	20 >>

SHEAR STRENGTH (kPa) Vane: Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:20:31 am

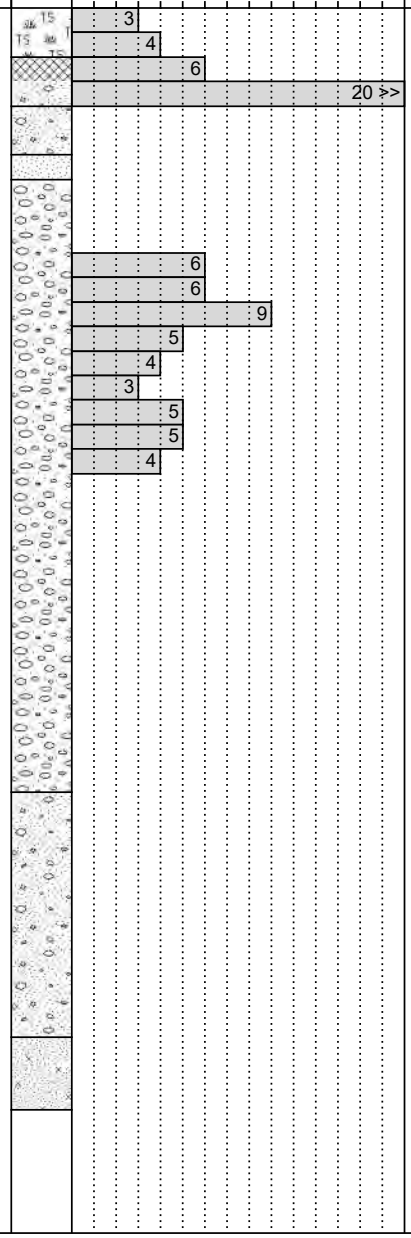
TEST PIT LOG

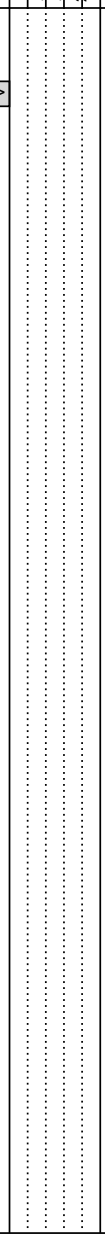
HOLE NO.: TP04

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 22/10/2024
COORDINATES: 1265567.0 mE, 4998235.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic silty SAND, trace rootlets, brown. 0.20 m		
UNCONTROLLED FILL	Silty, sandy fine to coarse GRAVEL, with fragments of steel, dark orange. Dry to moist, gravels are rounded. Sand is fine to medium . 0.40 m		
	Fine to coarse SAND, with minor gravel and trace silt, grey and orange, loosely bedded. Medium dense, moist, gravels are fine to coarse, rounded. 0.60 m 0.70 m		
	Coarse SAND, grey, bedded. Medium dense, moist.		
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL, trace cobbles, with some beds of gravel with trace sand, grey and orange, bedded. Medium dense, moist, dipping between 5-10° towards 222°, gravels are subrounded to rounded. Sand is fine to coarse. 3.20 m		
	Gravelly fine to coarse SAND, with beds of coarse sand, grey, bedded. Medium dense, moist, dipping between 5-10° towards 222°, gravels are fine to coarse, subrounded to rounded. 4.20 m		
GLACIAL TILL	Silty SAND, with trace gravel, grey. Medium dense, moist to wet, horizontal contact, gravels are fine to medium, subrounded to rounded. 4.50 m		
	End Of Hole: 4.50 m		





WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit collapsing in coarser gravels

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:20:35 am

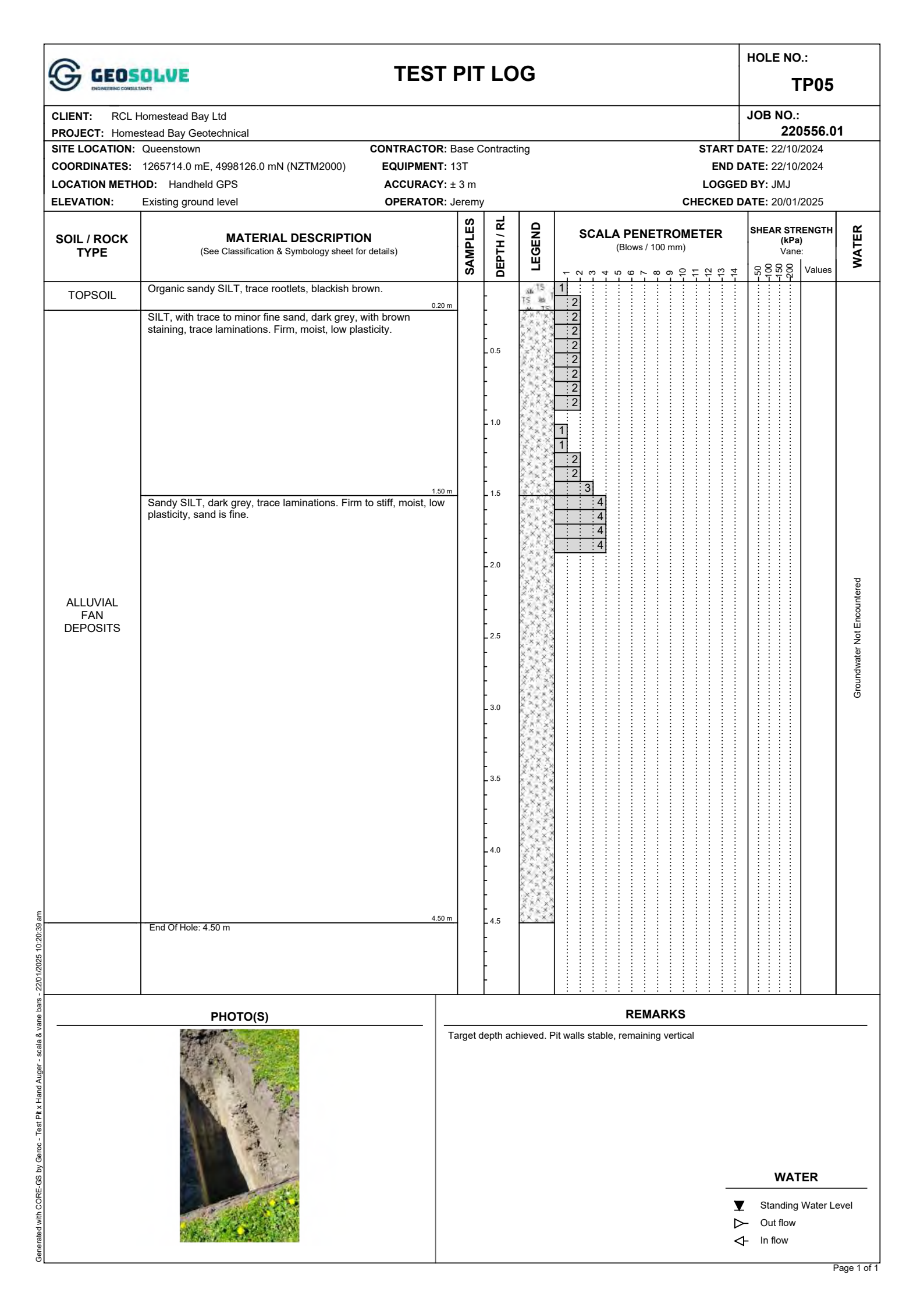
TEST PIT LOG

HOLE NO.: TP05

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 22/10/2024
COORDINATES: 1265714.0 mE, 4998126.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic sandy SILT, trace rootlets, blackish brown. 0.20 m						
ALLUVIAL FAN DEPOSITS	SILT, with trace to minor fine sand, dark grey, with brown staining, trace laminations. Firm, moist, low plasticity. 1.50 m						
	Sandy SILT, dark grey, trace laminations. Firm to stiff, moist, low plasticity, sand is fine. 4.50 m						
	End Of Hole: 4.50 m						



PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:20:39 am

TEST PIT LOG

HOLE NO.: TP06

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 22/10/2024
COORDINATES: 1265891.0 mE, 4998119.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic sandy SILT, trace rootlets, blackish brown. 0.20 m		
ALLUVIAL FAN DEPOSITS	SILT, with trace gravel and fine sand, dark grey, laminated. Firm, moist, low plasticity. 0.50 m		
	Sandy fine to coarse GRAVEL, dark grey. Medium dense, moist, gravels are rounded. Sand is medium to coarse. 0.70 m		
	SILT, with trace gravel and fine sand, dark grey, with brown mottling. Loose to medium dense, moist. 2.80 m		
	Sandy fine to coarse GRAVEL, with trace cobbles and boulders up to 200 mm in diameter, dark grey. Moist, gravels are rounded. Sand is medium to coarse. 3.00 m		
	SILT, with trace gravel and fine sand, dark grey, with brown mottling, trace laminations. Loose to medium dense, moist. 3.50 m		
	Sandy SILT, grey. Firm to stiff, moist to wet, low plasticity, sand is fine. 4.60 m		
	End Of Hole: 4.60 m		

LEGEND

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	Blows / 100 mm
0.0 – 0.2	1
0.2 – 0.4	2
0.4 – 0.6	2
0.6 – 0.8	1
0.8 – 1.0	2
1.0 – 1.2	5
1.2 – 1.4	6
1.4 – 1.6	3
1.6 – 1.8	2
1.8 – 2.0	2
2.0 – 2.2	1
2.2 – 2.4	3
2.4 – 2.6	2
2.6 – 2.8	1
2.8 – 3.0	1
3.0 – 3.2	2
3.2 – 3.4	1
3.4 – 3.6	1

SHEAR STRENGTH (kPa) Vane: 50, 100, 150, 200 — Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:20:43 am

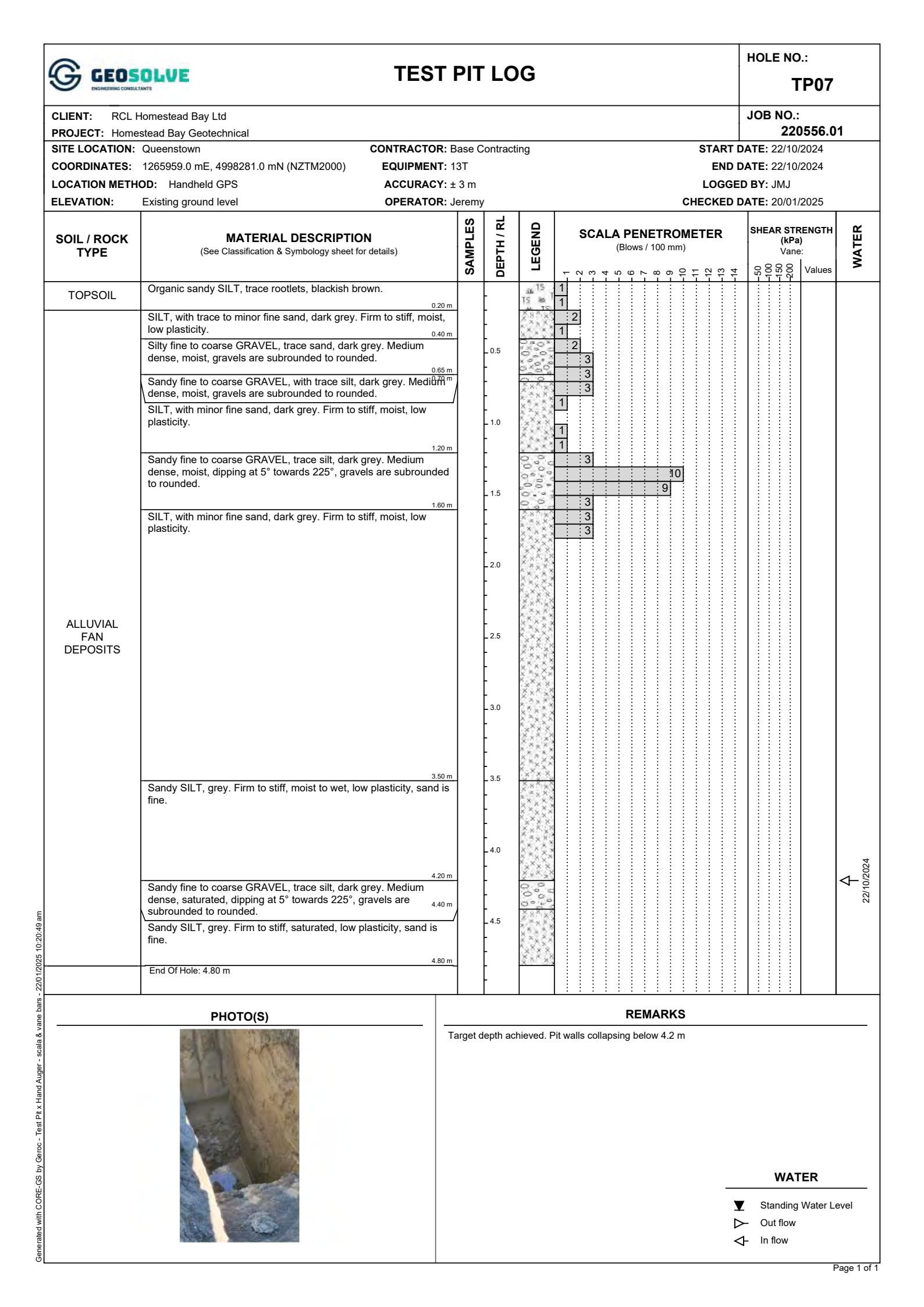
TEST PIT LOG

HOLE NO.: TP07

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 22/10/2024
COORDINATES: 1265959.0 mE, 4998281.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic sandy SILT, trace rootlets, blackish brown. 0.20 m						
ALLUVIAL FAN DEPOSITS	SILT, with trace to minor fine sand, dark grey. Firm to stiff, moist, low plasticity. 0.40 m						
	Silty fine to coarse GRAVEL, trace sand, dark grey. Medium dense, moist, gravels are subrounded to rounded. 0.65 m						
	Sandy fine to coarse GRAVEL, with trace silt, dark grey. Medium dense, moist, gravels are subrounded to rounded. 0.70 m						
	SILT, with minor fine sand, dark grey. Firm to stiff, moist, low plasticity. 1.20 m						
	Sandy fine to coarse GRAVEL, trace silt, dark grey. Medium dense, moist, dipping at 5° towards 225°, gravels are subrounded to rounded. 1.60 m						
	SILT, with minor fine sand, dark grey. Firm to stiff, moist, low plasticity. 3.50 m						
	Sandy SILT, grey. Firm to stiff, moist to wet, low plasticity, sand is fine. 4.20 m						
	Sandy fine to coarse GRAVEL, trace silt, dark grey. Medium dense, saturated, dipping at 5° towards 225°, gravels are subrounded to rounded. 4.40 m						
	Sandy SILT, grey. Firm to stiff, saturated, low plasticity, sand is fine. 4.80 m						
	End Of Hole: 4.80 m						



PHOTO(S)

REMARKS

Target depth achieved. Pit walls collapsing below 4.2 m

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:20:49 am

TEST PIT LOG

HOLE NO.: TP08

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
COORDINATES: 1265942.0 mE, 4998418.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 22/10/2024
END DATE: 22/10/2024
LOGGED BY: JMJ
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND
TOPSOIL	Organic sandy SILT, trace rootlets, blackish brown.			
	0.25 m Sandy SILT, with trace gravel, light grey. Stiff, moist.			
	0.30 m SILT, with trace to minor sand, dark grey, discontinuous 100 mm sandy gravel layer at 1.50 m. Firm to stiff, moist, sand is fine.			
	1.80 m Sandy fine to coarse GRAVEL, with minor silt, dark grey. Medium dense, moist, gravels are subrounded to rounded. Sand is fine to coarse.			
ALLUVIAL FAN DEPOSITS	2.00 m SILT, with some fine sand, grey with brown mottling, occasional discontinuous sandy gravel layers. Stiff, moist.			
	End Of Hole: 5.00 m 5.00 m			

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	Blows / 100 mm
0.0 – 0.5	1, 2, 3, 2, 2, 2, 2, 2, 2
0.5 – 1.0	3, 3, 2, 3, 3, 3, 3, 4, 3

SHEAR STRENGTH (kPa) Vane: — Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:20:55 am

TEST PIT LOG

HOLE NO.: TP09

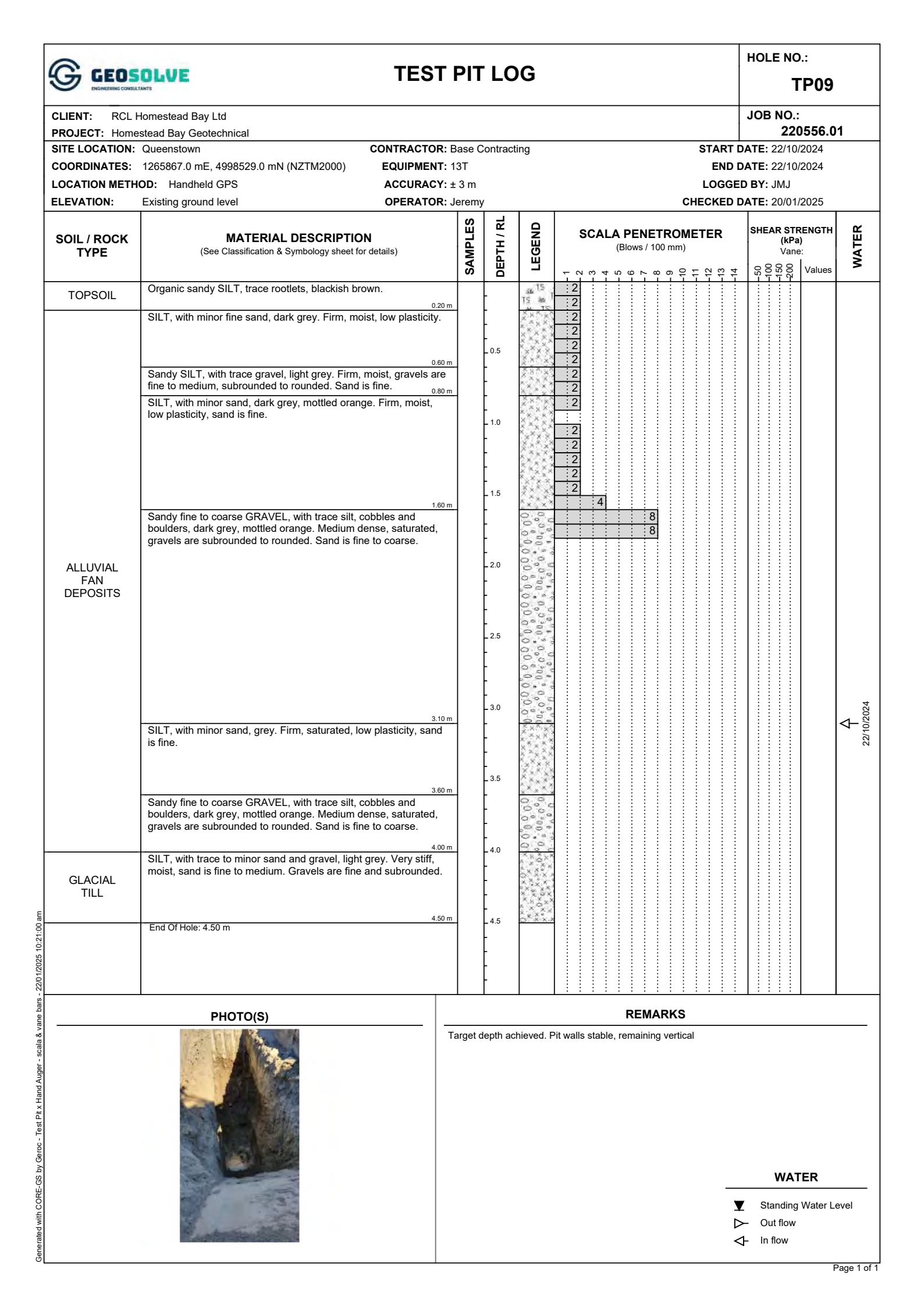
CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
COORDINATES: 1265867.0 mE, 4998529.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 22/10/2024
END DATE: 22/10/2024
LOGGED BY: JMJ
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic sandy SILT, trace rootlets, blackish brown. 0.20 m						
ALLUVIAL FAN DEPOSITS	SILT, with minor fine sand, dark grey. Firm, moist, low plasticity. 0.60 m						
	Sandy SILT, with trace gravel, light grey. Firm, moist, gravels are fine to medium, subrounded to rounded. Sand is fine. 0.80 m						
	SILT, with minor sand, dark grey, mottled orange. Firm, moist, low plasticity, sand is fine. 1.60 m						
	Sandy fine to coarse GRAVEL, with trace silt, cobbles and boulders, dark grey, mottled orange. Medium dense, saturated, gravels are subrounded to rounded. Sand is fine to coarse. 3.10 m						
	SILT, with minor sand, grey. Firm, saturated, low plasticity, sand is fine. 3.60 m						
	Sandy fine to coarse GRAVEL, with trace silt, cobbles and boulders, dark grey, mottled orange. Medium dense, saturated, gravels are subrounded to rounded. Sand is fine to coarse. 4.00 m						
GLACIAL TILL	SILT, with trace to minor sand and gravel, light grey. Very stiff, moist, sand is fine to medium. Gravels are fine and subrounded. 4.50 m						
	End Of Hole: 4.50 m						



PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:21:00 am

TEST PIT LOG

HOLE NO.: TP10

CLIENT: RCL Homestead Bay Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Queenstown

CONTRACTOR: Base Contracting

START DATE: 23/10/2024

COORDINATES: 1265552.0 mE, 4998050.0 mN (NZTM2000)

EQUIPMENT: 13T

END DATE: 23/10/2024

LOCATION METHOD: Handheld GPS

ACCURACY: ± 3 m

LOGGED BY: JMJ

ELEVATION: Existing ground level

OPERATOR: Jeremy

CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic sandy SILT, trace rootlets, blackish brown. 0.20 m						
ALLUVIAL FAN DEPOSITS	SILT, with minor sand, dark grey. Firm, dry to moist, low plasticity, sand is fine. 1.70 m						
	Sandy fine to coarse GRAVEL, with trace silt, dark brownish grey. Moist, gravels are subrounded. Sand is fine. 1.90 m						
	Sandy fine to coarse GRAVEL, trace silt, brownish grey. Medium dense, moist, gravels are mostly fine to medium and subrounded. 2.10 m						
GLACIAL POND SEDIMENT	SILT, with trace fine sand, grey. Stiff, dry, low plasticity, friable. 2.60 m						
	SILT, trace rootlets, grey, massive. Very stiff, dry, low plasticity, powdery texture. 3.40 m						
	Fine SAND, with minor silt and trace gravel, white and grey, massive. Hard, moist, gravels are medium to coarse, rounded. 4.40 m						
	End Of Hole: 4.40 m						

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:21:05 am

TEST PIT LOG

HOLE NO.: TP11

CLIENT: RCL Homestead Bay Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 23/10/2024

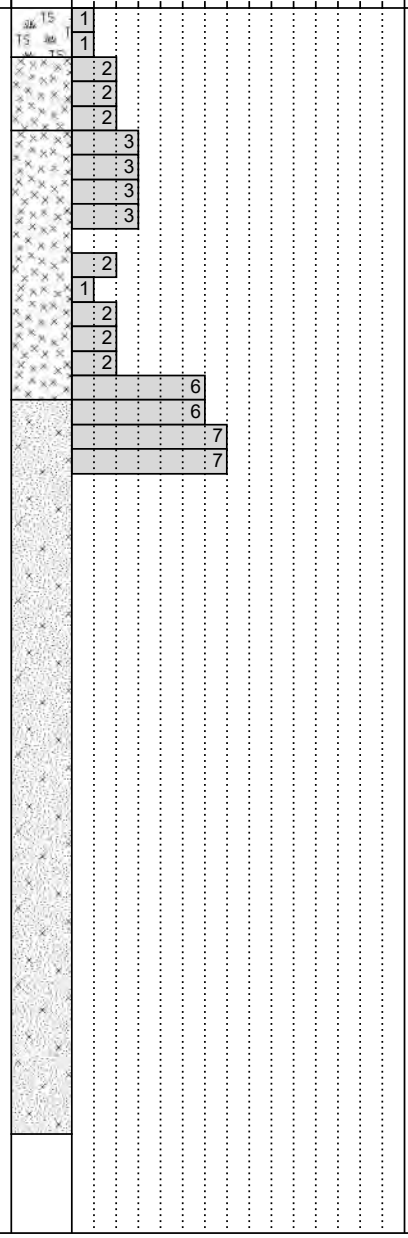
COORDINATES: 1265674.0 mE, 4997797.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 23/10/2024

LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ

ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)
TOPSOIL	Organic sandy SILT, trace rootlets, blackish brown. 0.20 m
ALLUVIAL FAN DEPOSITS	SILT, with trace fine sand, brownish grey. Firm, dry to moist, low plasticity. 0.50 m
	SILT, with trace fine sand, greyish brown. Firm, dry to moist, low plasticity. 1.60 m
GLACIAL POND SEDIMENT	Fine SAND, with trace silt, light grey and orange banding, minor laminations, interbedded with 10-50 mm of silt bands. Medium dense, moist. 4.60 m
	End Of Hole: 4.60 m

SAMPLES | DEPTH / RL | LEGEND | SCALA PENETROMETER (Blows / 100 mm) | SHEAR STRENGTH (kPa) Vane: Values | WATER



Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:21:10 am

TEST PIT LOG

HOLE NO.: TP12

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 23/10/2024
COORDINATES: 1265739.0 mE, 4997644.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 23/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic sandy SILT, trace rootlets, dark brown.		
	0.30 m		
ALLUVIAL FAN DEPOSITS	SILT, with trace fine sand, brownish grey. Firm, dry to moist, low plasticity.		
	0.60 m		
	SILT, with trace fine sand, grey. Firm, dry to moist, low plasticity.		
	0.70 m		
	SILT, with trace fine sand, with organic staining, brown. Firm, dry to moist, low plasticity.		
	0.75 m		
	SILT, with trace fine sand, grey. Firm, dry to moist, low plasticity.		
	1.40 m		
GLACIAL POND SEDIMENT	Sandy fine to medium GRAVEL, grey, bedded. Loose to medium dense, dry to moist, gravels are subrounded to rounded. Sand is medium to coarse.		
	1.60 m		
	Fine SAND, with trace silt, light grey, minor laminations within silt. Loose to medium dense, dry to moist, pockets of sandy gravel at base contact.		
	3.10 m		
	Sandy, fine to coarse GRAVEL, grey, bedded. Medium dense, dry to moist, gravels are subrounded to rounded. Sand is fine to coarse.		
	3.50 m		
	Silty, fine SAND, grey, bedded. Medium dense, dry to moist.		
	4.40 m		
	End Of Hole: 4.40 m		

LEGEND

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.0		2												
0.5			3											
1.0			3											
1.5			3											
2.0			3											
2.5			3											
3.0			3											
3.5			3											
4.0			3											
4.5			3											

SHEAR STRENGTH (kPa) Vane: 50, 100, 150, 200, Values

WATER: Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:21:14 am

TEST PIT LOG

HOLE NO.: TP13

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
COORDINATES: 1265951.0 mE, 4997874.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 23/10/2024
END DATE: 23/10/2024
LOGGED BY: JMJ
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Sandy organic SILT, trace rootlets, blackish brown. 0.40 m						
ALLUVIAL FAN DEPOSITS	Fine to medium SAND, with trace silt and organic inclusions, greyish brown. Loose, moist. 0.55 m		0.5				
	Sandy GRAVEL, trace silt and rootlets, greyish brown. Loose, moist. 0.90 m						
	SILT, with trace to minor sand, greyish brown. Firm, moist to wet, low plasticity, sand is fine. 2.10 m		1.0, 1.5, 2.0				
	Sandy fine to coarse GRAVEL, trace silt and cobbles, greyish brown. Medium dense, moist, dipping gently to 261°, gravels are subrounded. Sand is fine to coarse. 3.10 m		2.5, 3.0				
	SILT, with trace to minor sand, greyish brown. Firm, moist to wet, low plasticity, sand is fine. 3.50 m		3.5				
	Sandy fine to coarse GRAVEL, trace silt and cobbles, greyish brown. Medium dense, moist, dipping gently to 261°, gravels are subrounded. Sand is fine to coarse. 4.40 m		4.0				
	End Of Hole: 4.40 m		4.5				Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:21:18 am

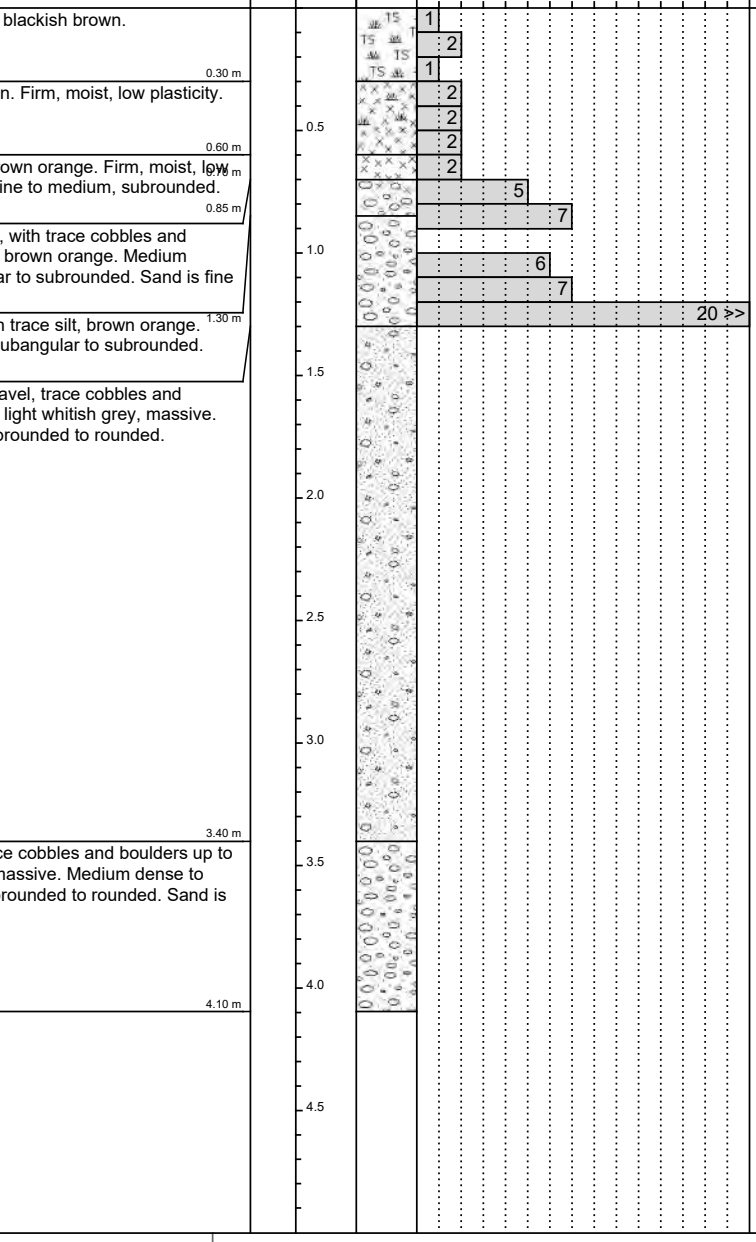
TEST PIT LOG

HOLE NO.: TP14

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 23/10/2024
COORDINATES: 1265945.0 mE, 4997695.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 23/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Sandy organic SILT, minor rootlets, blackish brown.		0.30 m
ALLUVIAL FAN DEPOSITS	Slightly organic SILT, blackish brown. Firm, moist, low plasticity.		0.60 m
	SILT, with trace sand and gravel, brown orange. Firm, moist, low plasticity, sand is fine. Gravels are fine to medium, subrounded.		0.85 m
	Sandy, silty fine to coarse GRAVEL, with trace cobbles and boulders up to 400 mm in diameter, brown orange. Medium dense, moist, gravels are subangular to subrounded. Sand is fine to coarse.		1.30 m
	Sandy, fine to coarse GRAVEL, with trace silt, brown orange. Medium dense, moist, gravels are subangular to subrounded. Sand is fine to coarse.		
GLACIAL TILL	Fine to coarse SAND, with minor gravel, trace cobbles and boulders up to 400 mm in diameter, light whitish grey, massive. Dense, dry to moist, gravels are subrounded to rounded.		3.40 m
OUTWASH DEPOSITS	Sandy, fine to coarse GRAVEL, trace cobbles and boulders up to 500 mm in diameter, orange grey, massive. Medium dense to dense, dry to moist, gravels are subrounded to rounded. Sand is fine to coarse.		4.10 m
	End Of Hole: 4.10 m		



PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:21:25 am

TEST PIT LOG

HOLE NO.: TP15

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 23/10/2024
COORDINATES: 1265934.0 mE, 4997527.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 23/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Sandy organic SILT, minor rootlets, blackish brown. 0.30 m		
ALLUVIAL FAN DEPOSITS	SILT, trace sand and organic inclusions, greyish brown. Firm, moist, low plasticity, sand is fine. 0.50 m		
	Sandy, silty, fine GRAVEL, brownish grey. Medium dense, moist, gravels are subangular to subrounded. Sand is fine to medium. 0.70 m		
	Silty, fine SAND, grey. Medium dense, moist. 0.80 m		
	Sandy, silty, fine GRAVEL, brownish grey. Medium dense, moist, gravels are subangular to subrounded. Sand is fine to medium.		
	Fine SAND, with minor silt, grey. Loose, wet, sand is fine. 1.30 m		
	Silty, fine SAND, grey. Medium dense, wet. 1.70 m		
	Fine to medium SAND, grey, bedded. Loose, wet. 2.00 m		
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL, with trace cobbles and boulders up to 400 mm in diameter, brown, bedded. Medium dense, moist, gravels are subrounded to rounded. Sand is fine to coarse. 4.40 m		
GLACIAL TILL	Fine to medium SAND, with minor gravel, whitish grey, massive. Dense, dry to moist, gravels are fine to coarse, rounded. 4.80 m		
	End Of Hole: 4.80 m		

LEGEND

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.0	1	1												
0.5			2	2	2	4	2	4	2					
1.0										1	3	2		
1.5												3	3	3
2.0														
2.5														
3.0														
3.5														
4.0														
4.5														

SHEAR STRENGTH (kPa) Vane: 50, 100, 150, 200 — Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:21:31 am

TEST PIT LOG

HOLE NO.: TP16

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
COORDINATES: 1265639.0 mE, 4997457.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 23/10/2024
END DATE: 23/10/2024
LOGGED BY: JMJ
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Sandy organic SILT, minor rootlets, brown. 0.25 m						
LOESS	Fine SAND, with trace silt, rootlets and organic inclusions, orange. Firm, moist. 0.40 m						
OUTWASH DEPOSITS	Sandy, fine to coarse GRAVEL, with trace cobbles and boulders up to 500 mm in diameter, orange, interbedded with sandy layers. Medium dense, moist, gravels are subrounded to rounded. Sand is fine to coarse.		0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5		1, 2, 2, 2, 9, 20 >>, 4, 6, 20 >>		Groundwater Not Encountered
	4.00 m End Of Hole: 4.00 m						

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:21:36 am

TEST PIT LOG

HOLE NO.: TP17

CLIENT: RCL Homestead Bay Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 23/10/2024

COORDINATES: 1265503.0 mE, 4997339.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 23/10/2024

LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ

ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND
TOPSOIL	Gravelly organic SILT, with trace sand and rootlets, brown. Dry to moist, gravels are fine to medium. 0.25 m			TS
OUTWASH DEPOSITS	Sandy, fine to coarse GRAVEL, trace rootlets, orange, bedded. Medium dense, dry to moist, gravels are subrounded. Sand is fine to coarse. 0.95 m		0.5	
	Sandy, fine to coarse GRAVEL, with trace cobbles and boulders up to 300 mm in diameter, grey and orange, bedded. Dense, dry to moist, gravels are subrounded. Sand is fine to coarse. 1.90 m		1.0 1.5	
	Fine to medium SAND, grey, bedded. Medium dense, moist. 2.20 m		2.0	
	Sandy, fine to coarse GRAVEL, with trace cobbles and boulders up to 150 mm in diameter, grey, bedded. Moist, gravels are subrounded. Sand is fine to coarse. 4.00 m		2.5 3.0 3.5 4.0	
	End Of Hole: 4.00 m		4.5	

SCALA PENETROMETER (Blows / 100 mm)

Depth	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.25 m						6								
							7							
								8						
								8						
									9					
0.95 m														20 >>
						6								
								8						
1.90 m														20 >>

SHEAR STRENGTH (kPa) Vane: 50 100 150 200 Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:21:43 am

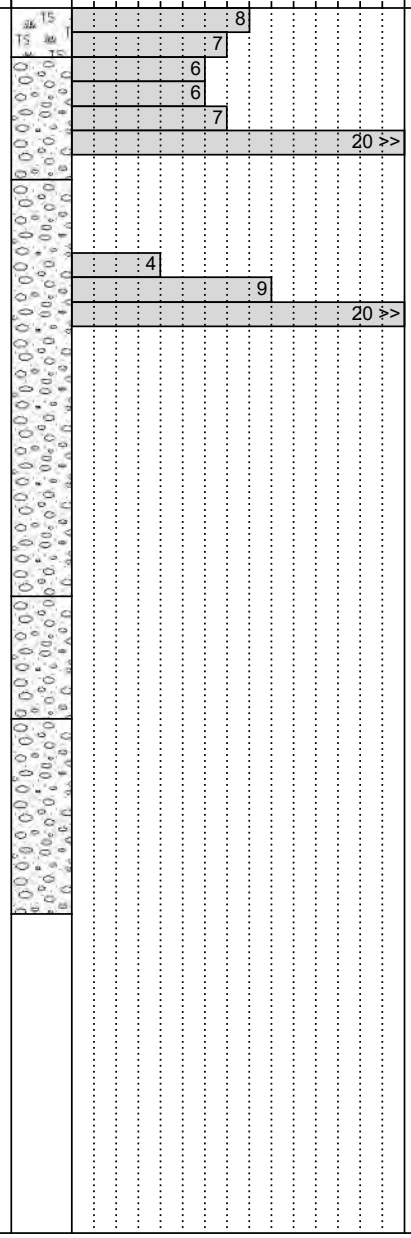
TEST PIT LOG

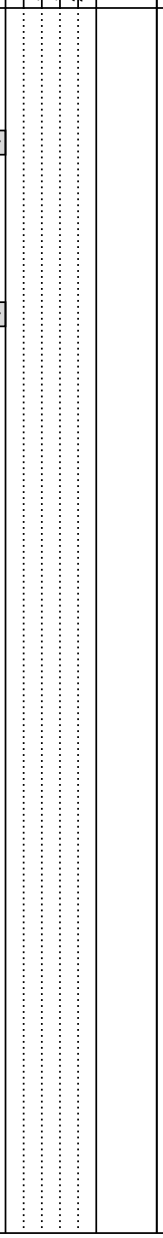
HOLE NO.: TP18

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 23/10/2024
COORDINATES: 1265426.0 mE, 4997339.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 23/10/2024
LOCATION METHOD: GIS\Web map viewer
ACCURACY: ± 5 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Gravelly organic SILT, with trace sand and rootlets, brown. Dry to moist, gravels are fine to medium. 0.20 m		
OUTWASH DEPOSITS	Sandy, fine to coarse GRAVEL, trace rootlets, orange, bedded. Medium dense, dry to moist, gravels are subrounded. Sand is fine to coarse. 0.70 m		
	Sandy, fine to coarse GRAVEL, with trace cobbles and boulders up to 300 mm in diameter, grey and orange, bedded. Dense, dry to moist, gravels are subrounded. Sand is fine to coarse. 2.40 m		
	Sandy, fine to coarse GRAVEL, grey, bedded. Dense, dry to moist, sand is fine to coarse. 2.90 m		
	Sandy, fine to coarse GRAVEL, with trace cobbles and boulders up to 300 mm in diameter, grey and orange, bedded. Dense, dry to moist, gravels are subrounded. Sand is fine to coarse. 3.70 m		
	End Of Hole: 3.70 m		





WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:21:51 am

TEST PIT LOG

HOLE NO.: TP19

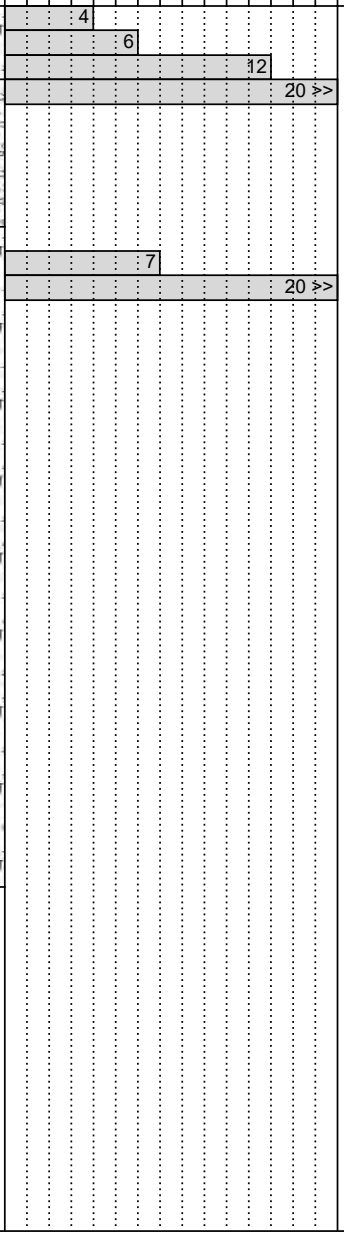
CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 24/10/2024
COORDINATES: 1265305.0 mE, 4997565.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 24/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Gravelly organic SILT, with trace rootlets, blackish brown. Moist. 0.30 m		
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL, trace rootlets within the top 200 mm, with trace cobbles and boulders up to 300 mm in diameter, orange, bedded. Medium dense, dry to moist, gravels are subangular to subrounded. Sand is fine to coarse. 0.90 m		
	Sandy fine to coarse GRAVEL, interbedded with sand, with trace cobbles and boulders up to 200 mm in diameter, grey and orange, bedded. Medium dense, dry to moist, gravels are subangular to subrounded. Sand is fine to coarse. 3.60 m		
	End Of Hole: 3.60 m		

LEGEND

SCALA PENETROMETER (Blows / 100 mm)



SHEAR STRENGTH (kPa) Vane: 50 100 150 200 Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls stable, remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:21:56 am

TEST PIT LOG

HOLE NO.: TP20

CLIENT: RCL Homestead Bay Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 24/10/2024

COORDINATES: 1265503.0 mE, 4997570.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 24/10/2024

LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ

ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Gravelly organic SILT, with trace rootlets, blackish brown. Moist. 0.30 m			TS	1, 2		
LOESS	Sandy SILT with a trace of gravel and organics, brownish/orange. Low plasticity, moist, sand, fine; gravel, fine to medium, subrounded. 0.60 m		0.5		5, 5, 12, 20 >>		
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL with a trace of silt, brownish/orange. Medium dense, moist, gravel, subrounded; sand, fine to coarse. 0.80 m						
	Gravelly fine to coarse SAND with a trace of silt and cobbles, grey. Dense, moist, sand, mostly fine to medium; gravel, fine to coarse, rounded to subrounded. 1.20 m		1.0		20 >>		
	Sandy fine to coarse GRAVEL with trace cobbles and boulders, grey, interbedded sandy layers. Medium dense, moist, bedded, gravel, subrounded; sand, fine to coarse. 4.20 m		1.5, 2.0, 2.5, 3.0, 3.5, 4.0				Groundwater Not Encountered
	End Of Hole: 4.20 m		4.5				

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:22:02 am

TEST PIT LOG

HOLE NO.: TP21

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 24/10/2024
COORDINATES: 1265451.0 mE, 4997699.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 24/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Gravelly organic SILT, with trace rootlets, blackish brown. Moist. 0.20 m		0.5		1, 2, 5, 4, 6, 12, 20 >>		Groundwater Not Encountered
LOESS	Sandy SILT with a trace of gravel and organics, brownish/orange. Low plasticity, moist, sand, fine. Gravel, fine to medium, subrounded. 0.70 m						
GLACIAL TILL	Gravelly fine to coarse SAND with a trace of silt and cobbles, grey. Dense, moist, sand, mostly fine to medium. Gravel, fine to coarse, rounded to surrounded. Boulders up to 200 mm. 1.00 m		1.0		20 >>		
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL with trace cobbles and boulders, grey, interbedded sandy layers. Medium dense, moist, bedded, gravel, subrounded. Sand, fine to coarse. 4.20 m		1.5, 2.0, 2.5, 3.0, 3.5, 4.0				
	End Of Hole: 4.20 m		4.5				

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:22:08 am

TEST PIT LOG

HOLE NO.: TP22

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 24/10/2024
COORDINATES: 1265527.0 mE, 4994805.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 24/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Sandy organic SILT with a trace rootlets, dark brown. Moist. 0.30 m			TS	1		
COLLUVIUM	Sandy fine to coarse GRAVEL with minor silt and a trace of rootlets and organics, orange. Medium dense, moist, chaotic, gravel, subrounded. Sand, fine to medium. 0.70 m		0.5	TS	2, 3, 3		
GLACIAL POND SEDIMENT	Fine SAND, light orange, interbedded 200 mm with silty sand beds. Medium dense, moist to wet. 1.60 m		1.0		4, 4, 5, 4, 6, 20 >>		
OUTWASH DEPOSITS	Fine to medium SAND with some gravel and a trace of silt, grey. Dense, moist, bedded, gravel, fine to medium, subrounded to rounded. 2.60 m		1.5				
	Sandy fine to coarse GRAVEL with a trace of cobbles, dark grey. Medium dense, moist, bedded, gravel, rounded to subrounded. Sand, medium to coarse. 3.40 m		2.0				
	Gravelly coarse SAND, grey. Medium dense, wet, bedded, gravel, fine to coarse, rounded to subrounded. 4.40 m		2.5				
	End Of Hole: 4.40 m		3.0				
			3.5				
			4.0				
			4.5				

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:22:12 am

TEST PIT LOG

HOLE NO.: TP23

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 24/10/2024
COORDINATES: 1265281.0 mE, 4997801.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 24/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Sandy organic SILT with a trace rootlets, dark brown. Moist, strong organic odour.		0.35 m
GLACIAL POND SEDIMENT	Silty fine SAND with a trace of gravel, grey. Medium dense to dense, wet, minor laminations, gravel, fine to medium, subrounded.		2.00 m
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL with a trace of silt, cobbles and boulders, orange/grey. Medium dense, moist, bedded, gravel, subrounded to rounded. Sand, fine to coarse; boulders up to 250 mm.		4.40 m
	End Of Hole: 4.40 m		

LEGEND

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.5	1	2	3	3	3							12	15	15
1.0						6					11	12	20 >>	
1.5														
2.0														
2.5														
3.0														
3.5														
4.0														
4.5														

SHEAR STRENGTH (kPa) Vane: 50, 100, 150, 200 — Values

WATER: Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:22:17 am

TEST PIT LOG

HOLE NO.: TP24

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
COORDINATES: 1265315.0 mE, 4997901.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 25/10/2024
END DATE: 25/10/2024
LOGGED BY: JMJ
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND
TOPSOIL	Sandy organic SILT with trace of rootlets, dark brown. Dry to moist, sand, fine. 0.20 m			
LOESS	Silty fine SAND with a trace of roots and organics, orange. Wet. 0.60 m			
GLACIAL TILL	Fine to medium SAND with minor silt and gravel with a trace of cobbles, grey/orange banding, interbedded siltier layers. Medium dense, moist, gravel, fine to coarse, subrounded. 1.90 m			
	Sandy SILT, light grey. Hard, dry, sand, fine. 2.40 m			
	Fine to coarse SAND with minor silt and gravel with a trace of cobbles and boulders, grey, interbedded siltier layers. Medium dense, moist, gravel, fine to coarse, subrounded. Boulders up to 750 mm diameter. 4.00 m			
	End Of Hole: 4.00 m			

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	Blows / 100 mm
0.0 – 0.1	1
0.1 – 0.2	2
0.2 – 0.3	1
0.3 – 0.4	2
0.4 – 0.5	3
0.5 – 0.6	3
0.6 – 0.7	4
0.7 – 0.8	7
0.8 – 0.9	7
0.9 – 1.0	6
1.0 – 1.1	9
1.1 – 1.2	13
1.2 – 1.3	20 >>

SHEAR STRENGTH (kPa) Vane: Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:22:21 am

TEST PIT LOG

HOLE NO.: TP25

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 25/10/2024
COORDINATES: 1265193.0 mE, 4997945.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 25/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)
TOPSOIL	Sandy organic SILT with minor gravel and trace rootlets, brown. Wet, sand, fine; gravel, fine to coarse, subrounded to subangular. 0.20 m
COLLUVIUM	Fine to coarse SAND with minor gravel and a trace of silt and organics, grey/orange. Medium dense, moist, chaotic, gravel, fine to coarse, surrounded. 0.6 m: two 20 mm thick brown beds near basal contact. 0.70 m
GLACIAL TILL	Fine to coarse SAND with minor gravel and a trace of cobbles and silt, grey with orange streaks. Medium dense, dry to moist, sand, mostly fine to medium; gravel, fine to coarse, subrounded to rounded. 1.80 m
	Gravelly fine to coarse SAND with a trace of silt and cobbles, grey/brown, interbedded siltier layers. Dense, dry to moist, gravel, fine to coarse, subrounded to rounded. Boulders up to 200 mm diameter. 4.20 m
	End Of Hole: 4.20 m

SAMPLES | DEPTH / RL | LEGEND

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	Blows / 100 mm
0.2 – 0.5	2, 3, 3, 4, 20 >>
0.7 – 1.0	4, 5, 7, 14, 20 >>

SHEAR STRENGTH (kPa) Vane: 50, 100, 150, 200 — Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:22:27 am

TEST PIT LOG

HOLE NO.: TP26

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
COORDINATES: 1265437.0 mE, 4998029.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 25/10/2024
END DATE: 25/10/2024
LOGGED BY: JMJ
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND
TOPSOIL	Sandy organic SILT with trace rootlets, brown. Moist, sand, fine. 0.30 m			TS
COLLUVIUM	Silty fine SAND with a trace of gravel and organics, orange. Loose to medium dense, moist, chaotic.			
GLACIAL TILL	Fine to coarse SAND with a trace of silt, gravel, cobbles and boulders, grey with orange banding. Medium dense, moist to wet, gravel, fine to coarse, rounded to subrounded. Boulders up to 400 mm diameter. 1.20 m		0.5, 1.0	
	Fine to coarse SAND with a trace of silt, gravel, cobbles and boulders, light grey, interbedded siltier layers. Medium dense, moist to wet, gravel, fine to coarse, rounded to subrounded. Boulders up to 400 mm diameter. 2.40 m		1.5, 2.0	
	Gravelly fine to coarse SAND with a trace of silt, cobbles and boulders, grey. Dense, moist to wet, gravel, fine to coarse, rounded to subrounded. Boulders up to 400 mm diameter. 3.90 m		2.5, 3.0, 3.5	
	End Of Hole: 3.90 m		4.0, 4.5	

SCALA PENETROMETER (Blows / 100 mm)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
2	2	3	4	4	6	8	9	9					
4	9	14	20 >>										

SHEAR STRENGTH (kPa) Vane:

50	100	150	200	Values

WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:22:32 am

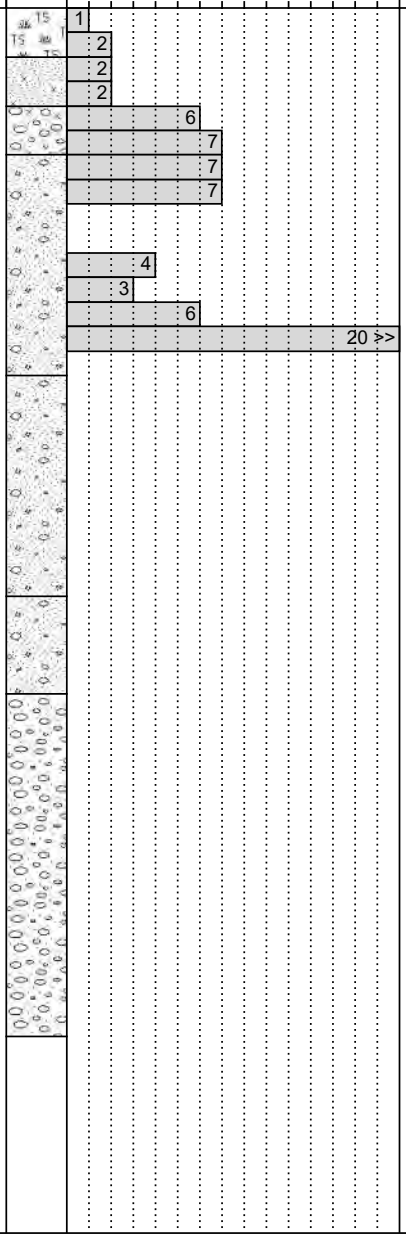
TEST PIT LOG

HOLE NO.: TP27

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 25/10/2024
COORDINATES: 1265322.0 mE, 4998132.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 25/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Sandy organic SILT with trace of rootlets, dark brown. Dry to moist, sand, fine. 0.20 m		
LOESS	Silty fine SAND with a trace of rootlets and organics, orange. Loose to medium dense, moist to wet. 0.40 m		
COLLUVIUM	Sandy fine to coarse GRAVEL with minor silt and trace organics, orange/grey. Medium dense, moist to wet, chaotic, gravel, fine to coarse, subrounded; sand, fine to coarse. 0.60 m		
OUTWASH DEPOSITS	Gravelly fine to coarse SAND with a trace of silt, cobbles and boulders, grey/orange, interbedded siltier layers. Medium dense to dense, moist to wet, gravel, fine to coarse, subrounded. Boulders up to 250 mm diameter. 1.50 m		
	Gravelly fine to coarse SAND with a trace of silt, cobbles and boulders, orange/grey, interbedded siltier layers. Dense, moist, gravel, fine to coarse, subrounded. Boulders up to 400 mm diameter. 2.40 m		
	Gravelly SAND with a trace of silt, cobbles and boulders, grey. Dense, moist to wet, gravel, fine to coarse, subrounded Boulders up to 400 mm diameter. 2.80 m		
	Sandy fine to coarse GRAVEL with a trace of cobbles and boulders, grey/brown. Medium dense, moist, bedded, gravel, fine to coarse, subrounded. Boulders up to 300 mm. 4.20 m		
	End Of Hole: 4.20 m		



SHEAR STRENGTH (kPa)
Vane: 50 100 150 200 Values

WATER
Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Pit walls collapsing from 2.8 m. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:22:36 am

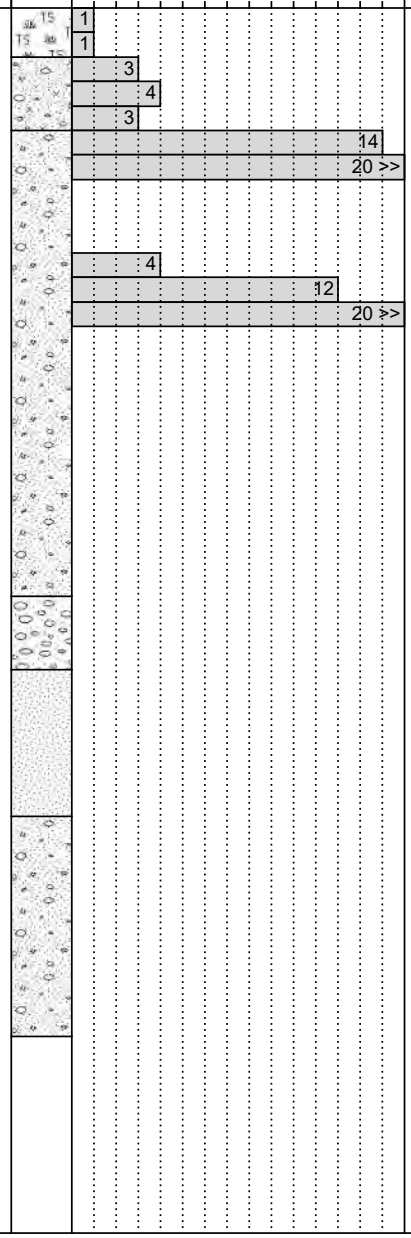
TEST PIT LOG

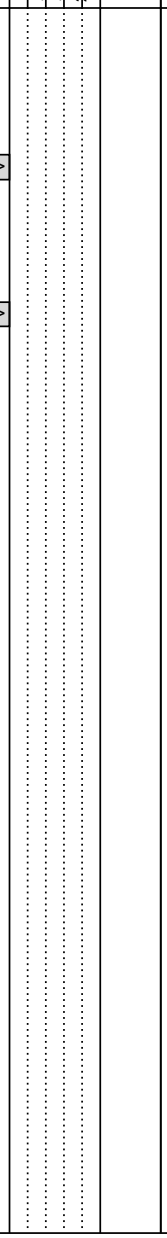
HOLE NO.: TP28

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 25/10/2024
COORDINATES: 1265098.0 mE, 4998124.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 25/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Sandy organic SILT with trace of rootlets, dark brown. Dry to moist, sand, fine. 0.20 m		
COLLUVIUM	Fine to coarse SAND with minor gravel and silt with a trace of organics, orange. Medium dense, moist to wet, chaotic, gravel, fine to coarse, subrounded. 0.50 m		
OUTWASH DEPOSITS	Fine to coarse SAND with minor gravel and a trace of silt, cobbles and boulders, orange/grey. Dense, moist, gravel, fine to coarse, subrounded. Boulders up to 400 mm. 2.40 m		
	Sandy fine to coarse GRAVEL with a trace of cobbles and boulders, grey. Medium dense, moist, bedded, sand, fine to coarse; gravel, subrounded. Boulders up to 250 mm. 2.70 m		
GLACIAL TILL	Fine SAND, grey. Medium dense, dry to moist. 3.30 m		
	Fine to coarse SAND with minor gravel and a trace of silt, cobbles and boulders, orange/grey. Dense, moist, gravel, fine to coarse, subrounded. Boulders up to 400 mm. 4.20 m		
	End Of Hole: 4.20 m		





WATER

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:22:40 am

TEST PIT LOG

HOLE NO.: TP29

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 25/10/2024
COORDINATES:
EQUIPMENT: 13T
END DATE: 25/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)
TOPSOIL	Organic SILT with a trace of rootlets, dark brown. Moist. 0.30 m
LOESS	Silty fine SAND with a trace of organics, orange. Loose to medium dense, moist to wet. 0.50 m
COLLUVIUM	Gravelly fine to medium SAND with minor to trace silt and a trace of cobbles, orange. Loose to medium dense, moist, chaotic, gravel, fine to coarse, subrounded to rounded. 1.00 m
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL with trace cobbles, orange and grey, interbedded sandy gravels and fine sands. Medium dense, moist, bedded, gravel, subrounded to rounded; sand, fine to coarse. 1.40 m
	Gravelly fine to coarse SAND with trace cobbles, dark grey. Dense, moist, bedded, gravel, rounded to subrounded; sand, medium to coarse. 4.20 m
	End Of Hole: 4.20 m

SAMPLES | DEPTH / RL | LEGEND | SCALA PENETROMETER (Blows / 100 mm) | SHEAR STRENGTH (kPa) Vane: Values | WATER

SCALA PENETROMETER (Blows / 100 mm): 1 1 1 | 2 2 | 2 | 3 | 4 | 5 | 6 | 20 >>

SHEAR STRENGTH (kPa) Vane: 50 100 150 200 Values

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:22:44 am

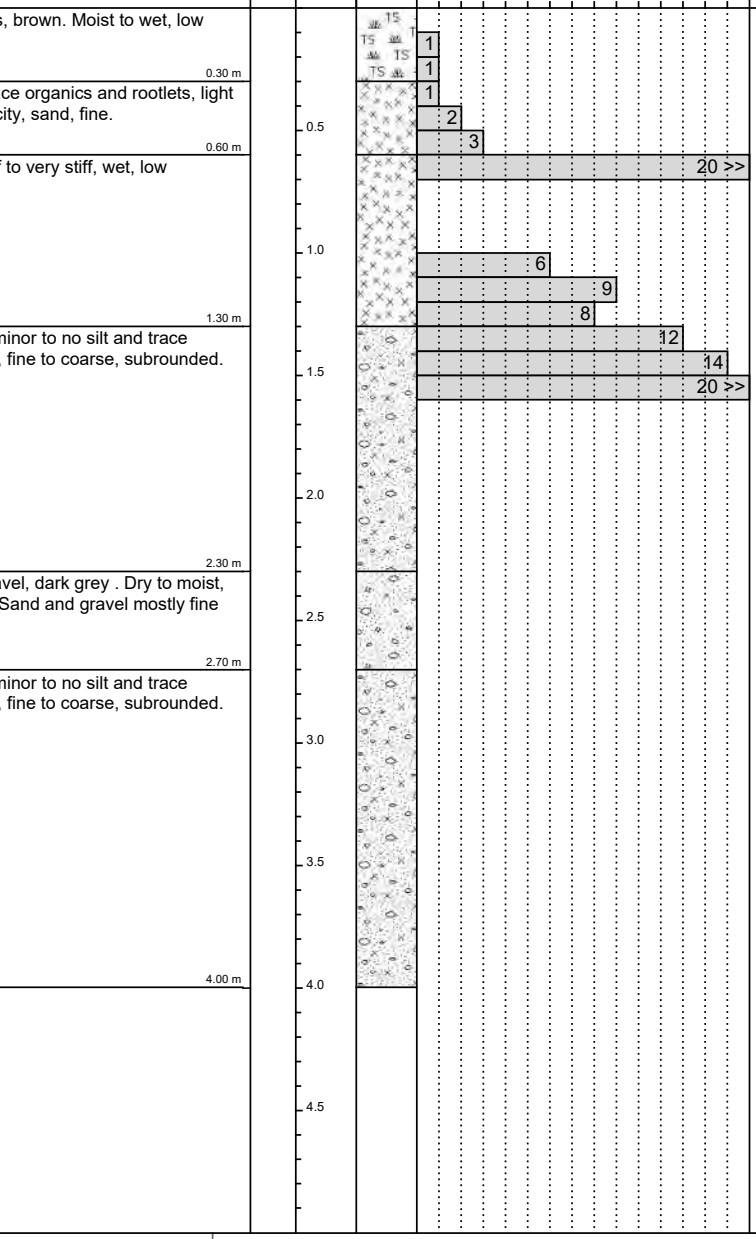
TEST PIT LOG

HOLE NO.: TP30

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 25/10/2024
COORDINATES: 1265294.0 mE, 4998366.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 25/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic SILT with a trace of rootlets, brown. Moist to wet, low plasticity. 0.30 m		
WEATHERED GLACIAL TILL	SILT with minor to trace of sand, trace organics and rootlets, light orange/brown. Firm, wet, low plasticity, sand, fine. 0.60 m		
GLACIAL TILL	SILT, grey with orange streaks. Stiff to very stiff, wet, low plasticity. 1.30 m		
	Gravelly fine to coarse SAND with minor to no silt and trace cobbles, grey. Dense, moist, gravel, fine to coarse, subrounded. 2.30 m		
	Fine to coarse SAND with some gravel, dark grey . Dry to moist, gravel, fine to coarse, subrounded. Sand and gravel mostly fine to medium, trace coarse. 2.70 m		
	Gravelly fine to coarse SAND with minor to no silt and trace cobbles, grey. Dense, moist, gravel, fine to coarse, subrounded. 4.00 m		
	End Of Hole: 4.00 m		



SHEAR STRENGTH (kPa)
Vane: 50 100 150 200 Values

WATER
Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:22:50 am

TEST PIT LOG

HOLE NO.: TP31

CLIENT: RCL Homestead Bay Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

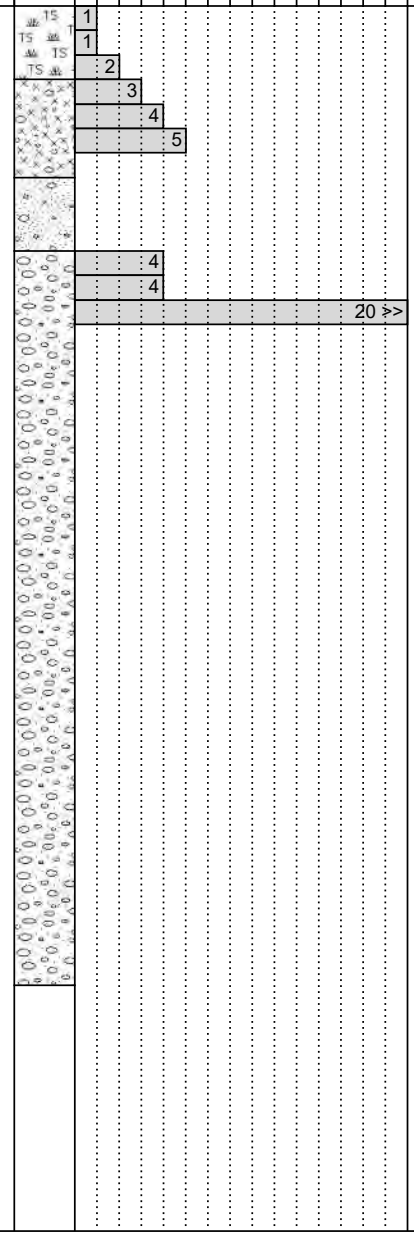
SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 25/10/2024

COORDINATES: 1265025.0 mE, 4998362.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 25/10/2024

LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ

ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic SILT with trace rootlets, brown. Moist, low plasticity. 0.30 m		
COLLUVIUM	Sandy SILT with minor gravel and trace organics, orange. Firm, moist, low plasticity, sand, fine to coarse, mostly fine. Gravel, fine to coarse, subrounded. 0.70 m		
OUTWASH DEPOSITS	Fine to coarse SAND with some gravel and a trace of silt and cobbles, grey. Dense, moist, gravel, fine to coarse, subrounded. Sand is mostly fine. 1.00 m Sandy fine to coarse GRAVEL with a trace of cobbles and boulders, dark grey. Dense, moist, bedded, gravel, subrounded to rounded; sand, fine to coarse, mostly medium to coarse. Boulders up to 250 mm in diameter. 4.00 m		
	End Of Hole: 4.00 m		



PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:22:56 am

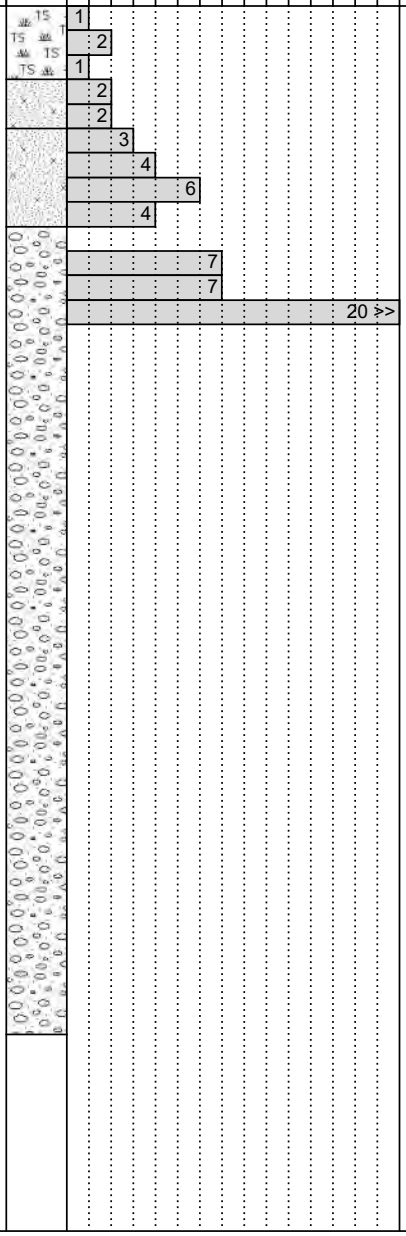
TEST PIT LOG

HOLE NO.: TP32

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 25/10/2024
COORDINATES: 1264932.0 mE, 4998640.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 25/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic SILT with trace rootlets, dark brown. Wet. 0.30 m		
LOESS	Silty fine SAND with trace organics, orange. Loose, wet. 0.50 m		
COLLUVIUM	Gravely fine SAND with minor silt and trace cobbles, orange/brown orange. Medium dense, wet, chaotic, gravel fine to coarse, subrounded to rounded. 0.90 m		
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL with trace cobbles and boulders, orange/grey becoming grey. Dense, moist, bedded, gravel, subrounded to rounded. Sand, fine to coarse, mostly medium to coarse. Boulders up to 250 mm diameter. 4.20 m		
	End Of Hole: 4.20 m		



SHEAR STRENGTH (kPa)
Vane: 50 100 150 200 Values

WATER
Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:23:02 am

TEST PIT LOG

HOLE NO.: TP33

CLIENT: RCL Homestead Bay Ltd

PROJECT: Homestead Bay Geotechnical

JOB NO.: 220556.01

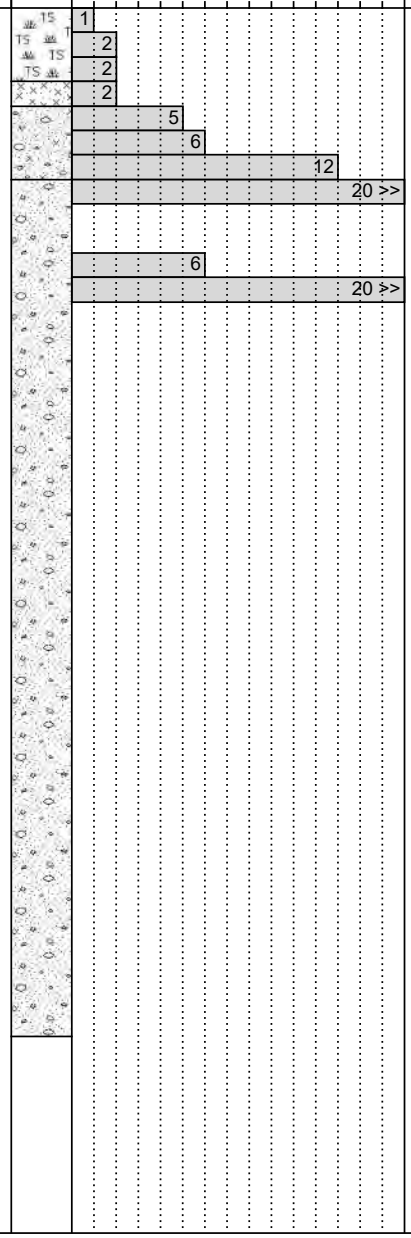
SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 25/10/2024

COORDINATES: 1265108.0 mE, 4998567.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 25/10/2024

LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ

ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic SILT with trace rootlets, dark brown. Moist.		
	0.30 m		
LOESS	Sandy SILT with a trace of gravel and organics, orange. Firm, moist, low plasticity, sand, fine; gravel, fine to coarse, subrounded. 0.40 m		
COLLUVIUM	Gravelly fine to carse SAND with minor silt, orange. Medium dense, moist, gravel, fine to coarse, subrounded to rounded. 0.70 m		
GLACIAL TILL	Gravelly fine to coarse SAND with trace silt and cobbles, orange/grey, beds of medium to coarse sand. Dense, moist, sand, rarely coarse; gravel, fine to coarse, subrounded to rounded.		
	4.20 m		
	End Of Hole: 4.20 m		



PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:23:06 am

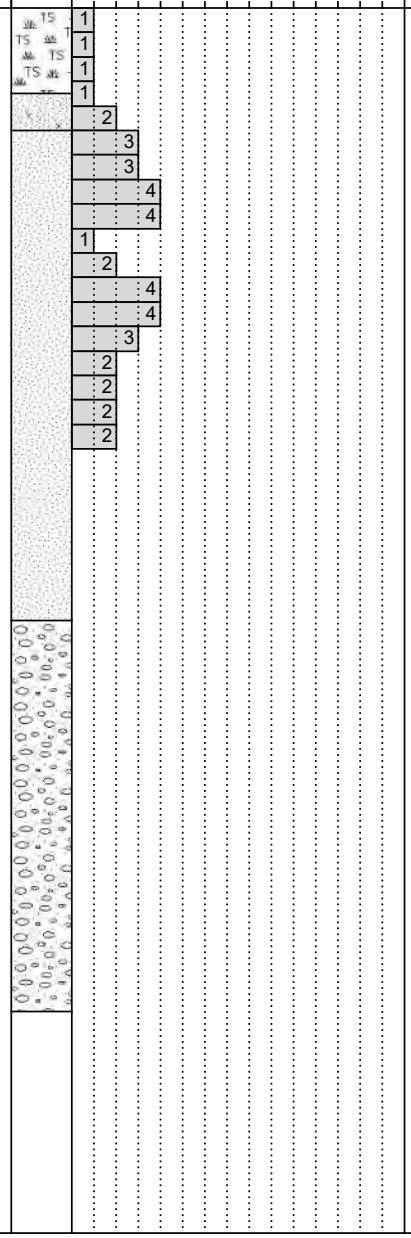
TEST PIT LOG

HOLE NO.: TP34

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 29/10/2024
COORDINATES: 1264674.0 mE, 4999141.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 29/10/2024
LOCATION METHOD: GIS\Web map viewer
ACCURACY: ± 5 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic SILT with minor sand and gravel with a trace of rootlets, dark brown. Wet, sand, fine to medium; gravel, fine to coarse, subrounded to rounded. 0.35 m		
LOESS	Fine SAND with minor silt and a trace of gravel and organic inclusions, orange, dipping towards 094°. Loose to medium dense, moist. 0.50 m		
ALLUVIAL FAN DEPOSITS	Fine SAND with trace rootlets, grey/orange becoming grey. Loose, moist. 2.50 m		
	Sandy fine to coarse GRAVEL with trace cobbles, grey/orange. Medium dense, moist, bedded, gravel, subrounded; sand, fine to coarse. 4.10 m		
	End Of Hole: 4.10 m		



PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:23:11 am

TEST PIT LOG

HOLE NO.: TP35

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
COORDINATES: 1264800.0 mE, 4998955.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 29/10/2024
END DATE: 29/10/2024
LOGGED BY: JMJ
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic SILT with minor roots and rootlets, dark brown. Wet. 0.20 m						
ALLUVIAL FAN DEPOSITS	SILT with a trace rootlets in upper 400 mm, brownish grey. Firm, moist, low plasticity. 1.50 m						
	Sandy fine to coarse GRAVEL, brownish grey. Medium dense, wet, gravel, subrounded; sand, fine to coarse, mostly medium to coarse. 3.80 m						
	End Of Hole: 3.80 m						

Scala penetrometer blows (1 2 3 4 5 6 7 8 9 10 11 12 13 14): 1, 2, 2, 1, 2, 2, 1, 1, 1, 1, 2, 2, 2, 2, 9, 20 >>

Shear strength (kPa) Vane: 50 100 150 200

Depth / RL: 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5

Groundwater Not Encountered

PHOTO(S)

REMARKS

End of test, test pit walls collapsing. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:23:15 am

TEST PIT LOG

HOLE NO.: TP36

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 29/10/2024
COORDINATES: 1264854.0 mE, 4998761.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 29/10/2024
LOCATION METHOD: GIS\Web map viewer
ACCURACY: ± 5 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic SILT with minor rootlets, black. Wet.		
	0.35 m		
UNCONTROLLED FILL	Sandy fine to medium GRAVEL with a trace of silt, brown/grey, rootlets in upper 300 mm. Medium dense, wet, uniform, gravel, subangular; sand, fine to coarse, mostly medium to coarse.		
	1.30 m		
ALLUVIAL FAN DEPOSITS	Sandy fine to coarse GRAVEL, grey/orange, interbedded sandier layers increasing near basal contact. Dense, wet, bedded, gravel, subrounded; sand, fine to coarse.		
	2.20 m		
	Fine SAND with a trace of silt and rootlets, grey. Medium dense, moist.		
	4.40 m		
	End Of Hole: 4.40 m		

LEGEND

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	Blows / 100 mm
0.0 – 0.1	1
0.1 – 0.2	2
0.2 – 0.3	1
0.3 – 0.4	3
0.4 – 0.5	4
0.5 – 0.6	4
0.6 – 0.7	4
0.7 – 0.8	4
0.8 – 0.9	4
0.9 – 1.0	4
1.0 – 1.1	5
1.1 – 1.2	8
1.2 – 1.3	14
1.3 – 1.4	20 >>

SHEAR STRENGTH (kPa) Vane: Values

WATER: Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:23:20 am

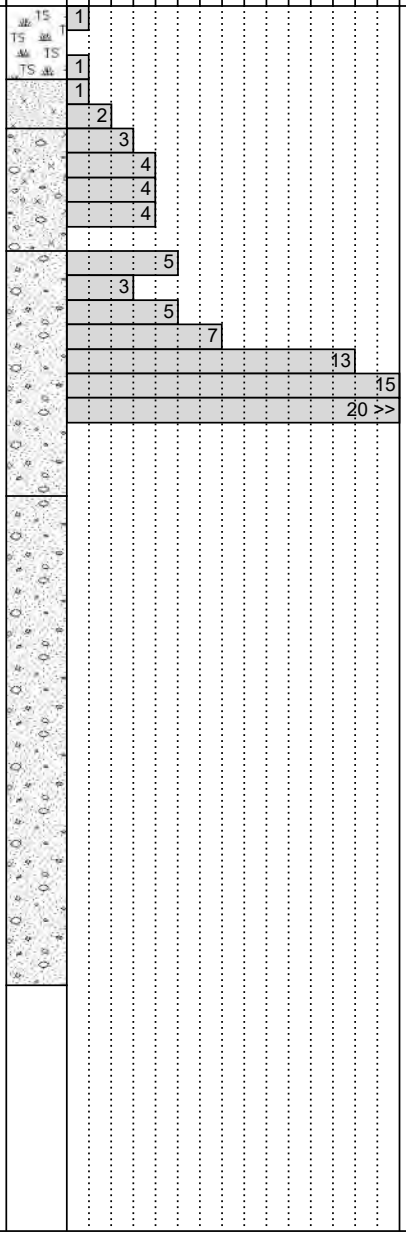
TEST PIT LOG

HOLE NO.: TP37

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 29/10/2024
COORDINATES: 1265285.0 mE, 4998628.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 29/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic SILT with a trace of rootlets, dark brown. Wet. 0.30 m		
LOESS	Fine SAND with minor silt and a trace of organics, orange/brown. Loose, wet. 0.50 m		
COLLUVIUM	Gravelly fine SAND with minor silt, orange/brown. Medium dense, wet, gravel, fine to medium, subrounded to subangular. 1.00 m		
GLACIAL TILL	Fine to medium SAND with some gravel and a trace of silt, orange/grey. Medium dense, moist, gravel, fine to coarse, mostly fine to medium, subrounded. 2.00 m		
	Fine to medium SAND with some gravel and a trace of silt and cobbles/boulders, orange/grey. Dense, moist, gravel, fine to coarse, mostly fine to medium, subrounded. Boulders up to 300 mm diameter, subrounded. 4.00 m		
	End Of Hole: 4.00 m		



PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:23:25 am

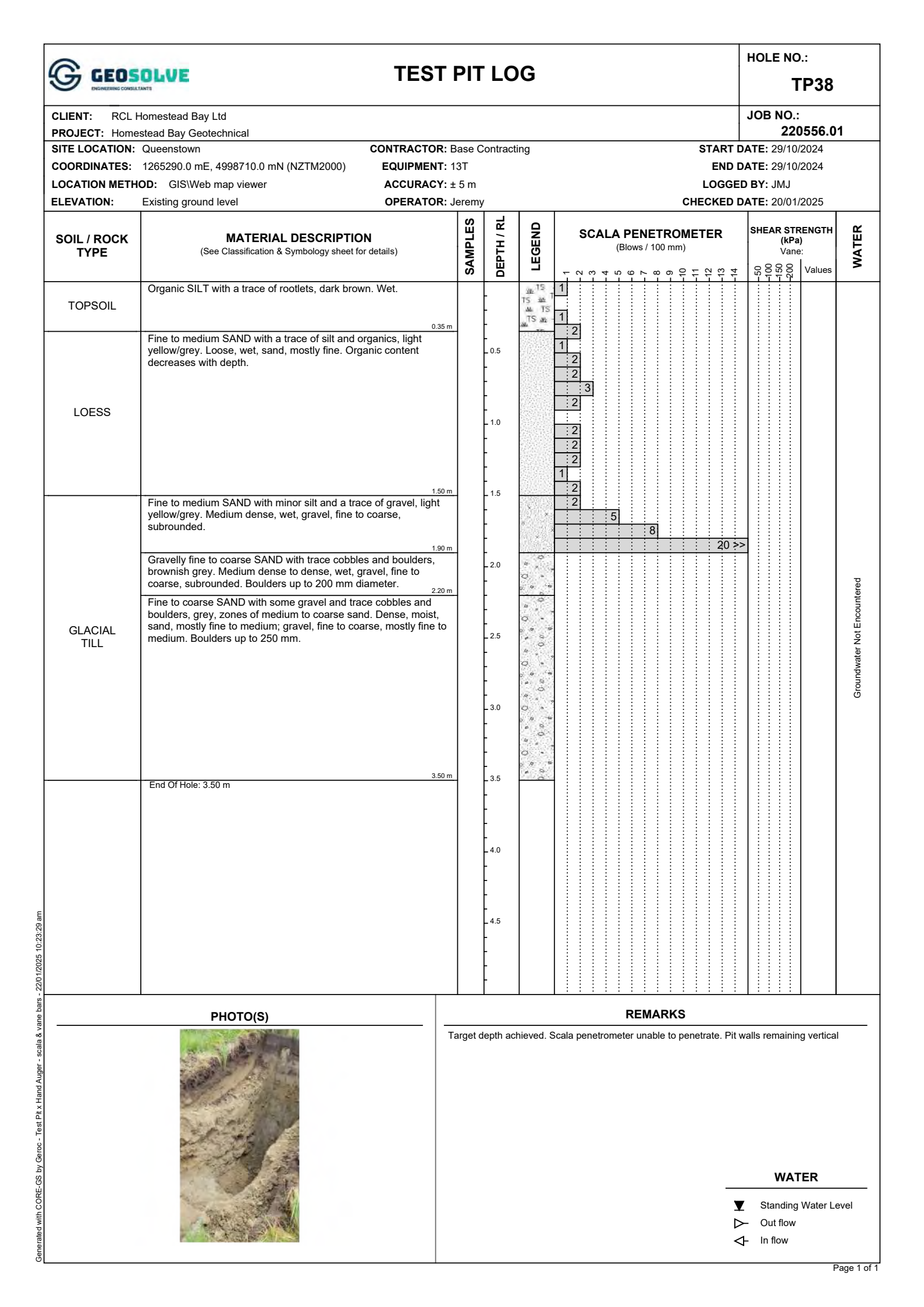
TEST PIT LOG

HOLE NO.: TP38

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 29/10/2024
COORDINATES: 1265290.0 mE, 4998710.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 29/10/2024
LOCATION METHOD: GIS\Web map viewer
ACCURACY: ± 5 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic SILT with a trace of rootlets, dark brown. Wet. 0.35 m						
LOESS	Fine to medium SAND with a trace of silt and organics, light yellow/grey. Loose, wet, sand, mostly fine. Organic content decreases with depth. 1.50 m						
GLACIAL TILL	Fine to medium SAND with minor silt and a trace of gravel, light yellow/grey. Medium dense, wet, gravel, fine to coarse, subrounded. 1.90 m						
	Gravelly fine to coarse SAND with trace cobbles and boulders, brownish grey. Medium dense to dense, wet, gravel, fine to coarse, subrounded. Boulders up to 200 mm diameter. 2.20 m						
	Fine to coarse SAND with some gravel and trace cobbles and boulders, grey, zones of medium to coarse sand. Dense, moist, sand, mostly fine to medium; gravel, fine to coarse, mostly fine to medium. Boulders up to 250 mm. 3.50 m						
	End Of Hole: 3.50 m						



PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:23:29 am

TEST PIT LOG

HOLE NO.: TP39

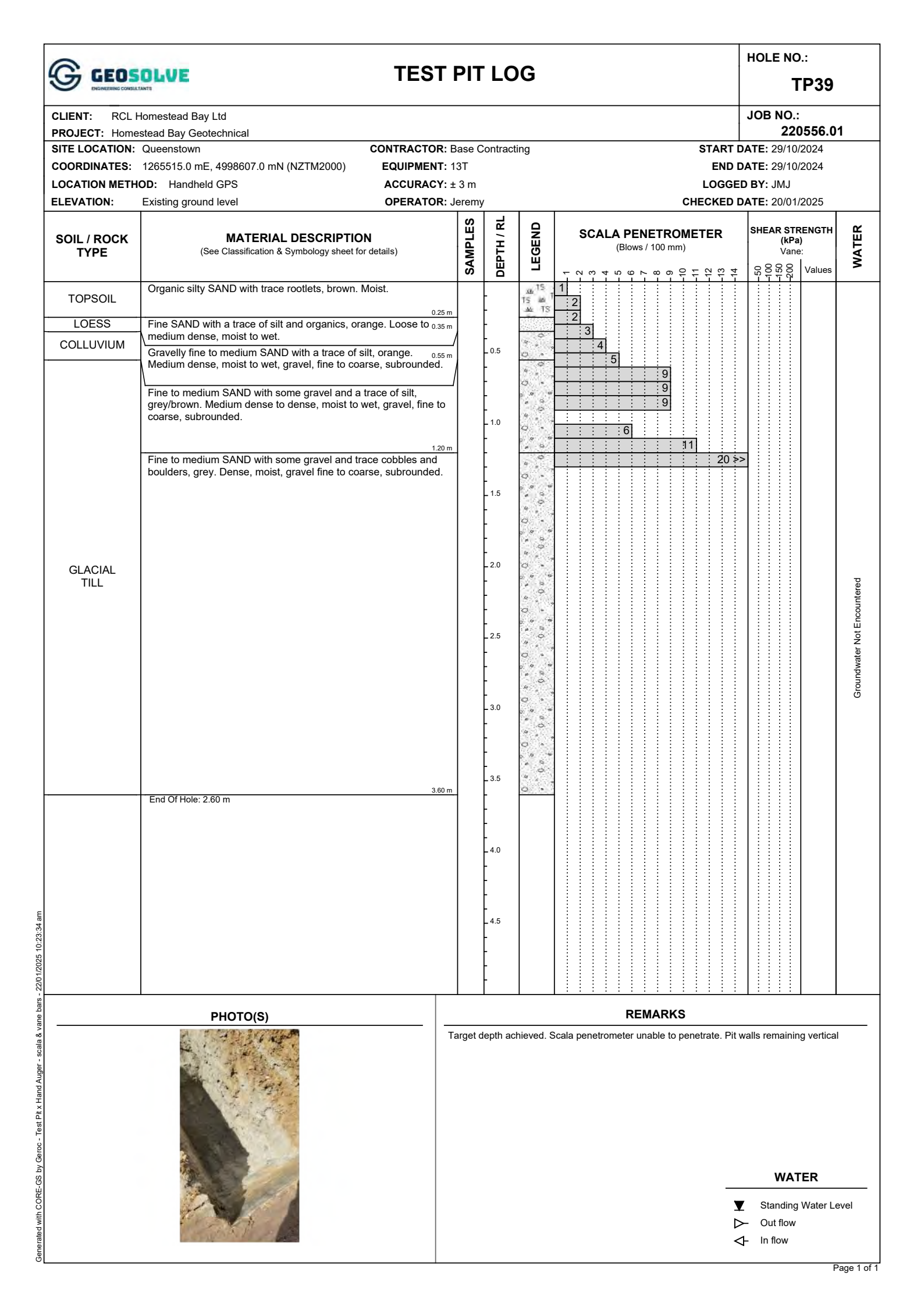
CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
COORDINATES: 1265515.0 mE, 4998607.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 29/10/2024
END DATE: 29/10/2024
LOGGED BY: JMJ
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic silty SAND with trace rootlets, brown. Moist. 0.25 m						
LOESS / COLLUVIUM	Fine SAND with a trace of silt and organics, orange. Loose to medium dense, moist to wet. 0.35 m						
	Gravelly fine to medium SAND with a trace of silt, orange. Medium dense, moist to wet, gravel, fine to coarse, subrounded. 0.55 m						
GLACIAL TILL	Fine to medium SAND with some gravel and a trace of silt, grey/brown. Medium dense to dense, moist to wet, gravel, fine to coarse, subrounded. 1.20 m						
	Fine to medium SAND with some gravel and trace cobbles and boulders, grey. Dense, moist, gravel fine to coarse, subrounded. 3.60 m						
	End Of Hole: 2.60 m						



Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Scala penetrometer unable to penetrate. Pit walls remaining vertical

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:23:34 am

TEST PIT LOG

HOLE NO.: TP40

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
COORDINATES: 12659656.0 mE, 4998600.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 29/10/2024
END DATE: 29/10/2024
LOGGED BY: JMJ
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic SILT with trace rootlets, black. Wet. 0.15 m		
ALLUVIAL FAN DEPOSITS	SILT with minor to trace sand, blackish/brown. Firm, wet, sand, fine. Moderately sensitive . 0.55 m		
	Silty fine SAND and sandy SILT, dark brown/grey. Firm, wet. Saturated from 0.9 m, well interbedded with discontinuous gravelly beds, sand, fine. Moderately sensitive silts . 1.40 m		
	Silty fine to coarse GRAVEL with minor sand, dark brown/grey. Saturated , sand, fine to medium. 1.60 m		
	Silty fine SAND and andy SILT, dark brown/grey. Firm, saturated, interbedded with discontinuous gravelly beds, sand, fine. Moderately sensitive silts. 2.70 m		
	End Of Hole: 2.70 m		

LEGEND

SCALA PENETROMETER (Blows / 100 mm)

Depth (m)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.0	1													
0.5	1	1	2	2										
1.0	1	1	2											
1.5	1	1	2	3	2	3								
2.0	1	1	1											
2.5														
3.0														
3.5														
4.0														
4.5														

SHEAR STRENGTH (kPa) Vane: 50, 100, 150, 200 — Values

WATER: 29/10/2024

PHOTO(S)

REMARKS

End of test, test pit walls collapsing. Seepages through out the pit walls, some with high outflow. Water level remaining at 1.3 m bgl, 15 minutes after completion of test pit excavation

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:23:39 am

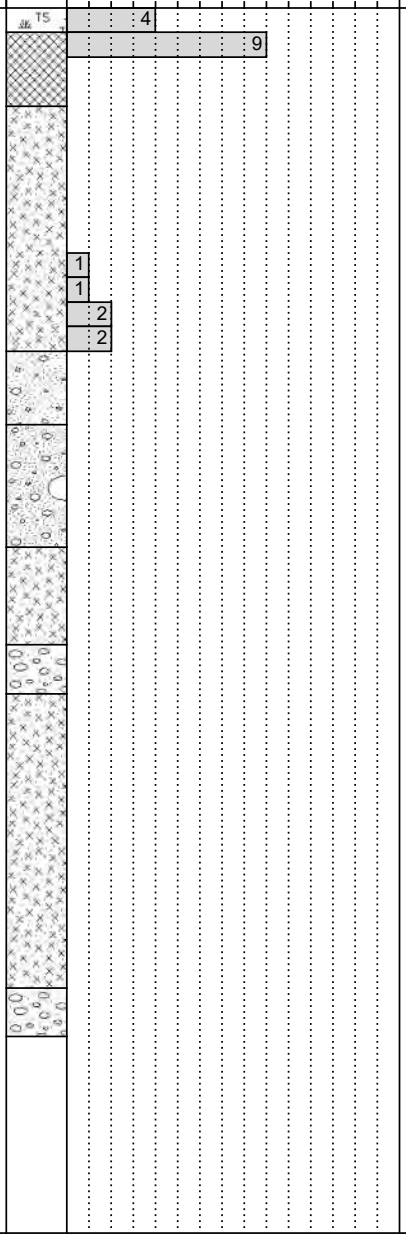
TEST PIT LOG

HOLE NO.: TP41

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 29/10/2024
COORDINATES: 1265986.0 mE, 4998873.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 29/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic SILT with trace rootlets, black. Saturated. 0.10 m		
UNCONTROLLED FILL	Medium to coarse GRAVEL with a trace of sand and silt, blackish grey. Medium dense, saturated, gravel, subrounded; sand, fine to medium. 0.40 m		
	SILT with minor sand, grey. Firm, wet , sand, fine. Moderately sensitive. 1.40 m		
	Gravelly fine to medium SAND with a trace of silt, grey. Medium dense, wet, gravel, fine to coarse, subrounded. 1.70 m		
	Boulders in gravelly SAND matrix, grey. Medium dense, wet, gravel, fine to coarse, subrounded; sand, fine to coarse. Boulders up to 600 mm diameter. 2.20 m		
ALLUVIAL FAN DEPOSITS	SILT with minor sand, grey. Firm, wet, sand, fine. Moderately sensitive. 2.60 m		
	Sandy fine to coarse GRAVEL with a trace of cobbles and boulders, grey. Medium dense, saturated, gravel, fine to coarse, subrounded; sand, fine to coarse. Boulders up to 600 mm diameter. 2.80 m		
	SILT with minor sand, grey. Firm, saturated, sand, fine. Moderately sensitive. 4.00 m		
	Sandy fine to coarse GRAVEL with a trace of cobbles and boulders, grey. Medium dense, saturated, gravel, fine to coarse, subrounded; sand, fine to coarse. Boulders up to 600 mm diameter. 4.20 m		
	End Of Hole: 4.20 m		



SHEAR STRENGTH (kPa)
Vane: 50 100 150 200 Values

WATER
29/10/2024

PHOTO(S)

REMARKS

Target depth achieved

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:23:43 am

TEST PIT LOG

HOLE NO.: TP42

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 30/10/2024
COORDINATES: 1265848.0 mE, 4998934.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 30/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic SILT with trace rootlets, black. Wet. 0.25 m						
ALLUVIAL FAN DEPOSITS	Slightly organic SILT with minor sand, dark black and grey. Firm, moist to wet, low plasticity, sand, fine. Non sensitive. 0.40 m				1, 1, 1, 1		
	Silty fine to coarse GRAVEL with trace sand and cobbles, dark grey. Firm, wet, gravel, subrounded to rounded; sand, fine to medium. 0.70 m		0.5		3, 4		
	Sandy SILT, grey. Stiff, wet, sand, fine. Slightly sensitive. 1.00 m				1, 1, 1		
	Silty fine to coarse GRAVEL with trace sand and cobbles, dark grey. Medium dense, saturated, gravel, subrounded to rounded; sand, fine to medium. 1.90 m		1.0		7, 9		
	Sandy SILT, grey. Stiff, saturated, sand, fine. Slightly sensitive. 3.50 m		1.5				30/10/2024
	End Of Hole: 3.50 m		2.0, 2.5, 3.0, 3.5, 4.0, 4.5				

PHOTO(S)

REMARKS

Pit collapsing below water table, test terminated. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:23:49 am

TEST PIT LOG

HOLE NO.: TP43

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
COORDINATES: 1265836.0 mE, 4998825.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 30/10/2024
END DATE: 30/10/2024
LOGGED BY: JMJ
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic SILT with trace rootlets, black. Wet. 0.20 m				1, 1		
ALLUVIAL FAN DEPOSITS	Slightly organic SILT with minor sand, dark black/grey. Firm, moist, low plasticity , sand, fine. Non-sensitive. 0.50 m				2, 2, 1		
	Silty fine to coarse GRAVEL with a trace of sand, dark grey. Medium dense, moist, gravel, subrounded to subangular; sand, fine to medium. 1.00 m		0.5		9, 20 >>		
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL with minor cobbles and trace boulders, dark grey. Medium dense, moist, gravel, subrounded to subangular; sand, fine to medium. Boulders up to 150 mm diameter. 2.20 m		1.0		9, 13, 20 >>		
	Fine SAND with a trace of gravel, grey. Medium dense, moist, gravel, fine to coarse, surrounded. 2.60 m		1.5				
	Silty fine to coarse GRAVEL with a trace of sand, dark grey. Medium dense, moist, gravel, subrounded to subangular; sand, fine to medium. 3.20 m		2.0				
GLACIAL TILL	Silty fine to medium SAND with a trace of gravel, light orange/grey. Medium dense, moist, gravel, fine to coarse, mostly fine to medium, rounded. 4.20 m		2.5				
	End Of Hole: 4.20 m		3.0				
			3.5				
			4.0				
			4.5				

Groundwater Not Encountered

PHOTO(S)

REMARKS

Target depth achieved. Ground water not encountered, pit walls vertical. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:23:54 am

TEST PIT LOG

HOLE NO.: TP44

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 30/10/2024
COORDINATES: 1265815.0 mE, 4998666.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 30/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic silty fine SAND with trace of rootlets, dark brown. Moist. 0.25 m				1, 1		
LOESS	Silty fine SAND with a trace of organics, orange. Loose to medium dense, moist, gravel, fine to coarse, rounded. 0.40 m				2, 2		
WEATHERED GLACIAL TILL	Sandy silty fine to coarse GRAVEL, orange. Medium dense, wet to saturated, gravel, subrounded to subangular; sand, fine to medium. 0.70 m		0.5		4, 4, 3		
	Fine to coarse SAND with minor gravel and silt, light grey. Loose, wet, gravel, fine to coarse, subrounded; sand, mostly fine. 1.00 m		1.0		1, 1		
GLACIAL TILL	Gravelly fine to coarse SAND with a trace of silt and cobbles/boulders, light grey. Dense, dry to moist, gravel, fine to coarse, mostly fine to medium, subrounded. Boulders up to 300 mm diameter. 1.60 m		1.5		4, 9, 20 >>		
	Fine to coarse SAND with minor gravel and a trace of silt, cobbles and boulders, light grey. Dense, dry to moist, gravel, fine to coarse, mostly fine to medium, subrounded. Boulders up to 300 mm diameter. 3.70 m		2.0 2.5 3.0 3.5				Groundwater Not Encountered
	End Of Hole: 3.70 m		4.0 4.5				

PHOTO(S)

REMARKS

Target depth achieved. Ground water not encountered, pit walls vertical. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:24:00 am

TEST PIT LOG

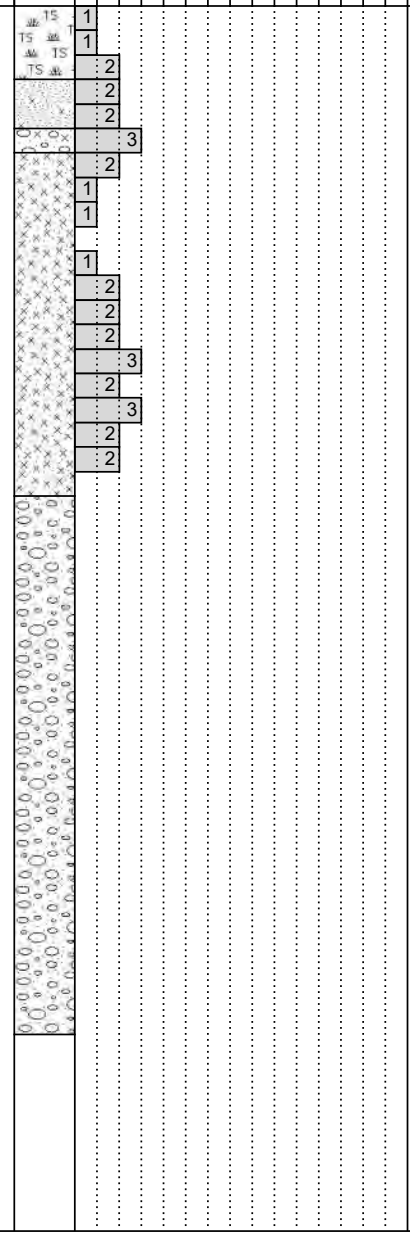
HOLE NO.: TP45

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 30/10/2024
COORDINATES: 1265662.0 mE, 4998725.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 30/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)
TOPSOIL	Organic silty fine SAND with trace rootlets, blackish/brown. Moist. 0.30 m
ALLUVIAL FAN DEPOSITS	Silty fine SAND with trace organics, dark grey. Loose, moist. 0.50 m Silty sandy GRAVEL with trace rootlets, dark grey, lenses out to 213°. Medium dense, moist, sand, fine to medium. Gravel, fine to medium, subrounded. 0.80 m SILT with minor sand, grey. Firm, moist, low plasticity, sand, fine. 2.00 m
OUTWASH DEPOSITS	Sand fine to coarse GRAVEL with minor cobbles and trace boulders, grey, interbedded bands of fine sand. Medium dense, moist, bedded, gravel, rounded to subrounded; sand, fine to coarse. Boulders up to 300 mm diameter. 4.20 m
	End Of Hole: 4.20 m

SAMPLES | DEPTH / RL | LEGEND | SCALA PENETROMETER (Blows / 100 mm) | SHEAR STRENGTH (kPa) Vane: Values | WATER



PHOTO(S)

REMARKS

Target depth achieved. Ground water not encountered, pit walls vertical. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:24:04 am

TEST PIT LOG

HOLE NO.: TP46

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
CONTRACTOR: Base Contracting
START DATE: 30/10/2024
COORDINATES: 1265622.0 mE, 4997884.0 mN (NZTM2000)
EQUIPMENT: 13T
END DATE: 30/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 3 m
LOGGED BY: JMJ
ELEVATION: Existing ground level
OPERATOR: Jeremy
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL	LEGEND	SCALA PENETROMETER (Blows / 100 mm)	SHEAR STRENGTH (kPa) Vane: Values	WATER
TOPSOIL	Organic silty fine SAND with trace rootlets, blackish/brown. Moist. 0.25 m			TS TS TS	1		
LOESS	Fine SAND with a trace of rootlets, light grey. Loose, dry to moist. 0.50 m				1 2 1		
ALLUVIAL FAN DEPOSITS	Silty fine SAND with trace organics, dark grey. Loose, moist. 0.70 m		0.5		1 2		
	SILT with minor sand, brownish/grey. Firm, moist, low plasticity, sand, fine. 2.60 m		1.0 1.5 2.0		2 2 1 1 2 1 1 2 1 1 1		
	Fine SAND with minor silt, grey. Loose, moist. 3.20 m		2.5 3.0				
	Silty fine SAND with trace organics, dark grey. Loose, moist. 3.80 m		3.5				
GLACIAL TILL	Sandy SILT with minor gravel, grey/orange. Stiff, moist, sand, fine; gravel, fine, subrounded. 4.40 m		4.0				
	End Of Hole: 4.40 m		4.5				Groundwater Not Encountered

Scala penetrometer scale: 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Shear strength (kPa) Vane: 50 100 150 200 Values

PHOTO(S)

REMARKS

Target depth achieved. Ground water not encountered, pit walls vertical. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

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TEST PIT LOG

HOLE NO.: TP47

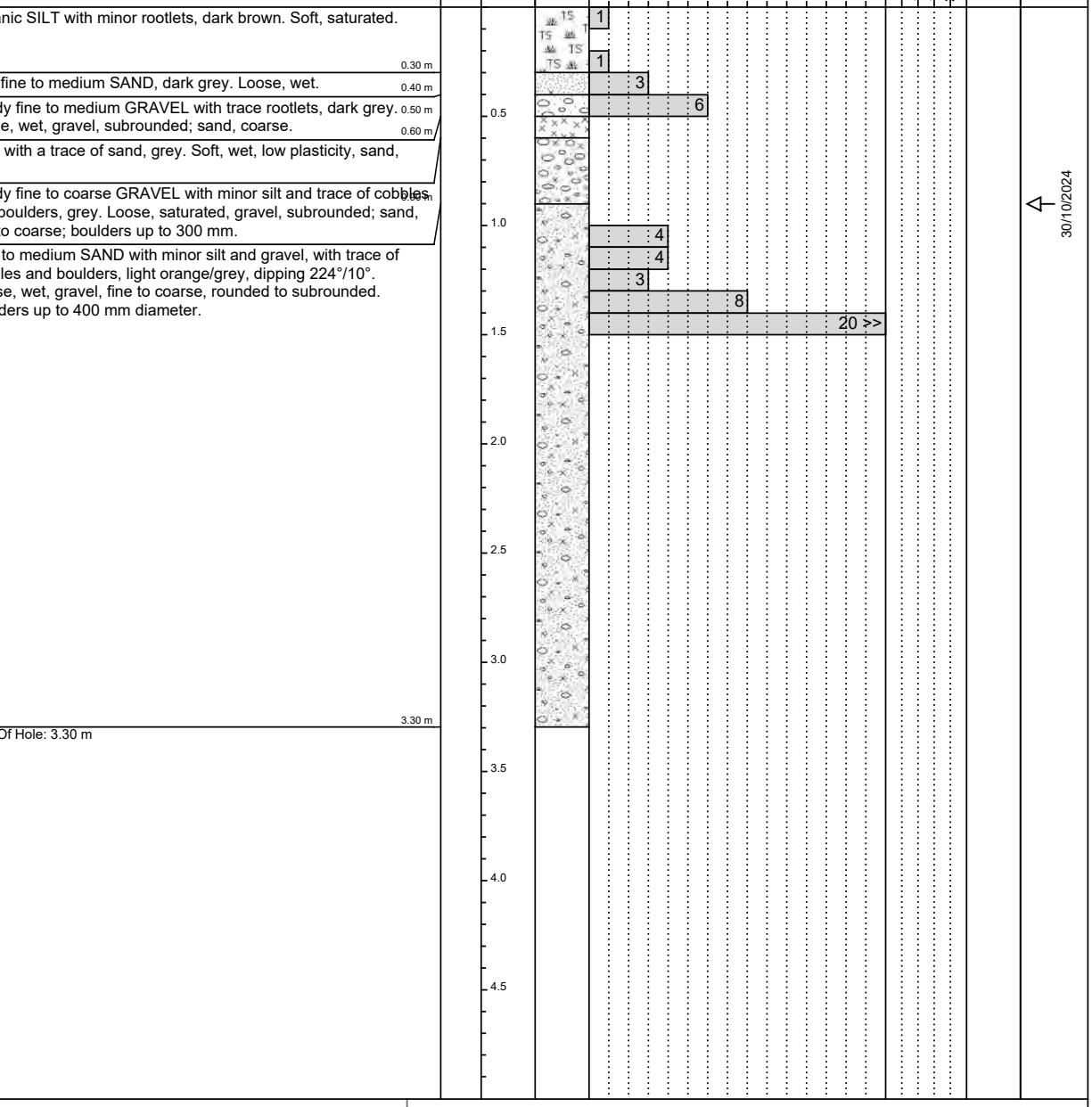
CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Queenstown
COORDINATES: 1265950.0 mE, 4998783.0 mN (NZTM2000)
LOCATION METHOD: Handheld GPS
ELEVATION: Existing ground level

CONTRACTOR: Base Contracting
EQUIPMENT: 13T
ACCURACY: ± 3 m
OPERATOR: Jeremy

START DATE: 30/10/2024
END DATE: 30/10/2024
LOGGED BY: JMJ
CHECKED DATE: 20/01/2025

SOIL / ROCK TYPE	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	SAMPLES	DEPTH / RL
TOPSOIL	Organic SILT with minor rootlets, dark brown. Soft, saturated. 0.30 m		
ALLUVIAL FAN DEPOSITS	Silty fine to medium SAND, dark grey. Loose, wet. 0.40 m		
	Sandy fine to medium GRAVEL with trace rootlets, dark grey. Loose, wet, gravel, subrounded; sand, coarse. 0.50 m / 0.60 m		
	SILT with a trace of sand, grey. Soft, wet, low plasticity, sand, fine.		
	Sandy fine to coarse GRAVEL with minor silt and trace of cobbles and boulders, grey. Loose, saturated, gravel, subrounded; sand, fine to coarse; boulders up to 300 mm. 0.80 m		
GLACIAL TILL	Fine to medium SAND with minor silt and gravel, with trace of cobbles and boulders, light orange/grey, dipping 224°/10°. Dense, wet, gravel, fine to coarse, rounded to subrounded. Boulders up to 400 mm diameter. 3.30 m		
	End Of Hole: 3.30 m		



PHOTO(S)

REMARKS

End of test, maximum excavator reach, hole collapsing. Scala penetrometer unable to penetrate

WATER

- Standing Water Level
- Out flow
- In flow

Generated with CORE-GS by Geroc - Test Pit x Hand Auger - scala & vane bars - 22/01/2025 10:24:15 am

SOIL LOG

HOLE NO.: BH01

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 21/10/2024
CO-ORDINATES: 1265689.0mE, 4998875.0mN (NZTM2000)
ELEVATION: 374m (NZVD2016)
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matthew
CHECKED DATE: 07/01/2025

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
TOPSOIL	Organic SILT with trace gravel and rootlets, dark brown. Gravels are fine to medium, angular to subrounded. 0.30 m									Cement 0.3m
ALLUVIAL FAN DEPOSITS	SILT, with trace gravel, with lenses of sand and organic inclusions, brownish grey. Soft, moist, low plasticity, gravels are fine, subangular to subrounded. Sand is fine to medium. 0.75 m			0.5 373.5						
	Silty fine SAND with trace gravel and organic inclusions , brownish grey. Loose, moist, non-plastic, gravels are fine to medium, subangular to rounded. 0.85 m		100							
	SILT with trace gravel, with lenses of sand and organic inclusions, brownish grey. Soft, moist, low plasticity, gravels are fine to medium, subangular to subrounded. Sand is fine to medium. 1.10 m			1.0 373.0						
	Silty fine SAND with some gravel, brownish grey. Loose, moist, gravels are fine to medium, subangular to subrounded. 1.30 m									
	Gravelly fine to medium SAND with minor silt, light grey. Loose, moist, gravels are fine subangular to rounded. 1.55 m			1.5 372.5			SPT (S) 1.50m 1, 1 / 2, 2, 2, 2 450mm N=8			
	Silty fine SAND with some gravel, brownish grey. Loose, moist, gravels are fine to medium, subangular to subrounded. 1.70 m									
	SILT with trace sand and gravel. With trace organic inclusions and rootlets, brownish grey, mottled orange and brown. Firm, moist , low plasticity, sand is fine. Gravels are fine and subrounded to rounded. 1.85 m		100							
	Silty fine SAND with some gravel, brownish grey. Loose, moist, gravels are fine to medium, subangular to subrounded. 1.95 m			2.0 372.0						
	CORELOSS. 2.30 m									
	SILT with trace sand, light grey. Firm, dry, low plasticity, sand is fine. 2.50 m		83	2.5 371.5						Bentonite
	Silty fine SAND with some gravel, brownish grey. Loose, moist, gravels are fine to medium, subangular to subrounded. 2.75 m									
	Sandy fine to coarse GRAVEL with minor silt, brownish grey. Loose, moist, gravels are subangular to subrounded. Sand is fine to medium. 3.00 m									

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 9/01/2025 10:44:14 am

SOIL LOG

HOLE NO.: BH01

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 21/10/2024
CO-ORDINATES: 1265689.0mE, 4998875.0mN (NZTM2000)
ELEVATION: 374m (NZVD2016)
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matthew
CHECKED DATE: 07/01/2025

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
ALLUVIAL FAN DEPOSITS	SILT, grey. Soft, moist, low plasticity.		100	3.5 / 370.5			SPT (S) 3.00m 2, 2 / 2, 2, 2, 1 450mm N=7			
	3.55 m SILT with some sand and minor gravel, brownish grey. Firm, moist , low plasticity, sand is fine. Gravels are fine, subrounded to rounded .									
	3.95 m Sandy fine to coarse GRAVEL with trace silt, brownish grey. Medium dense, moist, gravels are angular to rounded. Sand is fine to coarse.		83	4.0 / 370.0						
	4.50 m Sandy, fine to coarse GRAVEL with some silt, grey. Dense, moist, gravels are angular to rounded. Sand is fine to coarse.		100	4.5 / 369.5			SPT (S) 4.50m 8, 10 / 8, 8, 10, 13 450mm N=39			
				5.0 / 369.0					22/10/2024	
			94	5.5 / 368.5						Bentonite
	5.60 m Silty fine SAND with trace fine gravel, brownish grey, mottled orange. Medium dense, moist, gravels are subrounded to rounded.									
	5.85 m SILT with some sand and trace gravel, brownish grey, mottled orange. Firm, moist, low plasticity, sand is fine. Gravels are fine, subrounded to									
	6.65 m									

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 9/01/2025 10:44:15 am

SOIL LOG

HOLE NO.: BH01

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 21/10/2024
CO-ORDINATES: 1265689.0mE, 4998875.0mN (NZTM2000)
ELEVATION: 374m (NZVD2016)
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matthew
CHECKED DATE: 07/01/2025

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
	rounded .		94				SPT (S) 6.10m 3, 2 / 4, 4, 4, 4 450mm N=16			
	6.65 m									
	Silty fine SAND, brownish grey. Medium dense, wet, low plasticity.		100	6.5 367.5						
	6.75 m									
	Sandy fine to medium GRAVEL, with some silt, grey. Medium dense, wet, gravels are subangular to rounded. Sand is fine to coarse.									
	7.10 m		87	7.0 367.0						
	SILT with some sand and trace gravel, brownish grey, mottled orange. Firm, moist, low plasticity, sand is fine. Gravels are fine, subrounded to rounded .									
	7.25 m									
ALLUVIAL FAN DEPOSITS	Sandy fine to coarse GRAVEL with trace silt , grey. Medium dense, moist, gravels are subangular to subrounded.			7.5 366.5						Bentonite
	7.60 m						SPT (S) 7.60m 3, 5 / 4, 3, 4, 4 450mm N=15			
	Silty fine to coarse SAND with trace gravel, brownish grey, with slight orange mottling. Medium dense, wet, sand is predominantly fine to medium. Gravels are fine, subrounded.		100	8.0 366.0						
	8.80 m		100	8.5 365.5						
ALLUVIAL FAN DEPOSITS	Sandy fine to coarse GRAVEL with trace silt , grey. Medium dense, moist, gravels are subangular to subrounded.									
	8.95 m									
	9.10 m									

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 9/01/2025 10:44:15 am

SOIL LOG

HOLE NO.: BH01

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 21/10/2024
CO-ORDINATES: 1265689.0mE, 4998875.0mN (NZTM2000)
ELEVATION: 374m (NZVD2016)
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matthew
CHECKED DATE: 07/01/2025

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
ALLUVIAL FAN DEPOSITS	SILT with minor sand, brownish grey, mottled orange. Firm, moist, low plasticity, sand is fine. 9.10 m		100				SPT (S) 9.10m 4, 3 / 4, 5, 5, 4 450mm N=18			Bentonite
	Silty, gravelly fine to coarse SAND, brownish grey. Medium dense, moist, gravels are fine to medium subangular to subrounded. 9.55 m		100	9.5 364.5						
	Silty fine to coarse SAND, with trace fine gravel, brownish grey. Medium dense, moist, non-plastic, sand is predominantly fine to medium. Gravels are subrounded. 9.80 m									
	Silty sandy fine to coarse GRAVEL, grey. Medium dense, moist, sand is fine to medium. 10.20 m		89	10.0 364.0						
GLACIAL TILL	Fine to medium SAND, with some silt and gravel, light brownish grey. Dense, moist, gravels are fine to coarse, subangular to subrounded. 10.70 m			10.5 363.5			SPT (S) 10.60m 14, 11 / 15, 17, 18 365mm Effective Refusal N=50+			
	Sandy fine to medium GRAVEL, grey and brown. Very dense, moist, gravels are subangular to subrounded. Sand is medium to coarse. 11.65 m		100	11.0 363.0						
	Gravelly fine to medium SAND with minor silt, light greyish brown. Very dense, moist, gravels are fine to coarse, subangular to rounded. 12.60 m		95	11.5 362.5						

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 9/01/2025 10:44:15 am

SOIL LOG

HOLE NO.: BH01

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 21/10/2024
CO-ORDINATES: 1265689.0mE, 4998875.0mN (NZTM2000)
ELEVATION: 374m (NZVD2016)
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matthew
CHECKED DATE: 07/01/2025

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	[CONT] Gravelly fine to medium SAND with minor silt, light greyish brown. Very dense, moist, gravels are fine to coarse, subangular to rounded.		95	12.5 361.5			SPT (S) 12.20m 17, 16 / 11, 9, 14, 16 445mm Effective Refusal N=50+			Bentonite
	12.60 m									
	Sandy fine to medium GRAVEL with trace silt, grey. Very dense, moist, gravels are subangular to subrounded. Sand is fine to coarse.		100							
	13.30 m			13.0 361.0						
	Gravelly fine to medium SAND with trace silt, light grey. Very dense, moist, gravels are fine to medium, subangular to rounded.		93							
	14.00 m			13.5 360.5			SPT (S) 13.70m 11, 17 / 24, 26 225mm Effective Refusal N=50+			
	Sandy SILT with some gravel, brownish grey with slight orange mottling. Very stiff, moist, low plasticity, sand is fine. Gravels are fine to coarse, subangular to rounded.		100	14.0 360.0						
	15.00 m		95	14.5 359.5						

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 9/01/2025 10:44:15 am

SOIL LOG

HOLE NO.: BH01

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 21/10/2024
CO-ORDINATES: 1265689.0mE, 4998875.0mN (NZTM2000)
ELEVATION: 374m (NZVD2016)
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matthew
CHECKED DATE: 07/01/2025

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	Sandy fine to coarse GRAVEL with trace minor silt, grey and brown. Very dense, dry, gravels are subangular to rounded. Sand is fine to coarse.		95	15.5 358.5			SPT (S) 15.20m 17, 13 / 12, 12, 21, 5 385mm Effective Refusal N=50+			Bentonite
	15.65 m									
	Sandy fine to coarse GRAVEL with some silt, grey brown. Very dense, moist, gravels are subangular to rounded. Sand is fine to medium.		100	16.0 358.0						
	16.30 m									
	Sandy fine to coarse GRAVEL with minor silt, whitish grey. Very dense, dry, gravels are angular to rounded. Sand is fine to coarse.		100	16.5 357.5			SPT (S) 16.70m 20, 17 / 20, 22, 8 330mm Effective Refusal N=50+			16.8m Gravel
			76	17.0 357.0 17.5 356.5						
	19.95 m									

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 9/01/2025 10:44:15 am

SOIL LOG

HOLE NO.: BH01

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 21/10/2024
CO-ORDINATES: 1265689.0mE, 4998875.0mN (NZTM2000)
ELEVATION: 374m (NZVD2016)
END DATE: 22/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matthew
CHECKED DATE: 07/01/2025

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%) 25 50 75	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected) 10 20 30 40	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	[CONT] Sandy fine to coarse GRAVEL with minor silt, whitish grey. Very dense, dry, gravels are angular to rounded. Sand is fine to coarse.		76	18.5 355.5			SPT (S) 18.30m 29, 21 115mm Effective Refusal N=50+			Gravel 19.8m
			100							
			100	19.0 355.0						
				19.5 354.5						
			100				SPT (S) 19.80m 26, 24 125mm Effective Refusal N=50+			
	19.95 m									
	End Of Hole: 19.95m			20.0 354.0						
				20.5 353.5						

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 9/01/2025 10:44:15 am

SOIL LOG

HOLE NO.: BH02

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 22/10/2024
CO-ORDINATES: 1265959.0mE, 4998127.0mN (NZTM2000)
ELEVATION: 391m (NZVD2016)
END DATE: 23/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matthew
CHECKED DATE: 07/01/2025

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
TOPSOIL	Organic SILT with trace gravel and rootlets, dark brown. Gravels are fine to medium, angular to subrounded. 0.30 m									Cement 0.3m
ALLUVIAL FAN DEPOSITS	Slightly organic gravelly, sandy SILT, dark brownish grey. Soft, wet, low plasticity, gravels are fine to coarse, angular to rounded. Sand is fine. 0.70 m			0.5 / 390.5						
	Slightly organic sandy SILT with trace gravel, brownish grey. Soft, wet, low plasticity, sand is fine. Gravels are fine to medium, subangular to rounded. 1.15 m		82	1.0 / 390.0						
	Silty fine SAND with some gravel, grey. Loose, wet, non-plastic, gravels are fine to medium subangular to rounded. 2.00 m		100	1.5 / 389.5			SPT (S) 1.50m 3, 2 / 2, 3, 3, 2 450mm N=10			Bentonite
	Sandy fine to coarse GRAVEL with some silt, grey. Loose, moist to wet, gravels are angular to subrounded. Sand is fine to coarse. 2.30 m			2.0 / 389.0						
	Fine to medium SAND with some silt and trace gravel, grey brown. Loose, moist, gravels are fine to medium, subangular. 3.80 m		50	2.5 / 388.5						

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 9/01/2025 10:44:19 am

SOIL LOG

HOLE NO.: BH02

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 22/10/2024
CO-ORDINATES: 1265959.0mE, 4998127.0mN (NZTM2000)
ELEVATION: 391m (NZVD2016)
END DATE: 23/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matthew
CHECKED DATE: 07/01/2025

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
ALLUVIAL FAN DEPOSITS	[CONT] Fine to medium SAND with some silt and trace gravel, grey brown. Loose, moist, gravels are fine to medium, subangular.		100	3.5 / 387.5			SPT (S) 3.00m 2, 2 / 2, 2, 2, 3 450mm N=9			Bentonite
	3.80 m		86							
	SILT with some sand and trace gravel, brownish grey, with slight orange mottling. Soft, moist, low plasticity, sand is fine to medium. Gravels are fine to medium subangular to subrounded.			4.0 / 387.0						
	4.3m - 4.5m: becoming sandy		91							
	4.50 m			4.5 / 386.5						
	Silty fine SAND with gravel, brownish grey. Loose, moist, non-plastic, gravels are fine.		100				SPT (S) 4.50m 2, 1 / 2, 3, 2, 3 450mm N=10			
				5.0 / 386.0						
			78	5.5 / 385.5						
	6.00 m									

REMARKS
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ALLUVIAL FAN DEPOSITS	Sandy fine to coarse GRAVEL with some silt, grey. Medium dense, moist, gravels are subangular to rounded. Sand is fine to coarse.		78	6.5 (384.5)			SPT (S) 6.10m 3, 3 / 4, 4, 6, 5 450mm N=19			
	6.90 m		100							
	Sandy SILT, grey, brown. Firm, moist, low plasticity, sand is fine.			7.0 (384.0)						
	7.35 m		91							
OUTWASH DEPOSITS	Silty, sandy fine to coarse GRAVEL, grey. Medium dense, moist, gravels are subangular to subrounded.			7.5 (383.5)						
	7.45 m									
	Silty, gravelly fine to medium SAND, grey. Medium dense, wet, non-plastic, gravels are fine to medium subangular to subrounded.									
	7.60 m									
	Sandy fine to coarse GRAVEL, with trace to some silt, grey. Medium dense to dense, moist to wet, gravels are angular to rounded. Sand is fine to coarse.		100	8.0 (383.0)			SPT (S) 7.60m 3, 8 / 10, 8, 8, 15 450mm N=41			
			100	8.5 (382.5)						
	9.10 m								23/10/2024	Bentonite

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DRILLER: Matthew
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UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
OUTWASH DEPOSITS	[CONT] Sandy fine to coarse GRAVEL, with trace to some silt, grey. Medium dense to dense, moist to wet, gravels are angular to rounded. Sand is fine to coarse. 9.10 m CORELOSS.		100 0 100	9.5 381.5			SPT (S) 9.10m 39, 11 100mm Effective Refusal N=50+			
	Sandy fine to coarse GRAVEL with trace to some silt, grey. Very dense, moist to wet, gravels are angular to rounded. Sand is fine to coarse. 10.60 m		0 100	10.0 381.0 10.5 380.5 11.0 380.0			SPT (S) 10.60m 9, 11 / 12, 24, 12, 2 385mm Effective Refusal N=50+			Bentonite
	12.00 m		59	11.5 379.5						

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UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	Sandy fine to coarse GRAVEL, grey. Very dense, moist to wet, gravels are subangular to rounded. Sand is medium to coarse.		50							
			100	12.5 / 378.5			SPT (S) 12.20m 13, 18 / 16, 14, 13, 7 420mm Effective Refusal N=50+			
	13.00 m									
	Sandy SILT with trace gravel, light grey. Very stiff, wet, low plasticity, sand is fine. Gravels are fine to medium angular to subrounded.		93	13.0 / 378.0						
	13.30 m									
	Sandy fine to coarse GRAVEL, grey. Very dense, wet, gravels are subangular to rounded. Sand is medium to coarse.			13.5 / 377.5						
			100	14.0 / 377.0			SPT (S) 13.70m 18, 18 / 19, 18, 13 365mm Effective Refusal N=50+			
	14.20 m		100							
	Sandy fine to coarse GRAVEL with minor to some silt, with trace cobbles and boulders, light brownish grey. Very dense, moist to wet, gravels are angular to rounded. Sand is fine to coarse.			14.5 / 376.5						
			71							
	16.85 m									

Bentonite

REMARKS
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ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matthew
CHECKED DATE: 07/01/2025

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	[CONT] Sandy fine to coarse GRAVEL with minor to some silt, with trace cobbles and boulders, light brownish grey. Very dense, moist to wet, gravels are angular to rounded. Sand is fine to coarse.		71	15.5 375.5			SPT (S) 15.20m 10, 14 / 15, 19, 16 370mm Effective Refusal N=50+			Bentonite
			100							16m
			96	16.0 375.0						
				16.5 374.5			SPT (S) 16.70m 10, 40 140mm Effective Refusal N=50+			Gravel
			100							
	16.85 m Silty, fine to coarse GRAVEL with trace to some sand and trace cobbles, bluish grey and brown. Very dense, wet, gravels are fine to coarse angular to subangular. Sand is medium to coarse .		63	17.0 374.0						
	17.50 m Gravelly SILT, with some sand and clay content, greyish brown. Stiff, wet, low plasticity, gravels are fine to coarse, subangular to rounded.		100	17.5 373.5						
	17.70 m Sandy SILT with minor gravel, greenish, greyish brown. Very stiff, moist, non-plastic, sand is fine. Gravels are fine to medium, subrounded.									
	18.00 m									

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ACCURACY: ± 1m
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CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matthew
CHECKED DATE: 07/01/2025

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%) 25 50 75	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected) 10 20 30 40	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	SILT with some sand and gravel, greenish brown, bluish grey, slightly laminated and fissured. Hard, dry, non-plastic, sand is fine. Gravels are fine to coarse subangular to rounded. With iron oxidation staining and calcrete nodules. 18.30 m		100							
	Gravelly SILT with minor sand, greenish brown, bluish grey, slightly laminated. Very stiff, moist to wet, low plasticity, gravels are fine to coarse. Sand is fine. With iron oxidation staining and calcrete nodules.		100	18.5 372.5			SPT (S) 18.30m 50 60mm Effective Refusal N=50+			Gravel 19m
	19.20 m		100	19.0 372.0						
	End Of Hole: 19.20m			19.5 371.5						
				20.0 371.0						
				20.5 370.5						

REMARKS
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SOIL LOG

HOLE NO.: BH03

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 23/10/2024
CO-ORDINATES: 1265487.0mE, 4998045.0mN (NZTM2000)
ELEVATION: 373m (NZVD2016)
END DATE: 24/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matthew
CHECKED DATE: 07/01/2025

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
TOPSOIL	Organic SILT with trace gravel and rootlets, dark brown. Gravels are fine to medium, angular to subrounded.			0.5 / 372.5						Cement 0.3m
	0.70 m									
ALLUVIAL FAN DEPOSITS	SILT with trace fine sand and gravel, and some organic inclusions, light greyish brown, with orange brown speckling. Soft, moist to wet, low plasticity.		100	1.0 / 372.0						
	1.60 m			1.5 / 371.5			SPT (S) 1.50m 2, 3 / 27, 23 245mm Effective Refusal N=50+			
GLACIAL POND SEDIMENT	Gravelly SILT with minor sand and trace rootlets, light greyish brown, with orange brown speckling . Stiff, wet, low plasticity, gravels are fine to medium, angular to subrounded. Sand is fine to medium.		100							
	1.90 m			2.0 / 371.0						
OUTWASH DEPOSITS	Sandy fine to coarse GRAVEL with trace cobbles, grey. Dense, moist, gravels are subangular to rounded. Sand is fine to medium.									
	2.10 m		100							
	Silty, sandy fine to coarse GRAVEL, greyish brown. Dense, moist , gravels are subangular to rounded. Sand is medium.									
	2.30 m									
	Sandy fine to coarse GRAVEL with minor silt, light greyish brown. Dense, moist , gravels are subangular to rounded. Sand is medium.									
	2.50 m			2.5 / 370.5						
	Silty, sandy fine to coarse GRAVEL, light grey and brown. Very dense, wet, Gravels are angular to rounded. Sand is fine to coarse.		100							Bentonite
	3.70 m									

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UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
OUTWASH DEPOSITS	[CONT] Silty, sandy fine to coarse GRAVEL, light grey and brown. Very dense, wet, Gravels are angular to rounded. Sand is fine to coarse.		100	3.5 369.5			SPT (S) 3.00m 7, 12 / 16, 13, 12, 9 440mm Effective Refusal N=50+			
	3.70 m Sandy fine to coarse GRAVEL with some silt, grey. Very dense, wet, gravels are subangular to rounded. Sand is medium to coarse.									
	3.95 m Sandy fine to coarse GRAVEL, grey. Very dense, moist, gravels are subangular to rounded .		89	4.0 369.0						
	4.20 m Sandy fine to coarse GRAVEL with some silt, grey, slightly brown. Very dense, wet, gravels are subangular to rounded. Sand is medium to coarse.			4.5 368.5			SPT (S) 4.50m 11, 17 / 26, 217, 17, 0 360mm Effective Refusal N=50+			
	4.60 m Sandy fine to medium GRAVEL with minor silt, grey and brown. Very dense, moist, gravels are angular to subrounded.		100	5.0 368.0					24/10/2024	Bentonite
	5.30 m Sandy, fine to coarse GRAVEL with trace to some silt, and trace cobbles, grey, brown and orange. Dense to very dense, moist, gravels are angular to rounded. Sand is fine to coarse.		100	5.5 367.5						
	6.60 m		64							

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OUTWASH DEPOSITS	[CONT] Sandy, fine to coarse GRAVEL with trace to some silt, and trace cobbles, grey, brown and orange. Dense to very dense, moist, gravels are angular to rounded. Sand is fine to coarse.		64							
			100	6.5 366.5			SPT (S) 6.10m 8, 9 / 10, 10, 10, 9 450mm N=39			
	6.60 m Sandy, fine to coarse GRAVEL with trace silt, grey brown. Very dense, moist, gravels are angular to rounded. Sand is fine to coarse.									
	7.00 m Sandy fine to coarse GRAVEL with minor to some silt, and trace cobbles, grey, brown and orange. Very dense, moist, gravels are angular to rounded. Sand is fine to coarse.		86	7.0 366.0						
				7.5 365.5						Bentonite
			100				SPT (S) 7.60m 11, 15 / 16, 14, 16, 4 395mm Effective Refusal N=50+			
				8.0 365.0						
			100							
				8.5 364.5						
			100							
	8.90 m Sandy fine to coarse GRAVEL with some silt , grey, brown, bluish grey and orange. Very dense. 9.85 m									

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OUTWASH DEPOSITS	moist, gravels are subangular to rounded. Sand is fine to coarse.		100							
			100	9.5 363.5			SPT (S) 9.10m 19, 23 / 22, 28 290mm Effective Refusal N=50+			
	9.85 m Sandy, fine to coarse GRAVEL with trace silt and cobbles, grey brown. Very dense, moist, gravels are angular to subrounded.		100	10.0 363.0						
	10.15 m Gravelly fine to medium SAND with trace silt, brown. Very dense, moist, gravels are fine to coarse, predominantly fine to medium, and subangular to subrounded.			10.5 362.5						
	10.50 m Silty gravelly fine to medium SAND, grey, brown and orange. Very dense, moist, gravels are fine to coarse subangular to subrounded .						SPT (S) 10.60m 23, 29 / 17, 18, 15 365mm Effective Refusal N=50+			Bentonite
	10.60 m Sandy fine to coarse GRAVEL with minor silt, grey brown. Very dense, moist, gravels are angular to subrounded .		100							
	11.45 m		50	11.0 362.0						
GLACIAL TILL	Sandy fine to coarse GRAVEL with minor to some silt, grey, brown, bluish grey and orange. Very dense, moist, gravels are fine to coarse, angular to rounded. Sand is fine to coarse.		100	11.5 361.5						
	12.10 m									

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UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	[CONT] Sandy fine to coarse GRAVEL with minor to some silt, grey, brown, bluish grey and orange. Very dense, moist, gravels are fine to coarse, angular to rounded. Sand is fine to coarse. 12.10 m Silty, sandy fine to coarse GRAVEL, greenish grey and purplish brown. Very dense, moist, gravels are angular to subrounded. Sand is medium to coarse. 12.50 m Silty, sandy fine to coarse GRAVEL, light greenish grey. Very dense, moist to wet, gravels are angular to rounded. Sand is medium to coarse. 13.00 m Medium to coarse SAND with some gravel, grey, brown. Very dense, moist to wet, gravels are fine to medium, subrounded. 13.10 m Sandy fine to coarse GRAVEL with some silt, grey, brown and orange. Very dense, moist to wet, gravels are subangular to rounded. Sand is fine to coarse. 13.40 m Medium to coarse SAND with some gravel, grey, brown. Very dense, moist to wet, gravels are fine to medium, subrounded. Sand is predominantly coarse. 13.55 m Sandy fine to coarse GRAVEL with some silt, grey, brown and orange. Very dense, moist to wet, gravels are subangular to rounded. Sand is fine to coarse. 13.70 m Silty, sandy fine to medium GRAVEL, light greenish grey and brown. Very dense, moist to wet, gravels are subangular to subrounded. Sand is fine to coarse. 14.05 m Sandy fine to medium GRAVEL with trace silt, light greenish grey and brown. Very dense, moist to wet, gravels are subangular to subrounded. Sand is medium to coarse. 14.20 m Silty, sandy fine to coarse GRAVEL, greenish grey and purplish brown and orange. Very dense, moist, gravels are angular to rounded. Sand is medium to coarse. 15.50 m		100 100 100 100 91	12.5 (360.5) 13.0 (360.0) 13.5 (359.5) 14.0 (359.0) 14.5 (358.5)		SPT (S) 12.20m 38, 12 105mm Effective Refusal N=50+ SPT (S) 13.70m 22, 24 / 43, 7 235mm Effective Refusal N=50+			Bentonite

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GLACIAL TILL	[CONT] Silty, sandy fine to coarse GRAVEL, greenish grey and purplish brown and orange. Very dense, moist, gravels are angular to rounded. Sand is medium to coarse.		91							
	15.50 m		100	15.5 357.5			SPT (S) 15.20m 19, 31 75mm Effective Refusal N=50+			
	Silty, sandy, fine to medium GRAVEL, light greyish brown, with dark brown speckling. Very dense, wet, gravels are subangular to subrounded. 15.60 m									
	Silty, sandy fine to coarse GRAVEL, brownish grey. Very dense, wet, gravels are angular to subrounded. Sand is fine to medium. 15.75 m									
	Sandy fine to coarse GRAVEL with some silt, grey and brown. Very dense, moist, gravels are subangular to subrounded. Sand is medium to coarse. 15.85 m 15.95 m		100	16.0 357.0						Bentonite
	Gravelly medium to coarse SAND with trace silt, grey and brown. Very dense, moist, gravels are fine to medium, subangular to subrounded. 16.05 m									
	Sandy fine to coarse GRAVEL with some silt, grey and brown. Very dense, moist, gravels are subangular to subrounded. Sand is medium to coarse.									
	Gravelly fine to coarse SAND with trace silt, orangish brown. Very dense, moist, gravels are fine to coarse, subangular to rounded. 16.45 m									
	Sandy fine to coarse GRAVEL with minor to some silt, with trace decayed organic matter, greenish grey and orangish brown. Very dense, wet, gravels are angular to rounded. Sand is fine to coarse.			16.5 356.5						
			100				SPT (S) 16.70m 24, 22 / 31, 19 280mm Effective Refusal N=50+			
GLACIAL TILL				17.0 356.0						16.8m
			88	17.5 355.5						Gravel
	18.05 m									

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 9/01/2025 10:44:24 am

SOIL LOG

HOLE NO.: BH03

CLIENT: RCL Homestead Bay Ltd
PROJECT: Homestead Bay Geotechnical
JOB NO.: 220556.01

SITE LOCATION: Kingston Road, Drift Bay 9371
START DATE: 23/10/2024
CO-ORDINATES: 1265487.0mE, 4998045.0mN (NZTM2000)
ELEVATION: 373m (NZVD2016)
END DATE: 24/10/2024
LOCATION METHOD: Handheld GPS
ACCURACY: ± 1m
LOGGED BY: WF
CONTRACTOR: Pro Drill
RIG: FRASTE XL 170 DUO
DRILLER: Matthew
CHECKED DATE: 07/01/2025

UNIT	MATERIAL DESCRIPTION (See Classification & Symbology sheet for details)	METHOD	TCR (%)	DEPTH / RL	GRAPHIC	SPT N-VALUE (Uncorrected)	SPT DATA (Uncorrected)	SAMPLES	WATER	INSTALLATION
GLACIAL TILL	[CONT] Sandy fine to coarse GRAVEL with minor to some silt, with trace decayed organic matter, greenish grey and orangish brown. Very dense, wet, gravels are angular to rounded. Sand is fine to coarse. 18.20 m Gravelly medium to coarse SAND with trace silt, greenish grey and brown. Very dense, wet, gravels are fine to medium, subangular to subrounded. Sandy fine to coarse GRAVEL with minor to some silt, with trace cobbles, greenish grey and orangish brown. Very dense, wet, gravels are angular to rounded. Sand is fine to coarse. 18.90 m		88 100 85	18.5 354.5			SPT (S) 18.30m 25, 25 120mm Effective Refusal N=50+			Gravel
	Sandy, fine to medium GRAVEL, greenish grey. Very dense, wet, gravels are subangular to rounded. Sand is medium to coarse. 19.05 m Gravelly medium to coarse SAND with trace silt, greenish grey and brown. Very dense, wet, gravels are fine to medium, subangular to subrounded. 19.30 m			19.0 354.0						
GLACIAL TILL	Gravelly, medium to coarse SAND, grey and brown. Very dense, moist, gravels are fine to medium, subangular to subrounded. 19.40 m Sandy fine to coarse GRAVEL, with some silt, grey and brown. Very dense, moist, gravels are subangular to rounded. 19.65 m Medium to coarse SAND with some silt, grey and brown. Very dense, moist. 19.85 m Silty, sandy fine to coarse GRAVEL, greenish grey and purplish brown and orange. Very dense, moist to wet, gravels are angular to rounded. Sand is medium to coarse.		100 100	19.5 353.5			SPT (S) 19.80m 50 50mm Effective Refusal N=50+			19.8m
	End Of Hole: 19.85m			20.0 353.0 20.5 352.5						

REMARKS
Target depth achieved

REF	DATE / TIME	LEVEL	REMARK

Generated with CORE-GS by Geroc - Combined Soil + Rock - 9/01/2025 10:44:24 am

Appendix C: Liquefaction Results

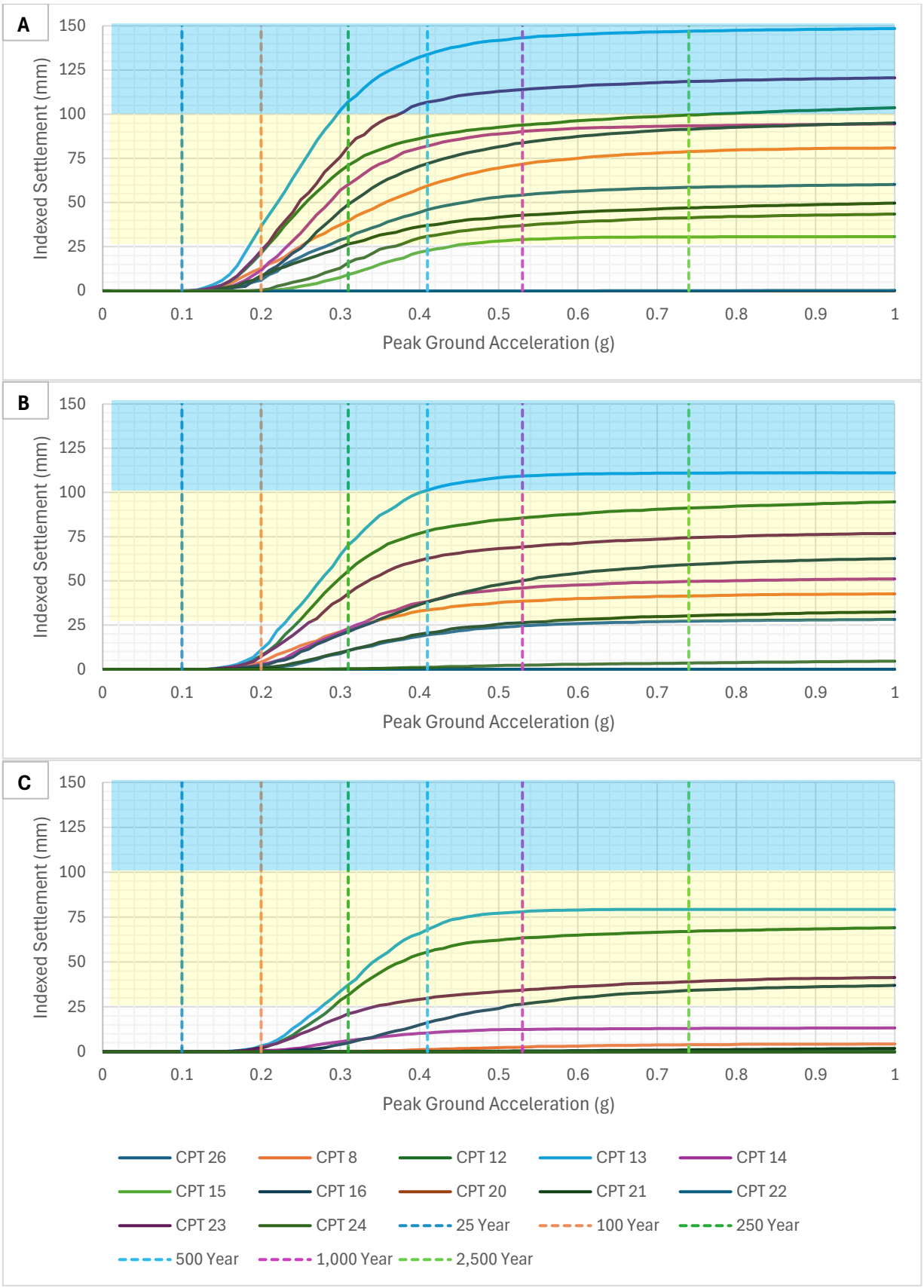


Figure 1: Indexed reconsolidation settlement vs peak ground acceleration. A, B and C are assumed groundwater levels of 2, 4 and 6 m below ground level respectively

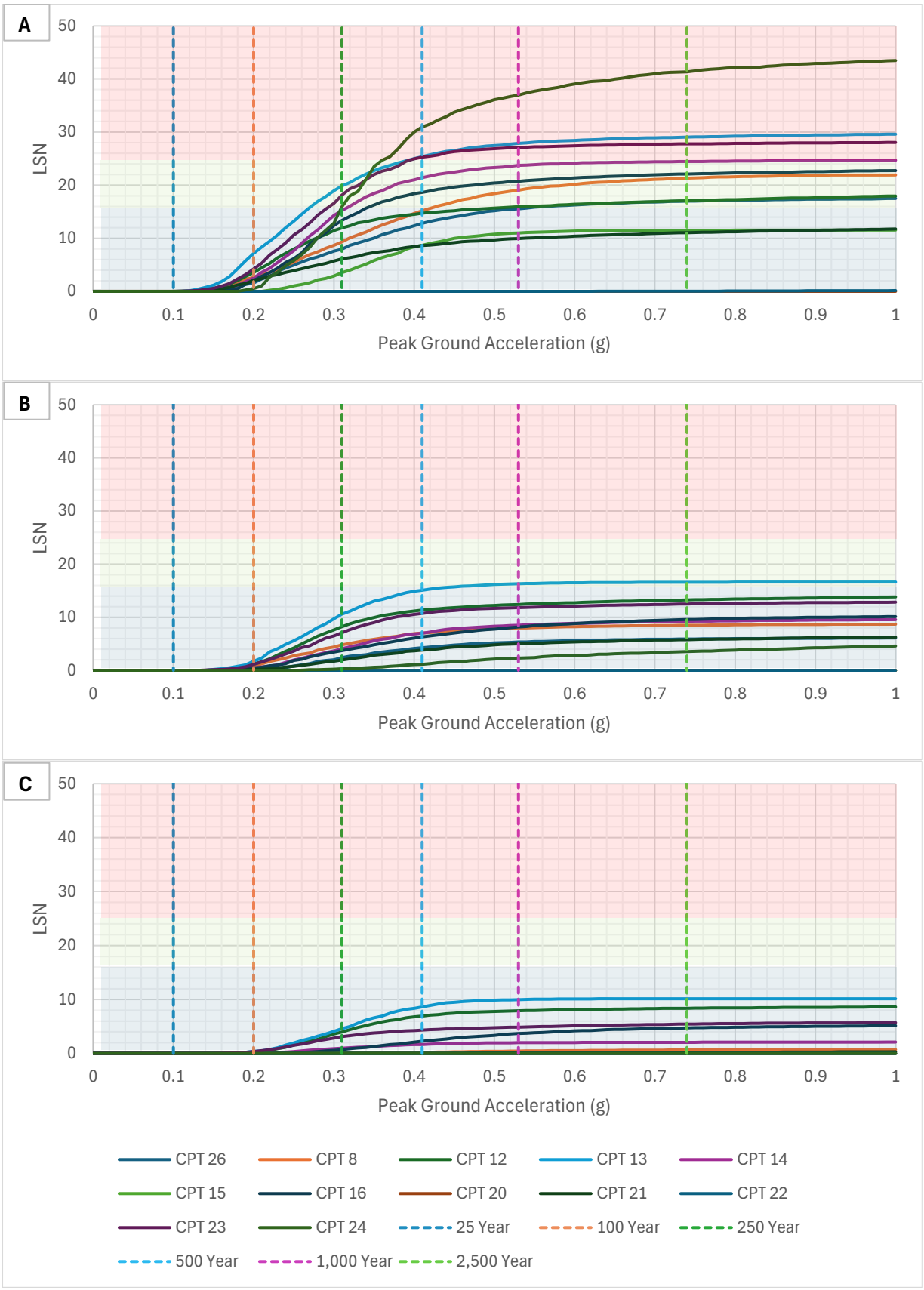


Figure 2: Liquefaction severity number vs peak ground acceleration. A, B and C are assumed groundwater levels of 2, 4 and 6 m below ground level respectively

Appendix H Fluent Solutions Peer Review of Natural Hazards Assessment

Project Number: 892
Project Name: Homestead Bay - Hydraulic Assessment - Peer Review
Peer Review By: GF
Checked By: AS
Date: 10-02-2025

			10-02-2025		13-03-2025	25-03-2025	Resolved
							To Consider
							Action Required
ID	**Page No**	**Section**	**Peer Review Comment**	**Response to Peer Review Comment**	**Peer Review Comment**		**Status**
1	7	4.1, Figure 4.1	Does the longest watercourses extend to the upper edge of the alpine sub-catchments? If not, how is travel time for flow from the upper end of the catchment accounted for?	Yes the longest flow path (calculated by HEC-HMS and checked with GIS) extends to the most distant point of the upper edge of the catchment. Statement added to Section 4.1 below figure 4.2.	Noted		Resolved
2	8	4.1, Table 4.2	For flow path slope, 10-85 average is used. It is recommended that the selection of this method be justified / clarified in relation to the catchment / watercourse topography and characteristics. Have you considered using the equal areas method to check the 10-85 method, as this seems to be used more frequently for Tc calculations in NZ.	The average 10-85 slope used (given by HEC-HMS) was found to be within <5% of the slope given by the equal areas method. As suggested this can be stated in the reporting. Statement added to Section 4.1 below figure 4.2.	Noted		Resolved
3	8	4.2	For Tc calculations, the Horton method (Friend's equation) has been used. This calculation method is generally used for overland flow/sheet flow duration estimation, and tends to be part of a multiple component approach which should include time for shallow concentrated flow and open channel flow. Has alternative calculational methods been considered (Ramser-Kirpich, Bransby-Williams, Multi component TOC approach?)	The Horton method was used to allow for clear comparison with the proposed 2024 QLDC LDS COP. This was compared with all methods of estimating the time of concentration (TC) and is less conservative by ~15% (in terms of resultant flow) compared to more conservative methods of estimating the (TC). As such, we have updated the reporting and modelling using the TC from the Bransby Williams method to ensure we are being suffciantly conservative. The various methds used to estimate TOC and lag time have been stated in Section 4.1 below figure 4.2 and futher diuscussion is provided in Section 4.5.	Noted, additional clarification provided in report on selection of Tc, and opted for a more conservative (i.e. shorter Tc).		Resolved
4	8	4.2	Can you clarify / justify why you opted for a 24-hour nested storm in lieu of a triangular storm for modelled hyetographs?	A 24-hr nested storm is stipulated in the proposed 2024 QLDC LDS COP for complex catchments with a TOC over 10 mins. In addition, when using a nested rainfall temporal pattern and the SCS method, storm flow volumes include all design rainfall event durations within a 24 hr period. The use of a nested storm hyetograph was considered an appropriately conservative approach given the uncertainty around time of concentration and potential requirement of conservative design storm volumes for design of stormwater infrastructure with storage components downstream.	Noted, this approach is considered appropriate for peak flow calculations. Should detention become relevant, we would recommend considering using alternative approaches like triangular hyetographs to test the sensitivity .		Resolved
5	10	4.4	Can you clarify what the relationship is that you used for Ia to S? Is it 0.05 x S? Is this assumption relevant for these catchments, where reasonably high infiltration rates are expected as per further discussion in the report?	Several sources cited a initial infiltration rate lower than the default 0.2S was appropriate for the application of the SCS loss estimation method using HEC-HMS in NZ. As such a more conservative value of 0.1S was used. We agree this is likely to be a conservative value for the fan catchments and consider the use of a low value for Ia for the alpine catchments appropriate given the lack of documented/measured evidence to justify a higher value. See section 4.4	Noted, the response provided clarifies our comment and provides additional substantiation for the selected Ia.		Resolved
6	10-11	4.4	CN value for Alpine Catchments - The CN value of 77 appears low considering the documentation referenced (*MS Srinivasan (2007) Selecting curve numbers for predicting storm flow in Otago catchments, Journal of Hydrology; New Zealand 46(2):91-104*) indicates a upper limit value for CN as high as 94 (Dart) and 96 (Shotover) for the CN value based off 5-year return period storm flows (wet antecedent moisture condition)? We recommend that a sensitivity analysis be included for higher CN values based on seasonality and the likelihood of snow and ice to be present in the alpine catchments.	While we have justified the CN used based on observed soils and catchment conditions I agree the curve number choosen is low compared to the values given in the MS Srinivasan 2007 Paper. We consider the higher CN value in this paper for the dart and Shotover to be outliers related to rainfall events coupled with snow melt or strong orographic effects (differing rainfall between rainfall gauge and catchment headwaters close to the west coast). We have allowed for potential snow and ice contributions to flows with a bulking factor in later section of the report and do not consider it appropriate to increase the curve number to account for this. The resultant ratio of rainfall to stormflow compares well with studies on small catchments in NZ and the adopted curve number is considered appropriate. References have been revised to support the CN used. Sensitivity analysis gives a potential increse in peak flow of ~14% for a curve number of 86 (cited value for bare earth). However, we conisider a curve number of 77 appropriate, see updated section 4.4.1.	Noted, the response and updated references provided clarifies our comment and provides additional substantiation for the selected CN value. We suggest that you may wish to consider the use of the reference "*A Shokri (2023) Development of a New Event-Based Rainfall-Runoff Equation Based on Average Rainfall Intensity During an Event, Environmental Modelling & Assessment https://doi.org/10.1007/s10666-023-09876-3* " in your report, as it does not necessarily include any catchments that are reprsentative of the catchments in this assessment, and also focuses on improvements to the SCS method rather than the calibration of curve numbers.		

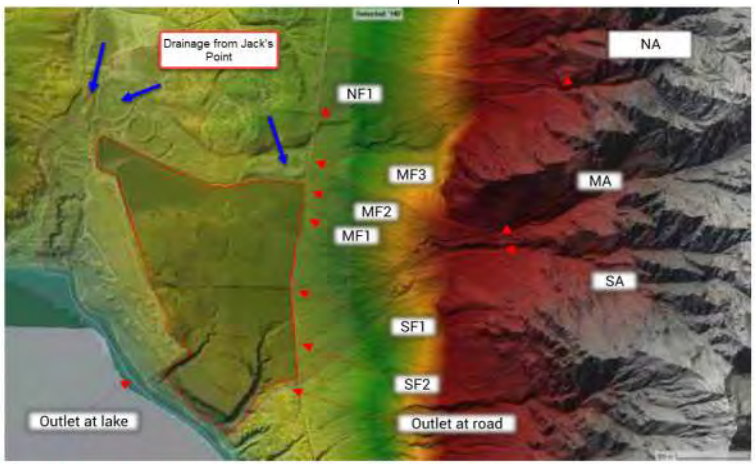
SOLUTIONS

Date: 10-02-2025

			10-02-2025		13-03-2025	25-03-2025	Resolved / To Consider / Action Required
ID	**Page No**	**Section**	**Peer Review Comment**	**Response to Peer Review Comment**	**Peer Review Comment**		**Status**
			Table 4 – Comparison of catchment-scale curve numbers – CN_{LS} vs. CN_{RF} for the selected Otago catchments. [1] CN_{LS} catchment-scale area-weighted curve number based on land use and soils from Soil Conservation Service (1972). [2] Wet antecedent moisture condition curve numbers calculated from moderate antecedent moisture condition curve numbers using equation 2 presented in the text. [3] CN_{RF}; catchment-scale curve number based on statistically-estimated 5-year return period rainfall and flow data [4] Antecedent moisture condition deduced based on CN_{RF} values using equations 5 and 6 presented in the text. [5] CN_{RF} > AMC 3 CN_{LS}, no AMC calculated.				Resolved
7	11	4.4	CN value for Fan Catchments - It appears as if the CN value of 68 was selected as a mean between the CN values from USDA SCS TR-55 for good hydrological condition, Soil Group B & C indicated in red in the snip below. This is the same value as the mean CN value reported in referenced document - *Brian s. Caruso 2011 Flood modelling in a high-country mountain catchment, New Zealand: comparing statistical and deterministic model estimates for ecological flows* . However the latter reference does state that CN values were based off an assumption of fair hydrological conditions, and it was a mean over a whole catchment. It is recommended that as part of a sensitivity analysis, higher CN values be considered, for example the mean of the fair hydrological condition (as per the reference documentation) values for the same soil groups (shown in red in markup below).	Given the very high permeability observed across the alluvial fans the CN of 68 is considered appropriate. Increasing the CN to the median value for fair hydrological condition increases the peak flow from fan catchments by ~22%. This is considered unrelaisticially high given the evidence for signifigant infiltration losses to groundwater across the fans. See revised Section 4.4.2.	Noted, the additional explanation provided in the report clarifies the selection of the CN.		Resolved
8	13	4.5	Peak Rate Factor (PRF) of 484 has been adopted for all catchments. Can you clarify whether alternative PRF's was considered for steeper alpine and flatter fan sub catchments?	Higher PRFs were considered. Using the standard PRF for the flatter fan catchments is considered appropriately conservative. See additional justification added to Section 4.5.	Clarification noted, and considering that the approach was to select a conservative (short) TC, this aligns with the additional explanations provided in the report and observed / logged stage during rain event.		Resolved
9	20	5.2	Can you clarify why stream avulsion from the Middle Creek to the Northern Creek and from the northern creek to Middle Creek was not considered, as this could affect northern diversion channel capacity?	Avulsion of Middle creek to the Northern Creek at the Road is not considered as this would result in less flow impacting the area proposed for development (Lot 8) and more flow into Lot 12 which will remain largely undeveloped. Avulsion of Northern Creek into Middle Creek is not possible as the northern creek currently runs at the lowest point between the northern and middle Alluvial fans and can not rise onto the middle alluvial fan. Explanation added to Section 5.2	Noted		Resolved
10	21	5.4	Check referencing to LiDAR data, links seems to direct to wrong LiDAR data	Corrected	Noted		Resolved
11	22	5.4 Figure 5.1	Would it be possible to provide a clearer or higher resolution layout of the 2D extent? The red dashed outline is very hard to distinguish on the figure.	Corrected	Noted		Resolved
12	22	5.4	Can you perhaps include refinement regions on the layout drawing and where smaller cell sizes was used and what the typical cell size used in channels was?	Futher detail for computational grid added to Section 5.4 and an image of the grid added to Appendix F.	Noted		Resolved

SOLUTIONS

Date: 10-02-2025

							Resolved
							To Consider
			10-02-2025		13-03-2025	25-03-2025	Action Required
ID	**Page No**	**Section**	**Peer Review Comment**	**Response to Peer Review Comment**	**Peer Review Comment**		**Status**
13	22	5.4	Substantial inflows from the north via the Jacks Point development will enter the northern and western drainage channels as sketched out in the figure below. Can you clarify why this was not considered in the development of this model?  Figure 5.1: HEC-RAS 2D model area (calculation area boundary shown as a dashed red line)	The scope of this report is flooding hazard from the catchment upslope of the eastern property boundary. Drainage from Jacks Point and from within the development (Lot 8 and Lot 12) are considered by Stantec in the design of the diversion channels and stormwater infrastructure. Comment added to Section 5.5.3.	Noted, although it is recommended that the comment "*Design iteration will be undertaken to ensure the diversion channels have sufficient capacity for stormwater from all sources by Stantec* ." be revisited. Although this hazard assessment does address the flooding hazards from the upslope eastern catchments in detail, it cannot fully assess the capacity or efficacy of the diversion channels, especially the Northern and Southern Diversion Channels and the capacity of the western conveyance channel without the inclusion of flows from the development site and the northern flow from Jack's Point if these are to be directed into these channels. This is especially pertinent to the northwestern corner where the confluence of flows will have an impact on flooding in that area. It appears as if Stantec will continue the flood assessment for the diversion channels and potential flooding impacts along the development boundaries. This should include the flows/hydrographs determined for the upslope eastern catchments from this report / model. We suggest that this message be strongly conveyed to clarify, and ensure that there will not be any scope gap.	Paragraph added to section 5.5.3 to clarify additional modelling requirements for diversion channels	Resolved
14	22-23	5.5.2	Can you provide clarification of layout and extent of Mannings n-values by including a drawing showing the n-value regions?	Example manning's n vaule layer added to Appendix F	Noted		Resolved
15	24	5.5.2	Can you clarify the correlation between the flood hazard curves in Figure 5.2 (H1-H6) and the terminology Moderate-Major-Minor used in the text?	Clarification added in Section 5.1	Noted		Resolved
16	26	5.5.3	Can you clarify whether the size of the northern diversion channel has been increased in the post development model?	Yes the post development hydraulic model uses the proposed widened northern diversion channel	Noted		Resolved
17	27	5.5.3	Can you support the minimum freeboard of 500mm in the diversion channels with cross sections and/or long sections, especially at critical locations along the channels?	Cross section added in lower (critical flatter area of northen diversion channel) to Section 5.6, figure 5.6.	We recommend that an Appendix be included showing a layout with profile lines at multiple locations in all of the diversion channels which shows results the water level in the channels, as this will demonstrate freeboard conditions are met under peak flow conditions. This is likely something that the Council would like to understand, as the current report does not provide that level of detail in the results. This could also provide additional clarification concerning the minor leakage from computational cells	Two additional cross sections have been included in Appendix F. We believe more cross sections at more locations, including the the channels along the the state highway could be beneficial to provide context and perspective of the channel size - peak flow - freeboard relationship, but also recognise that this will need to be demonstrated in detail design by Stantec.	To consider
18	27	5.5.3	Can you clarify how internal site drainage will interact with the diversion channels, especially the northern diversion channel. Is there an intention that on site drainage would drain into the channel, and has this been considered?	Internal site drainage and flow from Jacks Point to be assessed by Stantec	Noted, refer to the comment above under point 13.	Paragraph added to section 5.5.3 to clarify additional modelling requirements for diversion channels.	

SOLUTIONS

Date: 10-02-2025

			10-02-2025		13-03-2025	25-03-2025	Resolved
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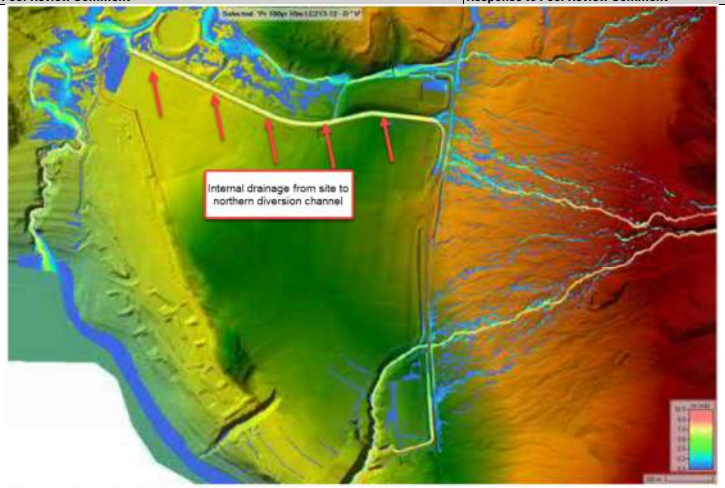
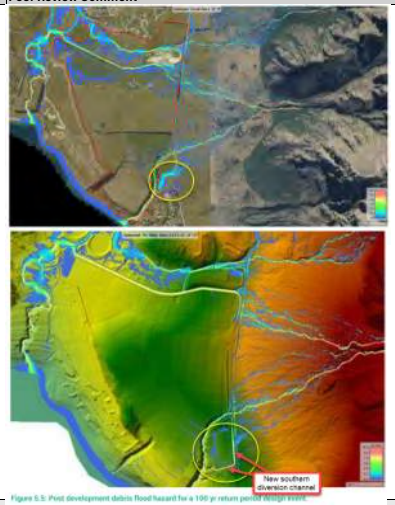
ID	**Page No**	**Section**	**Peer Review Comment**	**Response to Peer Review Comment**	**Peer Review Comment**		**Status**
			 Figure 5.5: Post development debris flood hazard for a 100 yr return period design event.				Resolved
19	26-27	5.5.3	Can you clarify whether rain on grid was included for 2D areas that is not covered by 1D modelled areas (HEC HMS), and why this has been excluded from the model, as there would be increased flows to for example the northern diversion channel?	No allowance for flow from inside the site or Jack's Point was allowed for in the model. Internal site drainage and flow from Jacks Point to be assessed by Stantec	Noted, refer to the comment above under point 13.	Paragraph added to section 5.5.3 to clarify additional modelling requirements for diversion channels	Resolved
20	27	5.5.3	Can you highlight the areas in Figure 5.5 that can be classified as "leaking" out of the diversions channels in the model as a result of the misaglinment of 2D cell faces.	Comment addeded to Figure 5.6	Noted, and as mentioned in point 17 having some cross sections in these areas included as results in an Appendix could assist in clarifying and this.	Two additional cross sections have been included in Appendix F. We believe more cross sections at more locations, including the the channels along the the state highway could be beneficial to provide context and perspective of the channel size - peak flow - freeboard relationship, but also recognise that this will need to be demonstrated in detail design by Stantec.	To consider
21	28	5.5.4	Can you clarify whether the increase in peak flow and timing of the peak flow will have an impact on the flooding extents in Jack's point, especially in the north-western confluence area where multiple flows will converge?	The increase in peak flow and timing as a result of diversion of flow from catchments upslope of the eastern boundary is negligble as detailed in Secion 5.6. Increases in flow from within the development boundary will be addressed by Stantec.	Noted, refer to the comment above under point 13.	Paragraph added to section 5.5.3 to clarify additional modelling requirements for diversion channels	Resolved
22	28	5.5.4	Can you clarify whether there is a change between pre- and post-development follow at the Outlet at road on south the southern boundary?	Comment added to Section 5.5.3 and 5.5.4	Noted		

SOLUTIONS

Date: 10-02-2025

Resolved	
To Consider	
Action Required	

			10-02-2025		13-03-2025	25-03-2025	
ID	**Page No**	**Section**	**Peer Review Comment**	**Response to Peer Review Comment**	**Peer Review Comment**		**Status**
							Resolved
Additional comment							
23	21	4.9			It appears that the time to peak remains the same between the two reports, including the reduction of the TC values. Can you confirm that the Time to peak indeed remains the same, or does this need to be updated as with the flow and volume data?	The	To consider

Fluent Infrastructure | Experience

Email office@fluentsolutions.co.nz
Accounts accounts@fluentsolutions.co.nz
Website www.fluentsolutions.co.nz

Ref: GL-25-03-27 GWF 000892.Docx

27 March 2025

RCL Homestead Bay Ltd
Level 1
13 Camp Street
QUEENSTOWN

Attention: Dan Wells

Dear Dan

Peer Review – Natural Hazards Assessment Homestead Bay

We have received and completed our peer review of the Geosolve report – *Natural Hazards Assessment Homestead Bay, Queenstown,* Rev 2, 19/03/2025.

We wish to reiterate that our peer review is limited to the following:

- Review of the hydrological assessment defining the anticipated flows from the upstream catchments resulting from the design storm. Please note that this does not include review of the hydrological model.
- Review of flood hazard calculations / assessment (by hydraulic flood modelling in HEC-RAS). Please note that this does not include review of the hydraulic model.
- Review of stormwater design inputs from the upstream catchments.
- Definition of the 100year and overdesign event flows.
- Review of peak flows for diversion design.

We hereby wish to confirm that we do not have any further comments other than those included in the memo, MEM-25-02-11-GF 000892, dated 11/02/2025 as well as the updated review register attached, dated 25/03/2025.

Yours faithfully
FLUENT INFRASTRUCTURE SOLUTIONS LTD
Per:

Gerhard Fourie
Senior Civil Engineer

Appendix I WSP Review of Natural Hazards Assessment

17 March 2025

Dan Wells
RCL Group
Level 1
13 Camp Street
Queenstown

Homestead Bay - Natural Hazards

6-XZ801.00_GEO_LET_001

Dear Dan,

Further to your recent instruction we have now completed an independent peer review of the Natural Hazard assessment completed by Geosolve Ltd associated with the subdivision consent application for the Homestead Bay development.

As part of the review we have assessed information provided by RCL Group and Geosolve as well as through discussion with both parties.

A site walkover was not required for this review as WSP had previously visited the site on other recent review work and had completed similar reviews on adjoining properties.

The review was therefore primarily based on the following provided information:

1) Natural Hazard Assessment – Geosolve Ltd, ref 220556.02 dated 17/01/2025 rev 1

2) Geotechnical Assessment – Geosolve Ltd, ref 220556.01 dated 24/01/2025 rev 1

The scope of work consisted of an independent review of the methodology and approach taken to the identification of the likely natural hazards present within close proximity to the development site. A review of the likely risks and associated mitigation measures required to safeguard future development in accordance with the current Otago Regional Council (ORC) Policy Statement APP6, QLDC Operative District Plan and, where appropriate, the QLDC Land Development and Subdivision Code of Practice, was also completed.

In addition to the WSP review, Fluent Solutions have completed a review of the flood assessment analysis completed for the site.

Based on the peer review comments from both Fluent Solutions and WSP, Geosolve have now amended and updated the hazard assessment and associated recommendations. Comments and observations raised through the process have been addressed and included in the final version of the Natural Hazard Assessment report (rev 2) issued in March 2025.

As part of the review completed by WSP, key hazards commonly associated with development sites located within alluvial fan zones in the Queenstown Lakes District were considered. These typically included assessment of landslide, rockfall (including rock avalanche), debris flow, flood, liquefaction and occurrence of soft soils. In addition, lake based hazards such as high water flood and lake seiche were also considered, however these were of no concern due to site elevation levels.

Following the review of the key hazards and further to a feedback process involving both Fluent Solutions and Geosolve Ltd, the assessment concluded that the risks posed by natural hazards to the proposed residential development site are, overall, acceptable, provided that the proposed flood mitigation measures are appropriately designed and implemented.

WSP
Alexandra
Tarbert Buildings
69 Tarbert Street
Alexandra 9320, New Zealand
+64 3 440 2400
wsp.com/nz

An assessment of debris flow occurrence identified that the southern and middle alpine catchments could produce debris flow events capable of reaching the sites eastern boundaries however the maximum credible run outs had to adopt very conservative flow mobility parameters. On this basis the proposed flood mitigation measures were considered appropriate to mitigate any potential impact on the sites eastern margins from hyper concentrated muddy-flow events.

The qualitative assessments completed in accordance with the ORC APP6 methodology all concluded that quantitative risk assessment was not required for any hazard considered.

Based on the assessments completed and the conclusions drawn we consider the natural hazards assessment has followed an appropriate and current best practice methodology and that the hazard extents have been appropriately mapped and investigated in order to inform a qualitative assessment of risk posed to the development.

We concur with the observations and comments of Fluent Solutions with respect to flood risk and agree with the approach and conclusions reached by Geosolve in that alluvial fan hazards present an acceptable level of risk to the proposed development.

It is recommended that the proposed flood mitigation measures are adhered to and implemented as part of the final design.

We trust the above is sufficient for your present requirements.

Regards

Rob Bond
Technical Principal - Geotechnical Engineering

Appendix J Power and Telecommunications Availability Confirmations

Chorus NZ Ltd
4 Graham Street
Auckland CBD
Auckland

Dan Wells
Project Manager
RCL Group
Queenstown

10Th March 2025

Hi Dan,

Thank you for providing an indication of your development plans in this area. I can confirm that UFB fibre reticulation has been provided to the boundary of all lots.

Chorus will be able to extend our network to provide connection availability to Lot 12 Deposited Plan 364700 and Lot 8 Deposited Plan 443832, Homestead Bay, Queenstown**".**

However, please note that this undertaking would of course be subject to Chorus understanding the final total property connections that we would be providing, roll-out of property releases/dates and what investment may or may not be required from yourselves and Chorus to deliver the infrastructure to and throughout the site in as seamless and practical way as possible.

The costs involved can only be finalised at the time that you are ready to proceed.

Chorus is happy to work with you on this project as the network infrastructure provider of choice. What this ultimately means is that the end customers (business and home owners) will have their choice of any retail service providers to take their end use services from once we work with you to provide the physical infrastructure.
Please reapply with a detailed site plan when you are ready to proceed.

Thanks

Kind Regards,

Danny Masterson
Business Development Manager
021849233
Chorus NZ Ltd

251 Racecourse Road, PO Box 1642,
Invercargill 9840, New Zealand
P: 03 211 1899
F: 03 211 1880
E: enquiries@powernet.co.nz

Ref: RCL – Homestead Bay

10th March 2025

rcl Group
Level 1, 13 camp Street
Queenstown 9300

Attention: Dan Wells

Dear Dan

Provision of Electrical Supply – Homestead Bay, DP364700 & DP443832, Kingston Road, Queenstown 9371,

Please accept this letter as notification that PowerNet Limited on behalf of Lakeland Network Limited, can confirm there is satisfactory high voltage electricity network reticulation in the area, for development of the proposed site.

This will allow for connections from 15kVA single phase to larger three phase supplies as required, of the new development once electrically designed.

Yours faithfully

PJChittock

Phil Chittock
Network Engineer (Queenstown)
45 Brookes Road, Frankton, Queenstown, PO Box:1642, Invercargill 9840, New Zealand
Email: PChittock@powernet.co.nz, Mobile:+64 27 229 3119

Stantec is a global leader in sustainable engineering, architecture, and environmental consulting. The diverse perspectives of our partners and interested parties drive us to think beyond what's previously been done on critical issues like climate change, digital transformation, and future-proofing our cities and infrastructure. We innovate at the intersection of community, creativity, and client relationships to advance communities everywhere, so that together we can redefine what's possible.

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