Milford Opportunities

MILFORD OPPORTUNITIES PROJECT

GEOTECHNICAL FEASIBILITY

24 APRIL 2024 CONFIDENTIAL

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GEOTECHNICAL FEASIBILITY

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0	2024-02-28	DRAFT – Client Comments
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EXECUTIVE SUMMARY

The Milford Opportunities Project (MOP) involves exploring ways to do tourism differently at Milford Sound Piopiotahi. The MOP has reviewed the current facilities along the Milford Road corridor and generated a Masterplan to improve the experience for the benefit of people and place.

The MOP has been through two stages up to this point and is currently undergoing an Engineering Feasibility Assessment as part of Stage 3 of the project. The feasibility assessment aims to assess the risks to each of the identified hubs, nodes, and short stops (referred to as sites) identified as places for development in the Masterplan. The feasibility assessment includes multiple disciplines, such as natural hazards and climate change, and considers many aspects that may affect the feasibility of each site.

This report covers the Geotechnical Feasibility Assessment for the development of each site, and comments are limited to the topic of ground conditions and risks associated with them. To complete the assessment, information was collected from various sources, including a site visit, and publicly available information. Additional commentary on constructability of foundation options has been included for some of the structures identified in the Masterplan.

The upgrades proposed in the Masterplan for the sites have been assessed as being geotechnically feasible, based on our assumptions of structure type and use, Importance Level, foundation type, and ground conditions. This report also offers broad comments on the possible cost implications involved with investigation, design and construction of the foundation solutions in the more challenging sites. At a high level, any of the structures assessed to be an Importance Level 4 structure (natural hazard refuges) will require significant foundations that are designed to protect the building and all occupants during and after a serious natural hazard event. The foundation solutions for these cases will likely have increased costs associated with the geotechnical investigation, design and construction, when compared to other structures with a lower Importance Level proposed in the Masterplan.

Preliminary geotechnical investigation recommendations have been prepared for each of the MOP sites. These recommendations are based on the assumed ground conditions and the structures proposed in the Masterplan. In addition, guidance has been taken from Earthquake Geotechnical Engineering Module 2[1]. Once the final layout and structure details for the site are more clearly understood, the preliminary ground investigation recommendations should be revisited to check that they are still fit for purpose.

A summary of the geotechnical feasibility of each structure located at the hubs, nodes and short stops is presented in Table 1 below. The following terms are used as high-level guides for the Geotechnical Investigation, Geotechnical Design and the Construction Complexity for the foundations.

Geotechnical Investigations	Simple (Shallow Investigation – Scala, HA, TP and DPSH)
	Standard (BH, DPSH, and CPT)
	Low Complexity (BH, CPT, and Downhole Seismic/MASW)

[1] Earthquake Geotechnical Engineering Module 2 – Geotechnical Investigations for Earthquake Engineering, MBIE & NZGS, Nov 2021

	High Complexity (larger scope of BH, CPT, Downhole Seismic/MASW, and site-specific seismic hazard assessments) Other (tailored investigation)

Geotechnical Investigation Methods

CPT	Cone Penetration Test
BH	Borehole
DPSH	Super Heavy Dynamic Probe
Scala	Scala Penetrometer Test
HA	Hand Auger
MASW	Multichannel Analysis of Surface Waves
TP	Test Pit

Geotechnical Design	Simple (Importance Level (IL) 1 or IL N/A) Standard (IL2) Low Complexity (IL3) High Complexity (IL4) Other (outside of Building Code)
Construction Complexity (Foundations)	Simple (Pavement) Standard (Timber Piles, Shallow Strip or Spread Foundations) Low Complexity (Piles, Reinforced Soils) High Complexity (Pile, Deep Ground Improvements, Rock Anchors)

Table 1: MOP Geotechnical Feasibility Summary

Name - Facility	Geotechnical Feasibility	Assumed Liquefaction Potential	Geotechnical Investigation	Geotechnical Design	Construction Complexity (foundations)
Te Anau – Visitor Centre	Feasible (location dependant)	Town Centre – Negligible to Low Foreshore – Medium or higher	Town Centre – Standard Foreshore – Low Complexity	Town Centre – Standard Foreshore – Low Complexity	Town Centre – Standard Foreshore – Low Complexity
Te Anau – Transport Interchange	Feasible (location and option dependant)	Town Centre – Negligible to Low Foreshore – Medium or High	Town Centre & Single-Storey – Simple Foreshore & Single-Storey – Standard Town Centre & Multi-Storey – Low to High Complexity Foreshore & Multi-Storey – High Complexity	Town Centre & Single-Storey – Simple Foreshore & Single-Storey – Standard Town Centre & Multi-Storey – Low to High Complexity Foreshore & Multi-Storey – High Complexity	Town Centre & Single-Storey – Simple Foreshore & Single-Storey – Standard Town Centre & Multi-Storey – Low to High Complexity Foreshore & Multi-Storey – High Complexity
Te Rua-o-Te-Moko Fiordland National Park Gateway	Feasible	Negligible	Simple	Simple	Simple
Mirror Lakes Waiwhakaata – Bus Shelter & Facilities	Feasible	Negligible	Simple	Simple	Simple
Eglinton Reveal – Visitor Shelter	Feasible	Low	Standard	Standard	Standard
Eglinton Reveal – Carpark	Feasible (option dependant) - challenging	Low	Single-Storey – Simple Multi-storey – Low to High Complexity	Single-Storey – Simple Multi-storey – Low to High Complexity	Single-Storey – Simple Multi-storey – Low to High Complexity
Eglinton Reveal – Access Restriction Point	Feasible	Low	Standard	Standard	Standard
Knobs Flat Te Huakaue & Kiosk Creek – Accommodation Expansion	Feasible – challenging	Low to High	Low to High Complexity	Low to High Complexity	Low to High Complexity
Knobs Flat Te Huakaue & Kiosk Creek – Camping and Campervan Layout	Feasible	Low to High	Simple	Simple	Simple

Name - Facility	Geotechnical Feasibility	Assumed Liquefaction Potential	Geotechnical Investigation	Geotechnical Design	Construction Complexity (foundations)
Knobs Flat Te Huakaue & Kiosk Creek – Carpark	Feasible (option dependant) - challenging	Low to High	Single-Storey – Simple Multi-storey – Low to High Complexity	Single-Storey – Simple Multi-storey – Low to High Complexity	Single-Storey – Simple Multi-storey – Low to High Complexity
Knobs Flat Te Huakaue & Kiosk Creek – Accommodation at Kiosk Creek	Feasible – challenging	Low to High	Low to High Complexity	Low to High Complexity	Low to High Complexity
Knobs Flat Te Huakaue & Kiosk Creek – Trail Head Facilities	Feasible	Low to High	Simple to Standard	Simple to Standard	Simple to Standard
Cascade Creek – Flood Protection Infrastructure	Feasible	Medium	Other	Other	Standard to Low Complexity
Cascade Creek Ōtāpara – Camping and Campervan Sites	Feasible	Medium	Simple	Simple	Simple
Cascade Creek Ōtāpara – Bus Shelter	Feasible	Medium	Simple	Simple	Simple
Cascade Creek Ōtāpara – Toilet Facilities	Feasible	Medium	Simple	Simple	Simple
Cascade Creek Ōtāpara – Facilities for Kayaking	Feasible	Medium	Simple	Simple	Simple
Hinepipiwai Lake Marian Trails Head – Visitor Shelter & Facilities	Feasible	Negligible to Medium	Low Complexity	Low Complexity	Low Complexity
Hinepipiwai Lake Marian Trails Head – Wānanga (Living Classroom)	Feasible	Negligible to Medium	Low Complexity	Low Complexity	Low Complexity
Hinepipiwai Lake Marian Trails Head – Carpark	Feasible	Negligible to Medium	Simple	Simple	Simple
The Divide – Visitor Shelter	Feasible	Low	Standard	Standard	Standard
The Divide – Carpark	Feasible	Low	Simple	Simple	Simple
Gertrude Valley – Flood Protection Infrastructure	Feasible	Negligible to Low	Other	Other	Standard

Name - Facility	Geotechnical Feasibility	Assumed Liquefaction Potential	Geotechnical Investigation	Geotechnical Design	Construction Complexity (foundations)
Gertrude Valley – Visitor Shelter	Feasible	Negligible to Low	Standard	Standard	Standard
Gertrude Valley – Carpark	Feasible	Negligible to Low	Simple	Simple	Simple
Gertrude Valley – Trail Head Facilities	Feasible	Negligible to Low	Simple	Simple	Simple
Cleddau Cirque – Rockfall Refuge	Feasible – challenging	Low	High Complexity	High Complexity	High Complexity
Cleddau Cirque – Carpark	Feasible	Low	Simple	Simple	Simple
The Chasm – Carpark	Feasible	Low	Simple	Simple	Simple
The Chasm – Bus Shelter	Feasible	Low	Simple	Simple	Simple
The Chasm – Toilet Facilities	Feasible	Low	Simple	Simple	Simple
Milford Sound Piopiotahi – Visitor Accommodation	Feasible – challenging	High	High Complexity	High Complexity	High Complexity
Milford Sound Piopiotahi – Staff Accommodation	Feasible – challenging	High	High Complexity	High Complexity	High Complexity
Milford Sound Piopiotahi – Visitor Hub	Feasible – challenging	High	High Complexity	High Complexity	High Complexity
Milford Sound Piopiotahi – Carpark Relocation (see Deepwater Basin Carpark)	Feasible - challenging	See Deepwater Basin Carpark	See Deepwater Basin Carpark	See Deepwater Basin Carpark	See Deepwater Basin Carpark
Milford Sound Piopiotahi – Barren Peak Spur Treetop lookout	Feasible	High – low elevations Negligible – higher elevations	Simple	Walkway – Simple Lookout – Low Complexity	Walkway – Simple Lookout – Low Complexity
Milford Sound Piopiotahi – Covered Walkways	Feasible	High	Simple	Simple	Simple
Milford Sound Piopiotahi – Foreshore Engagement	Feasible	High	Simple	Simple	Simple

Name - Facility	Geotechnical Feasibility	Assumed Liquefaction Potential	Geotechnical Investigation	Geotechnical Design	Construction Complexity (foundations)
Freshwater Basin Node – Cable Car	Feasible – challenging	High – low elevations Negligible – higher elevations	High Complexity to Other	High Complexity to Other	High Complexity
Freshwater Basin Node – Bowen Falls/Valley Walk	Feasible	High – low elevations Negligible – higher elevations	Simple	Simple	Simple
Freshwater Basin Node – Bowen Falls Viewing Platforms	Feasible	High – low elevations Negligible – higher elevations	Simple	Standard	Standard
Freshwater Basin Node – Pontoon Walkway	Feasible – possibly challenging	Southeast – High Northwest – Negligible to High	Low Complexity	Low Complexity	Low Complexity
Freshwater Basin Node – Refuge	Feasible – challenging	High	High Complexity	High Complexity	High Complexity
Freshwater Basin Node – Boat Terminal Redevelopment	Feasible – challenging	High	Low to High Complexity	Low to High Complexity	Low to High Complexity
Deepwater Basin – Carpark	Feasible	High	Simple	Simple	Simple
Deepwater Basin – Boat Ramp	Feasible	High	Simple	Simple	Simple
Deepwater Basin – Kayaking Facilities	Feasible	High	Simple	Simple	Simple
Deepwater Basin – Refuge	Feasible – challenging	High	High Complexity	High Complexity	High Complexity
Deepwater Basin – Heliport	Feasible	High	Standard	Standard	Standard
Cleddau Delta Node – Viewing Decks	Feasible	High	Standard to low Complexity	Standard	Standard
Cleddau Delta Node – Refuge	Feasible – challenging	High	High Complexity	High Complexity	High Complexity
Cleddau Delta Node – Delta Link Bridge	Feasible	High	Standard to low Complexity	Standard to low Complexity	Standard to low Complexity

Name - Facility	Geotechnical Feasibility	Assumed Liquefaction Potential	Geotechnical Investigation	Geotechnical Design	Construction Complexity (foundations)
Little Tahiti -Staff Accommodation (Alt)	Feasible – challenging	Medium	High Complexity	High Complexity	High Complexity
Little Tahiti – Heliport (Alt)	Feasible	Medium	Standard	Standard	Standard

1 PROJECT BACKGROUND

1.1 MILFORD OPPORTUNITIES PROJECT MASTERPLAN

The Milford Opportunities Project (MOP) involves exploring ways to do tourism differently at Milford Sound Piopiotahi and along the Milford Road corridor for the benefit of people and place. To develop the Milford Opportunities Project Masterplan (Masterplan), the MOP has been through two stages, and is currently in the Third Stage Phase 1, which this report forms part of. The project stages are as follows:

- Stage 1: Establishing context, vision and objectives (completed in September 2018).
- Stage 2: Consultation, engagement and research to develop a Milford Opportunities Masterplan from Stage 1 (Masterplan launched in July 2021).
- Stage 3:
  - Phase 1 – Testing the feasibility of the Masterplan's recommendations.
  - Phase 2 – Planning, design and implementation.

1.2 MILFORD OPPORTUNITIES PROJECT STAGE 3

The MOP is currently moving through Stage 3 Phase 1, testing the feasibility of upgrades to the Milford corridor that are included in the Masterplan across multiple disciplines. The Masterplan outlines proposed additions to each hub, node or shortstop from Te Anau to Milford Sound Piopiotahi. The locations of the hubs, nodes or shortstops are shown in Figure 1 below and the proposed structures from the Masterplan are presented in Table 2, Section 2.

This report summarises the geotechnical conditions of each site, based on our current knowledge. For Stage 3 Phase 1 it was deemed appropriate to complete a high-level assessment based on existing information and a site tour – i.e., no geotechnical investigations have been completed at this stage.

Information about each site was collected from the site tour (completed 20 November 2023), existing geotechnical reports, and publicly available sources. A summary of the information reviewed for each of the sites is presented in Section 2.

Commentary regarding feasibility of the proposed structure, recommended geotechnical investigations required at each site, and initial comments on possible foundation solutions for the proposed structures is also provided in Section 2.

1.3 SCOPE OF WORKS

WSP scope of work for the Geotechnical Feasibility Report is as follows.

- Complete a desktop study of each node (as detailed in Table 2) to establish the likely geology of the area and specific areas of geotechnical interest that may impact on the proposed structures and services outlined in the MOP Master Plan.
- Commentary on the geotechnical feasibility of the proposed structures from the MOP Master Plan (as detailed in Table 1) for each site.

- Develop a schedule of minimum geotechnical testing requirements based on our current understanding of the proposed structures in the MOP Master Plan (as detailed in Table 4). The schedule will also include guidance on anticipated costs and an indicative length of programme.
- A desktop study of the site for the structures (as detailed in Table 6) for the MOP Walking & Cycling Feasibility Assessment to establish the likely geology of the area and specific areas of geotechnical interest that may impact on the proposed structures. A high-level assessment of the geotechnical feasibility of constructing the proposed structures.

During completion of the geotechnical feasibility report, Milford Opportunities provided the draft Beca Milford Sound Park and Ride Design Report[2]. Beca's report included assessments of parking at various nodes to support the proposed Park and Ride strategy outlined in the Masterplan. An exception to the scope of work was made to include assessment of this report as it proposed multi-storey carpark structures that were not included in the Masterplan. No other Stage 3 Phase 1 reports were assessed as they were outside of the scope of works.

[2] Milford Sound Park and Ride Design Report, Feasibility Study, February 2024, Beca Limited

Figure 1: Milford Opportunities Project - Hubs, Nodes and Short Stops Map[3]

1.4 SEISMIC HAZARD

1.4.1 NATIONAL SEISMIC HAZARD MODEL 2022

An updated National Seismic Hazard Model (NSHM, 2022) was recently released in New Zealand. The NSHM 2022 represents the latest scientific knowledge in earthquake hazard and is an important input to managing earthquake risk in the built environment[4]. A new draft Technical Specification TS 1170.5[5] was released for comment in February 2024, but it will be some time before TS 1170.5 is incorporated into the New Zealand Building Code.

[3] Milford Opportunities Project: A Masterplan for Milford Sound Piopiotahi and the Journey, May 2023 (A), Stantec, Boffa Miskell

[4] 2022 National Seismic Hazard Model Advisory (Rev 1), Oct 2022, SESOC, NZSEE, NZGS

[5] TS 1170.5: Structural Design Actions – Part 5 Earthquake Actions, February 2024, Standards New Zealand

Discussion regarding geotechnical feasibility in this report is based on geotechnical earthquake design parameters outlined in New Zealand Geotechnical Society (NZGS) Module 1[6], which incorporates findings of the NSHM 2022. Careful consideration will need to be given to the implications of TS 1170.5 on foundation and structural design during the next phase of this project.

1.4.2 ALPINE FAULT

The Alpine Fault is in close proximity to the various sites of the MOP. The closest sites located in Milford Sound Piopiotahi are approximately 18 km away, while the furthest site (Te Anau) is approximately 100km away. Latest scientific research[7] indicates that there is a 75% probability of an Alpine Fault earthquake occurring in the next 50 years, and there is an 80% chance that this would be a magnitude 8+ event.

Due to the proximity of the Alpine Fault trace to the site, all of the structures proposed by the Masterplan will be required to be designed to withstand greater seismic loading than in other regions in New Zealand. This will come at a greater cost of investigations, design and construction of structures at this location. Due to the significance of some of the structures (refuges) they will have additional requirements for investigation and design. This will include completing site-specific seismic hazard assessment to determine design inputs for both geotechnical and structural design. Foundation design will also need to carefully consider the impact that an Alpine Fault rupture will have on structure performance, including associated impacts such as liquefaction and lateral spreading of soils.

1.5 METHOD OF ASSESSMENT

Assessments in this report are based on a desktop study of available information and visual site observations only. This level of information is deemed appropriate for the feasibility study that is required at this stage, and the recommended investigations outline in Table 3, Section 3, have been informed by the result of desktop study.

A site tour of the Milford Corridor was completed on 20 November 2023 by a WSP Technical Principle Geotechnical Engineer and Contaminated Land Specialist with Simon Moran (Southland District Council). The site tour included stops at the following locations.

- Eglinton Reveal.
- Knobs Flat Te Huakaue & Kiosk Creek.
- Ōtāpara Cascade Creek.
- The Divide / Hinepipiwai Lake Marian Trails Head.
- Gertude Valley.
- Cleddau Cirque.
- Milford Sound Piopiotahi Visitor Hub.
- Freshwater Basin.

[6] Earthquake Geotechnical Engineering Practice: Module 1 – Overview of the Guidelines, Nov 2021, MBIE & NZGS

[7] AF8.org.nz

– Deepwater Basin.
– Cleddau Delta, and
– Little Tahiti (Milford Sound).

Te Rua-o-Te-Moko Fiordland National Park Gateway was driven through as part of the site tour, but the tour did not stop at this location as it was not safe to do so without traffic control.

Initial assessments of feasibility have been made based on the information above. Recommendations of further investigations have been made where appropriate.

2 HUBS, NODES & SHORT STOPS

The MOP Masterplan proposes to create a number of Hubs, Nodes and Short Stops (sites) between Te Anau and Milford Sound Piopiotahi along the Milford Road Corridor. These locations consist of new green field developments and modifications / additions to existing sites.

Table 2 lists the Hubs, Nodes and Short Stops from the MOP Masterplan that are part of this feasibility assessment. The table also lists some of the proposed facilities.

Table 2: MOP Masterplan Hubs, Nodes and Short Stops

Node	Name	Proposed Facilities
	Te Anau Hub	— Visitor Centre — Transport Interchange
1	Te Rua-o-Te-Moko Fiordland National Park Gateway	— Fiordland National Park Entrance
	Short stop: Mirror Lakes Waiwhakaata	— Bus shelter — Toilet Facilities
2	Eglinton Reveal	— Visitor Shelter — Carpark — Access Restriction Point
3	Knobs Flat Te Huakaue & Kiosk Creek	— Accommodation Expansion — Camping and Campervan Layout — Accommodation at Kiosk Creek — Short Walks – Trail Head Facilities
4	Ōtāpara Cascade Creek	— Flood Protection Infrastructure — Camping and Campervan Sites — Bus Shelter — Toilet Facilities — Facilities for Kayaking
5	The Divide / Hinepipiwai Lake Marian (the final location of this node is not yet decided)	— Lake Marian Visitor Shelter & Toilet Facilities — Lake Marian Wānanga (Living Classroom) — Lake Marian Carpark — The Divide Carpark — The Divide Visitor Shelter
6	Gertrude Valley	— Flood Protection Infrastructure — Visitor Shelter — Carpark — Gertrude Valley Walk – Trail Head Facilities
7	Cleddau Cirque	— Rockfall Refuge — Carpark
	Short stop: The Chasm	— Carpark — Bus Shelter — Toilet Facilities

Node	Name	Proposed Facilities
	Milford Sound Piopiotahi Visitor Hub	— Visitor Accommodation — Staff Accommodation — Visitor Hub Building — Bus Terminal — Carpark — Barren Peak Spur Treetop Lookout — Covered Walkways — Foreshore Engagements (viewing decks)
	Freshwater Basin Node (Milford Sound Piopiotahi)	— Cable Car or Similar Lift — Bowen Falls/Valley Walk — Bowen Falls Viewing Platforms — Bowen Falls Pontoon Walkway — Refuge — Redevelop the Boat Terminal
	Deepwater Basin Node (Milford Sound Piopiotahi)	— Carpark — Boat Ramp — Facilities for Kayaking — Refuge — Heliport
	Cleddau Delta Node (Milford Sound Piopiotahi)	— Water Viewing Decks — Refuge — Delta Link Bridge
	Little Tahiti (Milford Sound Piopiotahi)	— Staff Accommodation (alternate) — Heliport (alternate)

2.1 TE ANAU HUB

The following is noted of the Te Anau Hub:

- The Masterplan structures listed at this site are a visitor centre, a transport interchange including a possible carpark structure and possible town centre upgrades.
- Elevation: The town ranges approximately between 215 m Above Sea Level (ASL) to 250 m ASL.
- Closest active fault: Hauroko Fault, located approximately 20 km south.
- Geological Map Information: Te Anau is located within the mapped geological unit Holocene River Deposits (Unconsolidated gravel, sand, silt, clay, and minor peat of modern to postglacial flood plains, may be terraced). See Figure 2 below.
- Environment Southland Liquefaction Risk Map[8]: Medium Risk. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.
- No site visit has been completed.

[8] https://data-esgis.opendata.arcgis.com/datasets/esgis::southland-liquefaction-risk-2006-2012/explore

– Site location not yet selected – the Masterplan indicates site options could include; the town centre, on the town fringe or out of town, see Figure 3 below.

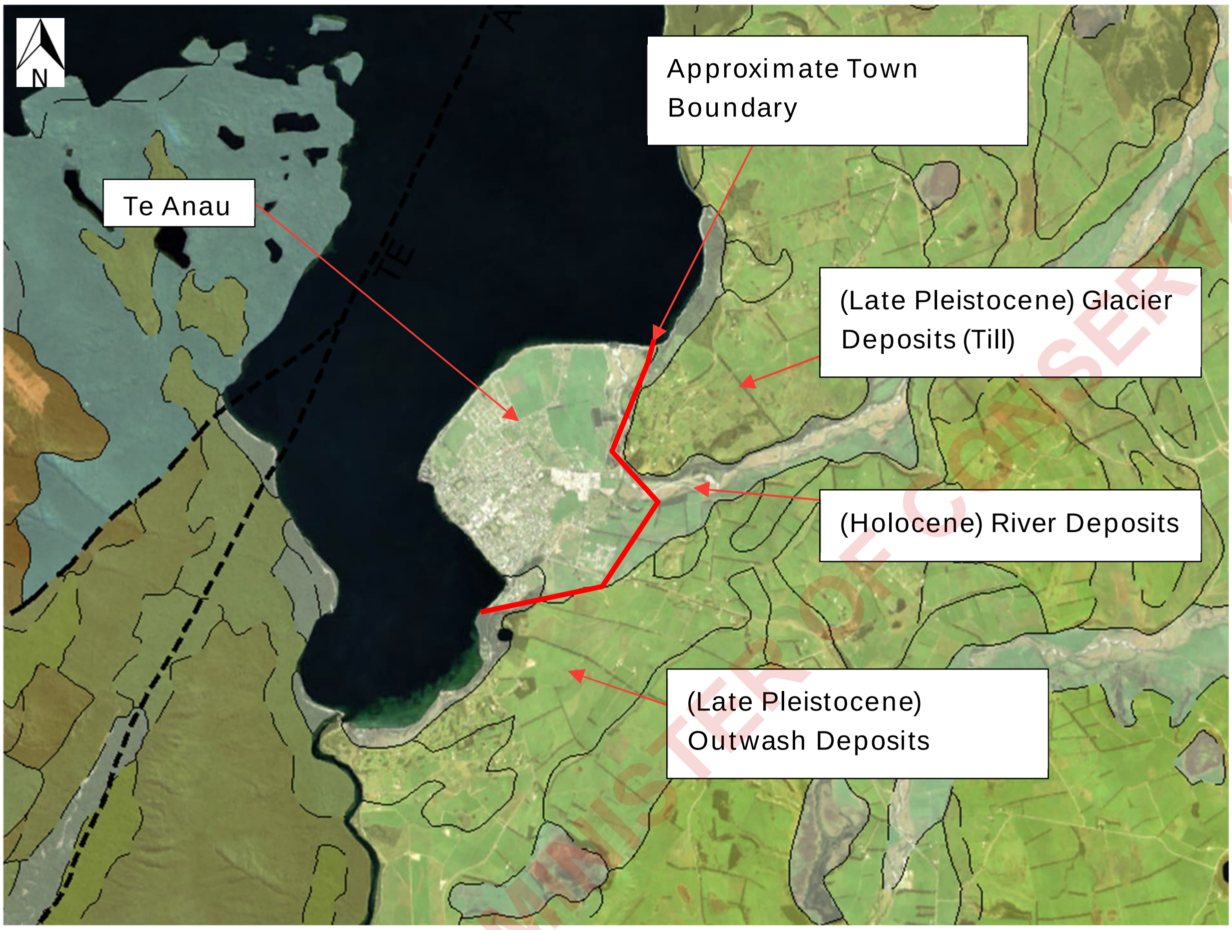

Figure 2: Te Anau – Published Geology[9]

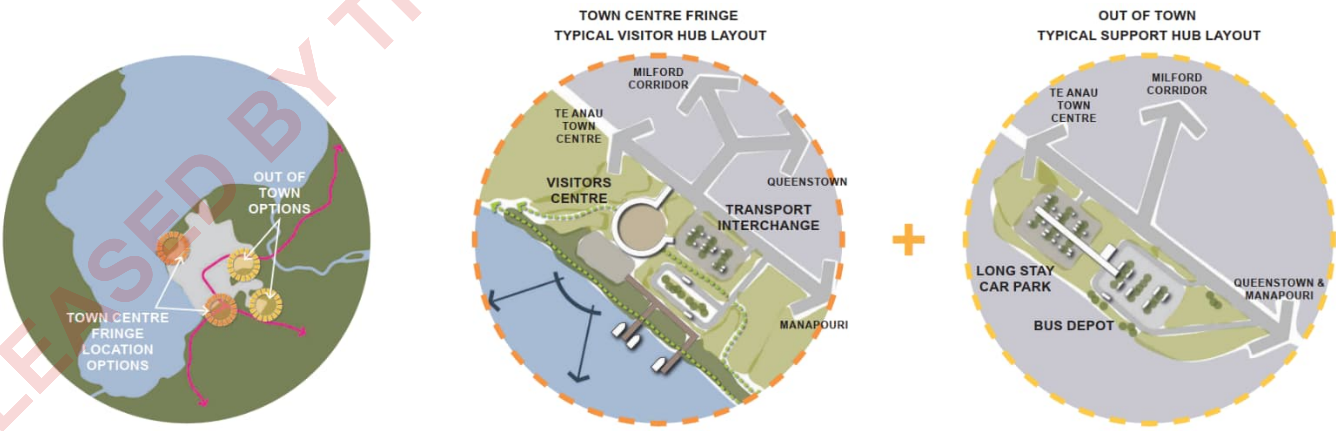

Figure 3: Te Anau Hub Locations and Concepts from Masterplan

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[9] https://data.gns.cri.nz/geology/

2.1.1 COMMENTARY ON FEASIBILITY OF PROPOSED STRUCTURES

There is limited publicly available geotechnical information available for Te Anau and the surrounding area. Logs from a geotechnical investigation completed at the Te Anau Primary School by GeoSolve were taken from the New Zealand Geotechnical Database[10]. The primary school is located northeast the town centre closer to the out of town hub locations. A single borehole and 9 test pits were completed around the school and extended to between 1.8m and 10.5m below ground level (bgl). The logs were consistent with the published geology, encountering very dense sandy Gravel to gravelly Sand. Ground water was encountered approximately 7.2m bgl.

Environment Southland liquefaction risk map lists Te Anau soils at a medium risk of liquefaction during a seismic event. However, the very dense soils and deep ground water at the primary school indicate a lower risk of liquefaction than the Environment Southland information. Soil conditions at other locations may not have the same very dense soils and shallower ground water levels, such as sites closer to Lake Te Anau and the Upukerora River. As such it is recommended that a site-specific geotechnical investigation that includes a liquefaction assessment is completed for the Te Anau Hub once the site has been selected.

In addition, the lake and river may also create a free face, where the soil and body of water meet, which may experience lateral spreading during a seismic event. Therefore, if the site is located near either the lake or river, the investigation should include an assessment of lateral spreading at the site.

Given the lack of available geotechnical investigation data it is not possible to determine if soils are likely to meet the definition of 'good ground' as defined in NZS3604:2011. However, simple, lightly loaded structures should be able to be designed and supported with shallow strip or spread footings. Shallow ground improvements may need to be considered depending on the actual ground conditions at the selected site. Ground investigation of the site will be required to confirm geotechnical parameters for design.

Multi-storey buildings or other more complex structures with higher loading requirements will require more complex foundation arrangements. Geotechnical investigations required to inform foundation design for these conditions will be more extensive when compared to simple structures. At this stage it has been assumed that most of the structures are single storey, simple, lightly loaded structures for the purpose of determining the proposed geotechnical investigation program in Section 3. The possible exception to this is the transport interchange which includes options for a parking structure up to three-storeys.

Beca issued a draft feasibility study report[11] of park and ride options for Milford Sound corridor in February 2024. The report proposes three options for carpark layouts at selected locations. These are a single-storey carpark, a two-storey structure, and a three-storey structure. A multi-storey carpark structure will require more complex foundations and consequently will involve a more detailed geotechnical investigation and complex design and construction. Shallow foundations (such as pad footings) may be suitable for the structures depending on ground conditions and final loadings. However, if ground conditions are poor and or loads exceed acceptable limits, deep foundations (piles) maybe required.

[10] https://www.nzgd.org.nz/

[11] Milford Sound Park and Ride Design Report, Feasibility Study, February 2024, Beca Limited

It should be noted that the cost difference between a single-storey carpark and a multi-storey parking structure will be significant both in investigation, design and construction costs. The geotechnical investigation costs between a two-storey and three-storey structure will be similar. The main difference in costs between a two-storey and three-storey structure will most likely be determined by whether the required foundations are shallow or deep. The design and construction costs for shallow foundations are generally less than for deep foundations.

Based on available information and development already present, it is geotechnically feasible to construct both simple, lightly loaded structures as well as more complex multi-storey structures within the Te Anau Town Centre. Once the final location, structure details are known, investigation and further assessment will be required to confirm the geotechnical feasibility and potential cost implications of constructing more complex structures.

2.2 NODE #1: TE RUA-O-TE-MOKO FIORDLAND NATIONAL PARK GATEWAY

The following is noted for Te Rua-o-Te-Moko Fiordland National Park Gateway:

- The Masterplan structures listed at this site are rows of pouwhenua on each side of the highway.
- Elevation: The site is approximately 300 m ASL.
- Closest active fault: Unnamed Fault #8429, located approximately 11 km northeast of the site.
- Geological Map Information: Site is located on the boundary between the following two mapped geological units, see Figure 4 below.
- Eastern Side Labelled: Boyd Creek Rock Formations (Discontinuous basal mudstone; thin-bedded graded sandstone, upper part is massive siltstone/mudstone with lenticular massive sandstone).
- Western Side Labelled: Outwash Deposits (Generally unweathered, well sorted, loose, sandy to bouldery gravel forming large terraces and outwash plains).
- Environment Southland Liquefaction Risk Map: Negligible Risk. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.
- Based on the MOP Masterplan concept, a site visit, and photographs the site is likely to be situated on outwash deposits. It should be noted that a culvert is located within the site that appears to drain the eastern side of the highway to the west. It is likely that either shallow ground water or overland water flow should be expected, see Photograph 1 below.

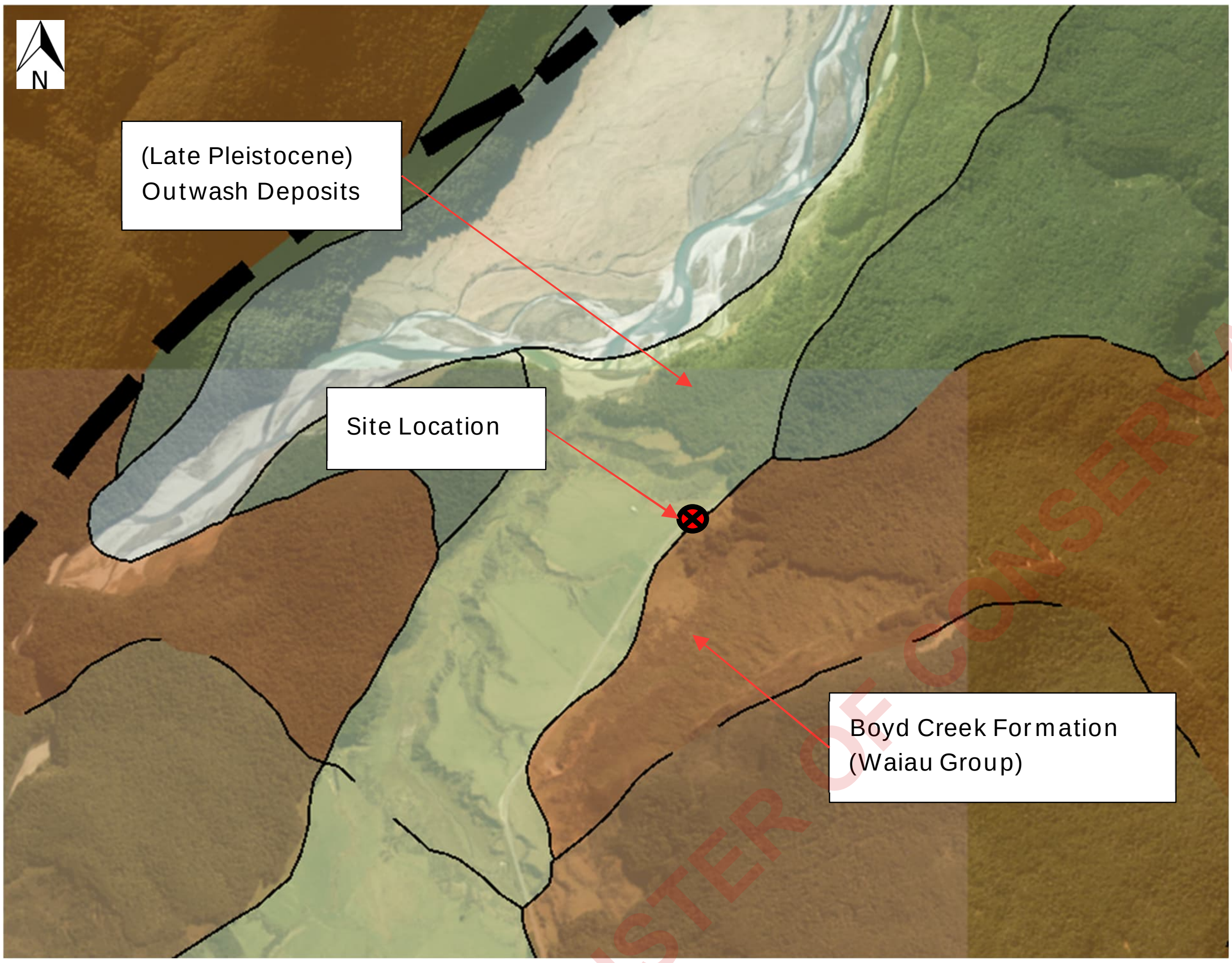


Figure 4: Te Rua-o-Te-Moko Fiordland National Park Gateway – Published Geology

Photograph 1: Te Rua-o-Te-Moko Fiordland National Park Gateway – Eastern side of the site (vegetation types appear to indicate wet ground conditions)[3]

2.2.1 COMMENTARY ON FEASIBILITY OF PROPOSED STRUCTURES

Based on the available information, the site soils likely consist of outwash deposits over bedrock at depth. The outwash deposits are likely to consist of sandy gravel. Photographs of the site show a culvert draining east to west. The culvert indicates possible wet ground conditions at various times of the year. Based on Environment Southland[8] mapping the site is considered to have a negligible liquefaction potential and available information indicates similar potential for liquefaction Given the structures will consist of a series of pouwhenua, it may be acceptable to repair / replace them after a seismic event, if liquefaction does occur.

Due to the shape, the foundation will have to also account for wind loading on the pouwhenua and foundation design will take this into account as part of the normal loading conditions.

Foundations for the pouwhenua could be either pad footings or piled foundations. The choice will be dependent on the soils present on site and the cost to mitigate seismic damages verse the costs to replace / repair the pouwhenua.

The development as shown in the MOP Masterplan, at this stage, is geotechnically feasible.

2.3 SHORT STOP: MIRROR LAKES WAIWHAKAATA

The following is noted for the Mirror Lakes Waiwhakaata:

- The Masterplan structures listed at this site are a bus shelter and toilet facilities.
- Elevation: the site is approximately 320 m ASL.
- Closest active fault: Unnamed Fault #8429, located approximately 2.4 km east of the site.
- Geological map information: Site is located on the boundary between the following two mapped geological units, see Figure 5 below:
- Underlying the road, carpark, and part of the walkway: Holocene fan deposits (Loose, commonly angular, boulders, gravel, sand and silt forming alluvial fans; grades into scree upslope) and valley alluvium.
- Underlying the mirror lakes themselves and part of the walkway: Holocene river deposits (unconsolidated gravel, sand, silt, clay and minor peat of modern to postglacial flood plains, may be terraced).
- Environment Southland Liquefaction Risk Map: Holocene Fan deposits listed as Negligible Risk, Holocene River deposits listed as Low Risk. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.
- Photographs from the earlier stages of the project indicate that the site is likely to be composed of flood plain sediment with saturated ground conditions. See Photograph 2 below.

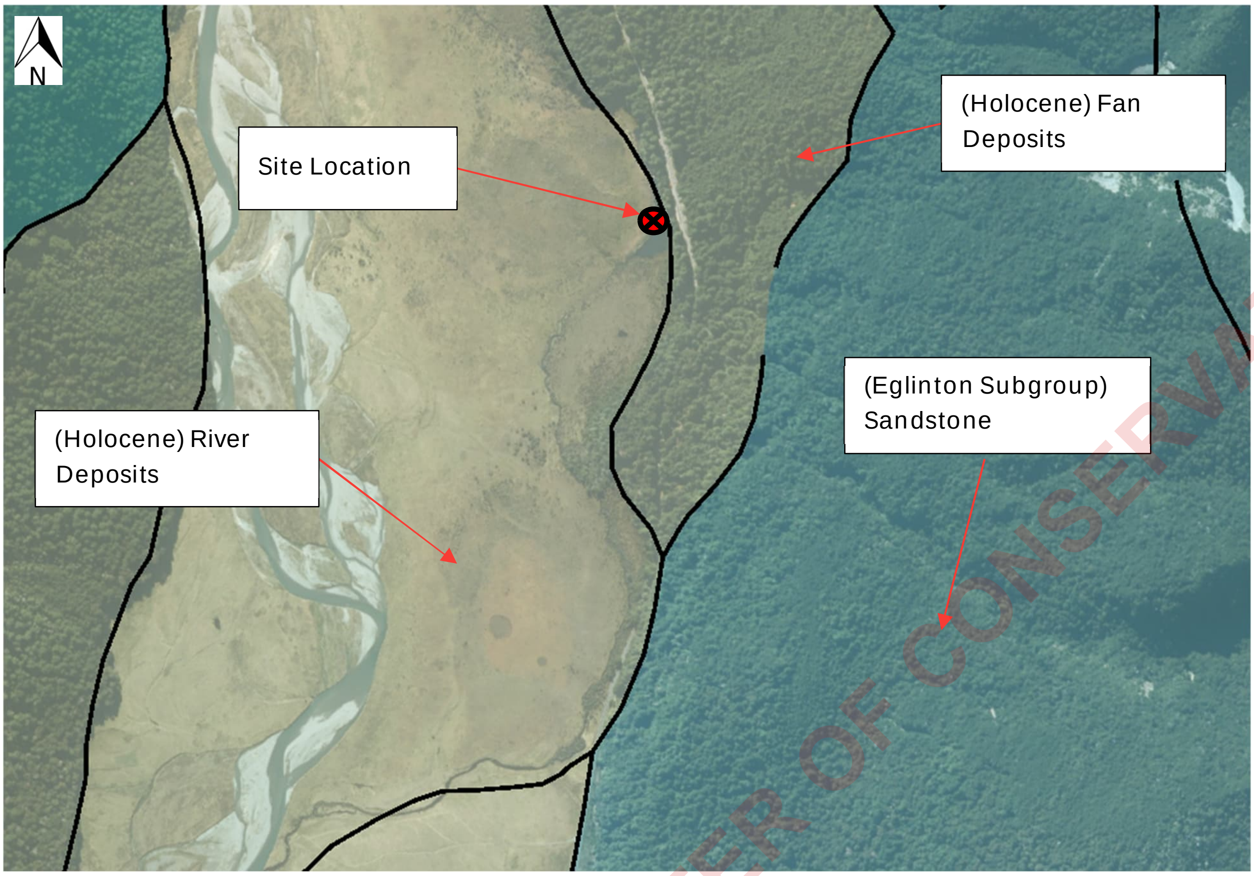
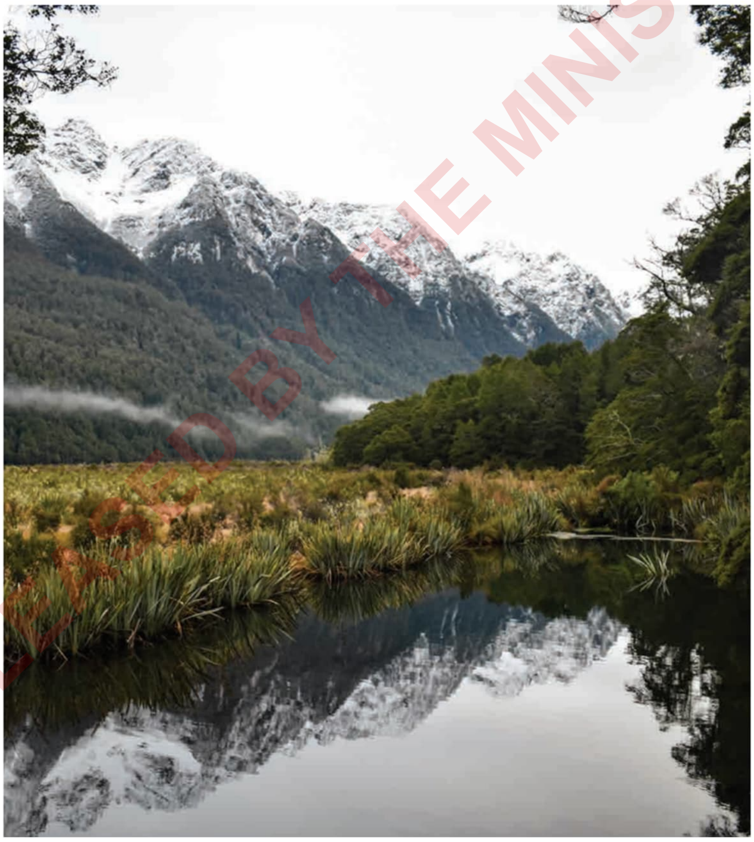


Figure 5: Short Stop: Mirror Lakes Waiwhakaata – Published Geology



Photograph 2: Short Stop: Mirror Lakes Waiwhakaata looking northwest across the Eglinton Valley (MOP Masterplan, 2021)

2.3.1 COMMENTARY ON FEASIBILITY OF PROPOSED STRUCTURES

Based on the Masterplan the proposed structures are to be located at the existing carpark. This is relatively close to the lake, but elevated above the lake, and ground water is assumed to be at a depth relative to the lake level. Site observations indicate that the carpark is founded on either the river deposits, and / or on the debris fan deposits with bedrock at depth. Based on the available information it is expected that the soils will have negligible to low liquefaction potential, and that lateral spread is unlikely to occur.

The river sediments and debris fan sediments are likely to comprise a wide distribution of grainsizes, from silt to gravel. In the debris fan deposits it is likely that the soils will also have cobbles and boulders present in varying quantities. The river and fan deposits are likely to be suitable for simple lightly loaded structures to be founded on. If large enough boulders are encountered additional effort may be required for excavation and construction to the required foundation depth.

Based on the MOP Masterplan, the proposed structures at this site include a bus stop, toilet facilities and interpretative displays. These structures will most likely be lightly loaded and may be founded on shallow strip or spread foundations. The expected soils at the site should have adequate bearing strength at relatively shallow depths to support structures of this type without piled foundations or significant ground improvement techniques.

The development as shown in the MOP Masterplan, at this stage, is geotechnically feasible.

2.4 NODE #2: EGLINTON REVEAL

The following is noted for the Eglinton Reveal node:

- The Masterplan structures listed at this site are a visitor shelter, a carpark, and an access restriction point.
- Elevation: the site is approximately 320 m ASL.
- Closest active fault: Unnamed Fault #8429, located approximately 4.3 km northeast of the site.
- Geological map information: Site is located within the mapped geological unit: Holocene fan deposits (Loose, commonly angular, boulders, gravel, sand and silt forming alluvial fans; grades into scree upslope) and valley alluvium. See Figure 6 below.
- Environment Southland Liquefaction Risk Map: Low Risk. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.
- Site visit and photographs indicate that the site is likely to be composed of alluvial fan sediment with ground water at shallow depth influenced by the river. See Photograph 3 below.

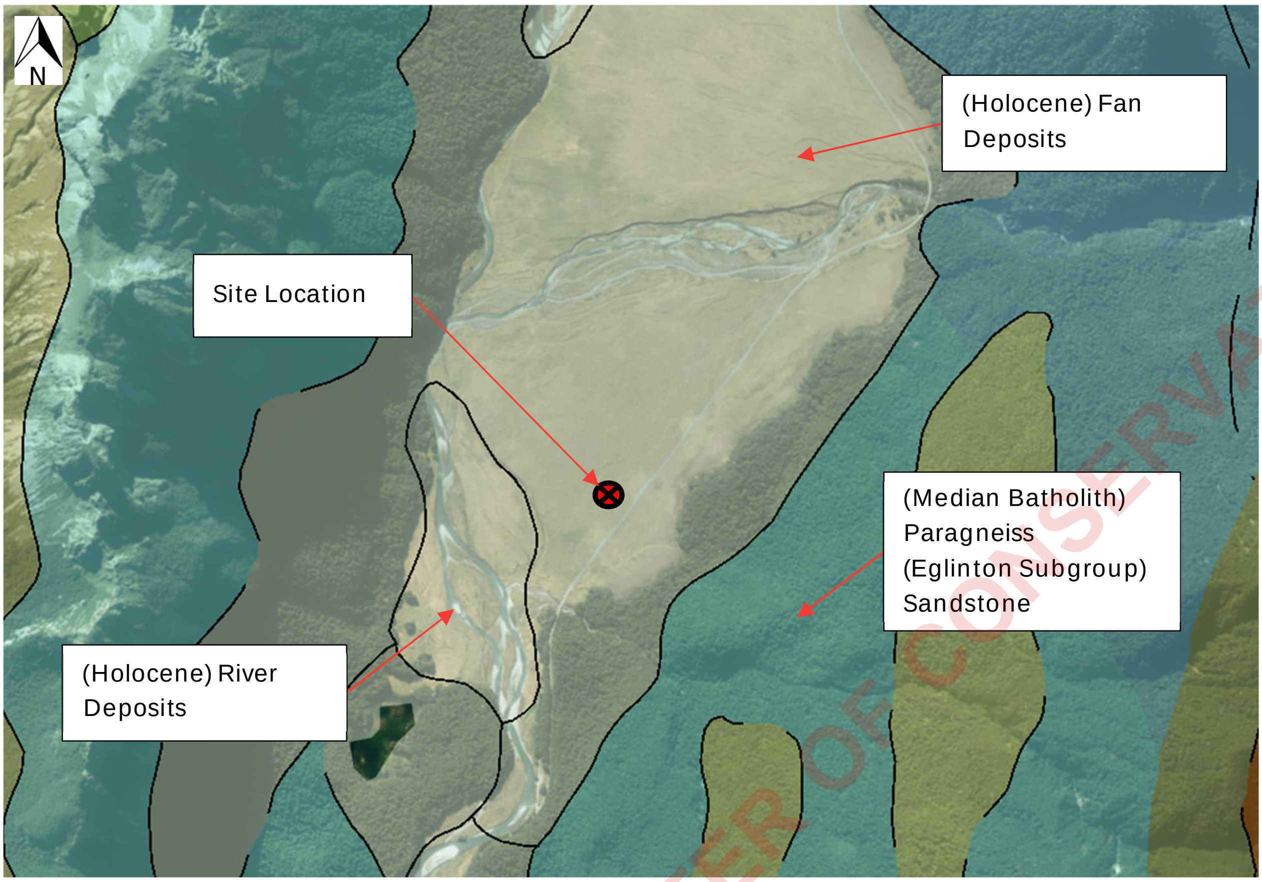


Figure 6: Eglinton Reveal – Published Geology

Photograph 3: Eglinton Reveal looking east (left) and north (right) from the proposed site location

2.4.1 COMMENTARY ON FEASIBILITY OF PROPOSED STRUCTURES

The site is likely underlain by alluvial fan deposits with bedrock at depth. The alluvial fan sediments are likely to comprise a wide distribution of grainsizes, from silt to gravel and cobbles. Based on the distance from the river, it is anticipated that groundwater will be encountered at shallow depths. At this stage the site is assumed to have a low liquefaction potential. Geotechnical investigation of the site will be required to confirm the soils onsite, whether groundwater is present at shallow depths and to determine if further liquefaction assessment of the site is necessary.

The proposed structures at this site include a visitor shelter with interpretative viewing areas, toilet facilities, and an access restriction point. Based on the published geology and our site observations, the soils assumed to be present at the site should have adequate bearing strength at or near the surface to support structures of this type (assuming an Importance Level (IL) 1[12]). These structures will most likely be simple lightly loaded and require shallow timber piles or shallow strip or spread foundations. It is not expected that structures will require deep piled foundations or significant ground improvements. If larger heavy structures are required, or the structures are of higher importance levels (IL2 or higher), then alternative foundations or ground improvements may be required.

The possible exception to this is the carparking at Eglinton Reveal. Beca's park and ride report[11] identified Eglinton Reveal as one of the park and ride locations. The report proposes three options for carparks layouts at select locations. These are a single-storey carpark, a two-storey structure, and a three-storey structure. A multi-storey carpark structure will require more complex foundations and consequently will involve a more detailed geotechnical investigation and more complex design and construction. Shallow foundations (such as pad footings) may be suitable foundation for the structures depending on ground conditions and final loadings. However, if ground conditions are poor and or loads exceed acceptable limits, deep foundations (piles) maybe required.

It should be noted that the cost difference between a single-storey carpark and a multi-storey parking structure will be significant in investigation, design and construction costs. The geotechnical investigation costs between a two-storey and three-storey structure will be similar. The main difference in costs between a two-storey and three-storey structure will most likely be determined by whether the required foundations are shallow or deep. The design and construction costs for shallow foundations are generally cheaper than deep foundations.

The development as shown in the MOP Masterplan, at this stage, is geotechnically feasible. Major determining factors for the feasibility of the site will be the Importance Level of the structures, the types of structures and their loading requirements, whether those structures need a liquefaction assessment, and the final site layout. Additional inputs from other disciplines may alter the site layout and geotechnical complexity.

2.5 NODE #3: KNOBS FLAT TE HUAKAUE & KIOSK CREEK

The following is noted for Knobs Flat Te Huakaue & Kiosk Creek

- The Masterplan structures listed at this site are an accommodation expansion, modifications to the camping and campervan layout, new accommodation at Kiosk Creek Te Huakaue and trail head facilities (refer Figure 9).
- Elevation: The site ranges from approximately 360 m to 370 m ASL.
- Closest active fault: Unnamed Fault, located approximately 6.5 km southeast of the site.

[12] AS/NZS 1170.0:2002. *Structural design actions Part 0: General Principles* (2002), Standards New Zealand

- Geological Map Information: Site is located within the mapped geological unit: Holocene fan deposits (loose, commonly angular, boulders, gravel, sand and silt forming alluvial fans; grades into scree (upslope) and valley alluvium), see Figure 7 below.
- Environment Southland Liquefaction Risk Map: Low Risk. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.
- A geotechnical investigation was completed by GeoSolve and issued as a draft in July 2019 for the Knobs Flat Te Huakaue site[13]. Note that the investigation did not include the Kiosk Creek area. The investigation consisted of 29 Test Pits (TP), 10 Super Heavy Dynamic Probe (DPSH) tests, 2 Scala Penetrometer Tests (Scala), 4 Sonic Boreholes (BH) and 1 Cored Borehole. The TPs were advanced to a maximum depth of 5.5m bgl and BHs to 20m bgl. See Figure 8 below.
- Results from the GeoSolve investigation generally align with the published geological mapping. GeoSolve noted the presence of man-made uncontrolled fill up to 0.8m depth encountered in Test Pits 1, 2, 3, 7 and 8 and BH04. Alluvial fan deposits appeared to be underlain by dense glacial till.
- GeoSolve's report, site visit and photographs indicate that the site has been disturbed by historical construction and earthworks. It is likely that uncontrolled fill has been placed over alluvial fan deposits, such as the parking lots. The site will also likely have deposits from the Kiosk Creek, which passes close to the east and north sides of the site. See Photograph 4 below.
- GeoSolve notes that the site has a liquefaction potential of low to major with significant variance across the site. GeoSolve also indicates that the site might experience lateral spreading. Liquefaction and lateral spreading is only expected occur in the alluvial river and fan deposits.

[13] *Geotechnical Report – Draft, Knobs Flat, Jul* 2019, GeoSolve

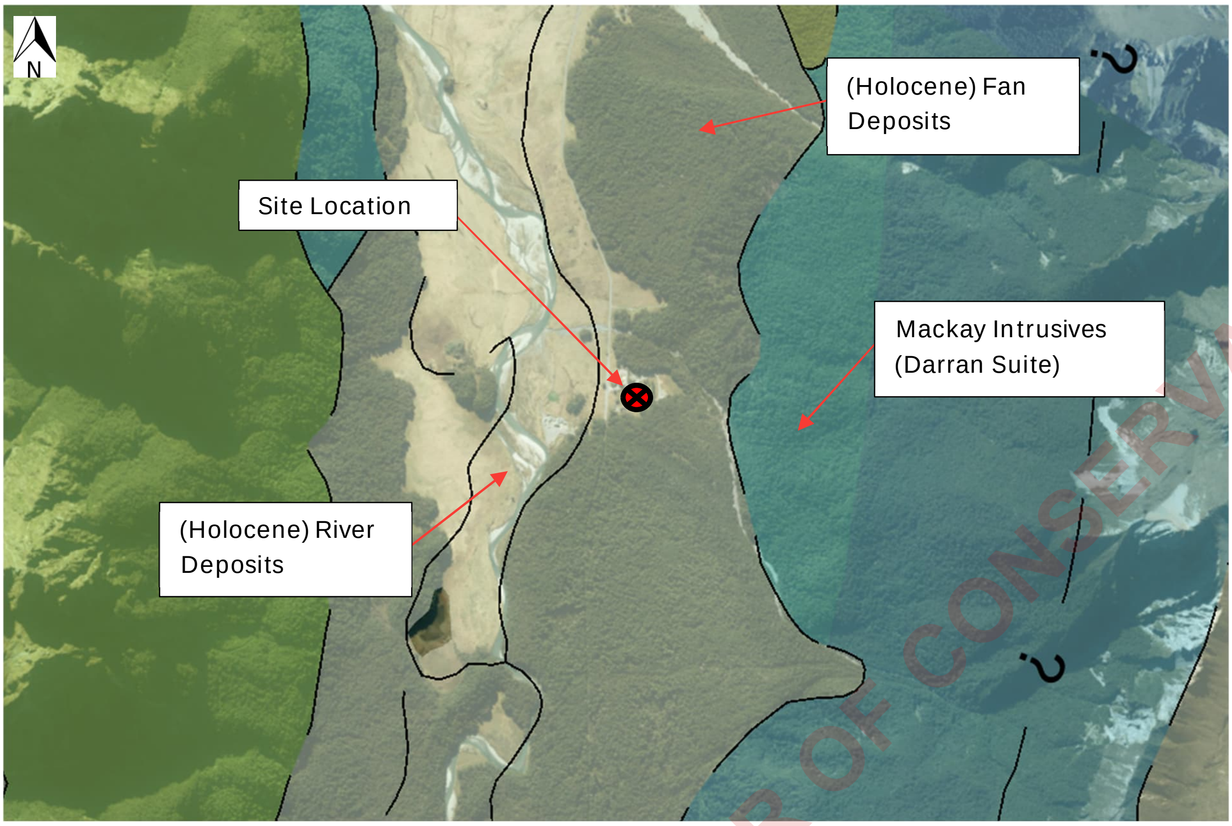


Figure 7: Knobs Flat Te Huakaue Kiosk Creek– Published Geology

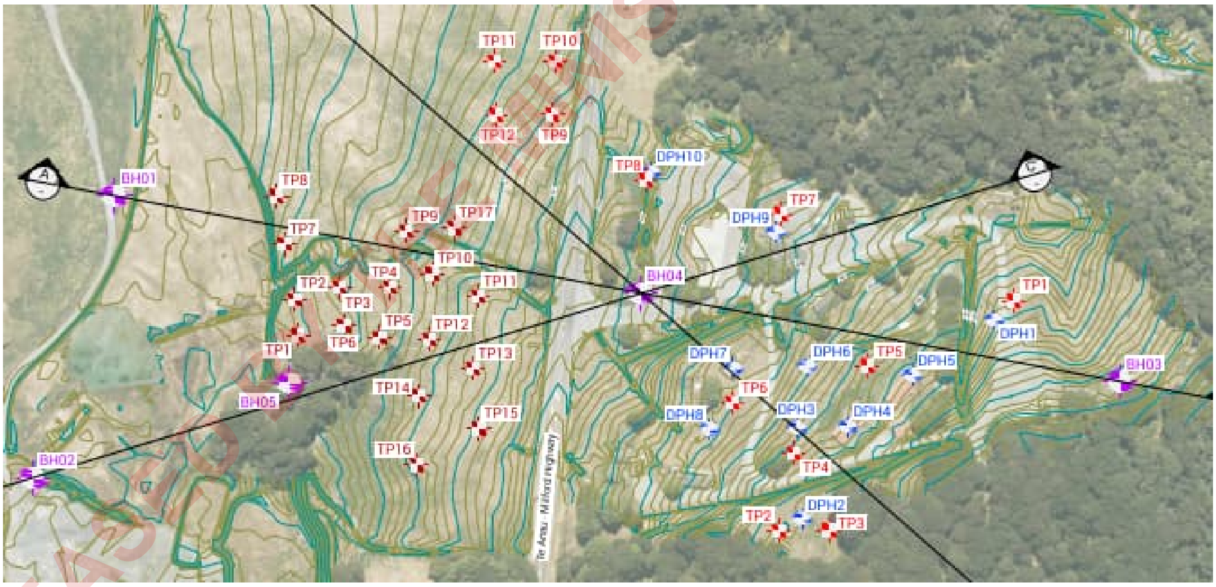


Figure 8: GeoSolve Map of their Geotechnical Investigation[13]

Photograph 4: Knobs Flat Te Huakaue parking lot with gravel stockpile

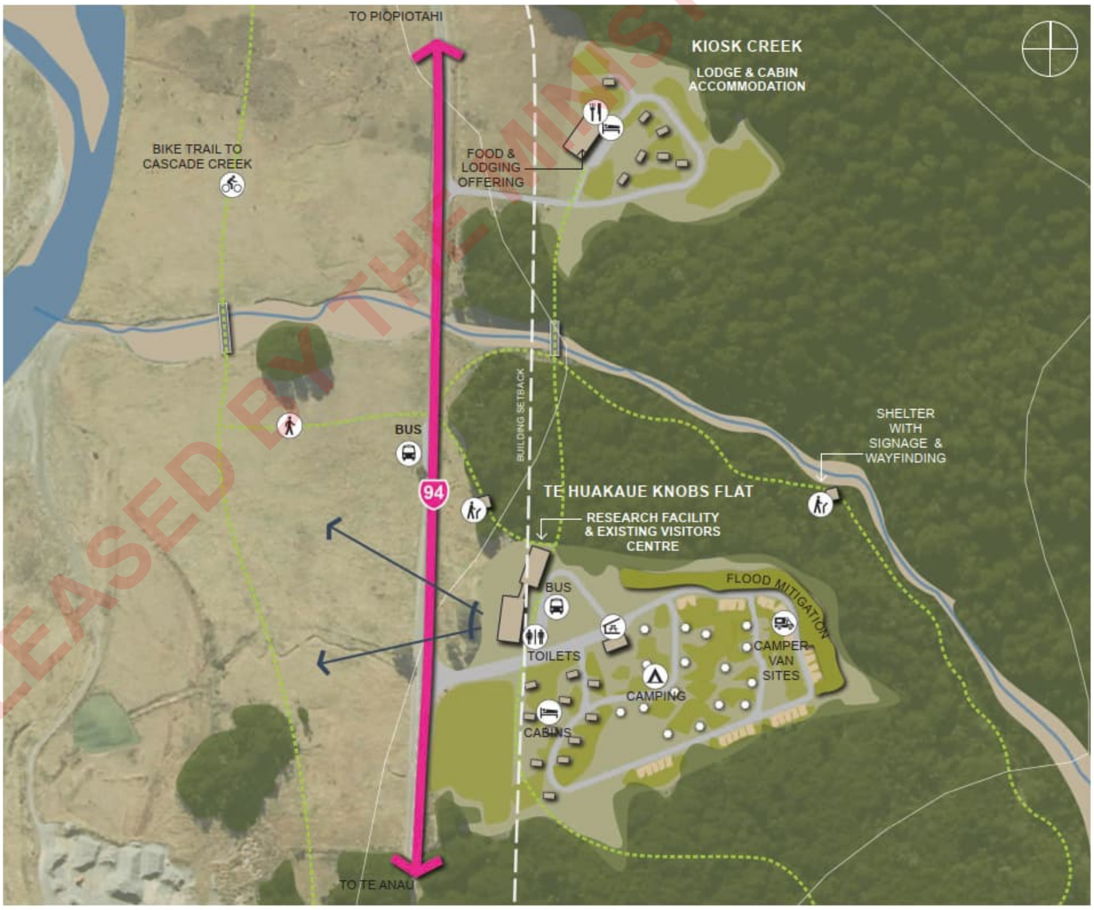


Figure 9: Conceptual plan for Knobs Flat Te Huakaue & Kiosk Creek[3]

2.5.1 COMMENTARY ON FEASIBILITY OF PROPOSED STRUCTURES

The site soils likely consist of alluvial fan deposits over bedrock at depth. The alluvial fan sediments are likely to be interbedded cobbles, gravels, sands and silts with variable (in thickness and area) fine grained layers. Due to past the activity on the site, uncontrolled fill is likely present over some areas.

Proposed additions to the site include expansion of the existing accommodation facilities, additional accommodation in the form of a small lodge at Kiosk Creek (to the north of the stream), optimising the existing camping and campervan layout, and trail head facilities for short walks. See Figure 9 for the conceptual plan for Knobs Flat Te Huakaue.

Due to the range and size of structures proposed for the site a range of foundations will likely be necessary. The structural details such as the shape, footprint and number of storeys will determine the types of foundations. For example, the bus stop will require a different foundation solution to the accommodation building. Ground conditions are also likely to vary across the site, which will impact the type of foundation recommended.

The draft geotechnical report by GeoSolve provides some preliminary foundation recommendations. The GeoSolve report was issued in 2019 and therefore, as discussed in Section 1.4.1, it won't have used the new NSHM 2022 to assess the seismic hazard to the site. Therefore, the recommendations presented in the report should be used with caution and only as a high-level guide as the new model may alter the recommendations for the site. The GeoSolve recommendations are summarized in Table 3 below.

Table 3: GeoSolve Preliminary Foundation Recommendations Summary

Structure	Foundation	Limitations
Timber Floor	Timber piles	Simple shapes, lightly loaded
Concrete Floor (1-2 storey Building	Ground improvements (reinforced gravel raft)	Smaller buildings (1-2 storey)
Lodge Accommodations (up to 6 storeys)	Bored Concrete Piles (CFA*) in conjunction with lateral spread protection	Up to 6 storey building

*Continuous Flight Auger (CFA)

In addition, consideration of the natural hazards associated with the site will also influence the foundation selection. For example, fill placement to raise the ground level to prevent inundation from flooding from Kiosk Creek may be required. Ground improvements maybe incorporated into the fill placement to provide improved foundation conditions. Detailed design of the foundations will need to incorporate the site assessment results from other disciplines, such as from the natural hazard assessment, to determine the final foundation options.

The GeoSolve report was produced prior to Beca's park and ride report[11] that identified Knobs Flat Te Huakaue & Kiosk Creek as one of the park and ride locations, and therefore does not comment on the possible this possible multi-storey structure. Beca's report proposes three options for carparks layouts at select locations. These are a single-storey carpark, a two-storey structure, and a three-storey structure. A multi-storey carpark structure will require more complex foundations and consequently will involve a more detailed geotechnical investigation and more complex design and construction. Shallow foundations (such as pad footings) may be suitable foundation for the structures depending on ground conditions and final loadings. However, if ground conditions are poor and or loads exceed acceptable limits, deep foundations (piles) maybe required.

It should be noted that the cost difference between a single-storey carpark and a multi-storey parking structure will be significant in investigation, design and construction costs. The geotechnical investigation costs between a two-storey and three-storey structure will be similar. The main difference in costs between a two-storey and three-storey structure will most likely be determined by whether the required foundations are shallow or deep. The design and construction costs for shallow foundations are generally cheaper than deep foundations.

The development as shown in the MOP Masterplan, at this stage, is geotechnically feasible. A significant factor in selecting the foundations will be the structures final design and loading requirements. Additional inputs from other disciplines may alter the geotechnical complexity.

2.6 NODE #4: ŌTĀPARA CASCADE CREEK

The following is noted for Ōtāpara Cascade Creek:

- The Masterplan structures listed at this site are flood protection infrastructure, modifications to the camping and campervan sites, a new bus shelter and toilet facilities, and facilities for kayaking.
- Elevation: The site is approximately 480 m ASL.
- Closest active fault: Livingstone Fault #8262, located approximately 8.2 km northeast of the site.
- Geological Map Information: Site is located within the mapped geological unit: Holocene river deposits (unconsolidated gravel, sand, silt, clay, and minor peat of modern to postglacial flood plains, may be terraced). See Figure 10 below.
- Environment Southland Liquefaction Risk Map: Medium Risk. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.
- Proximity to Ōtāpara Cascade Creek increases likelihood that the site has been inundated during flooding events. These previous events would have deposited new soils across the site. The site has flood mitigation bunds installed around the Ōtāpara Cascade Creek camp site. At this time no records were available for works completed on site. See Photograph 5 below.

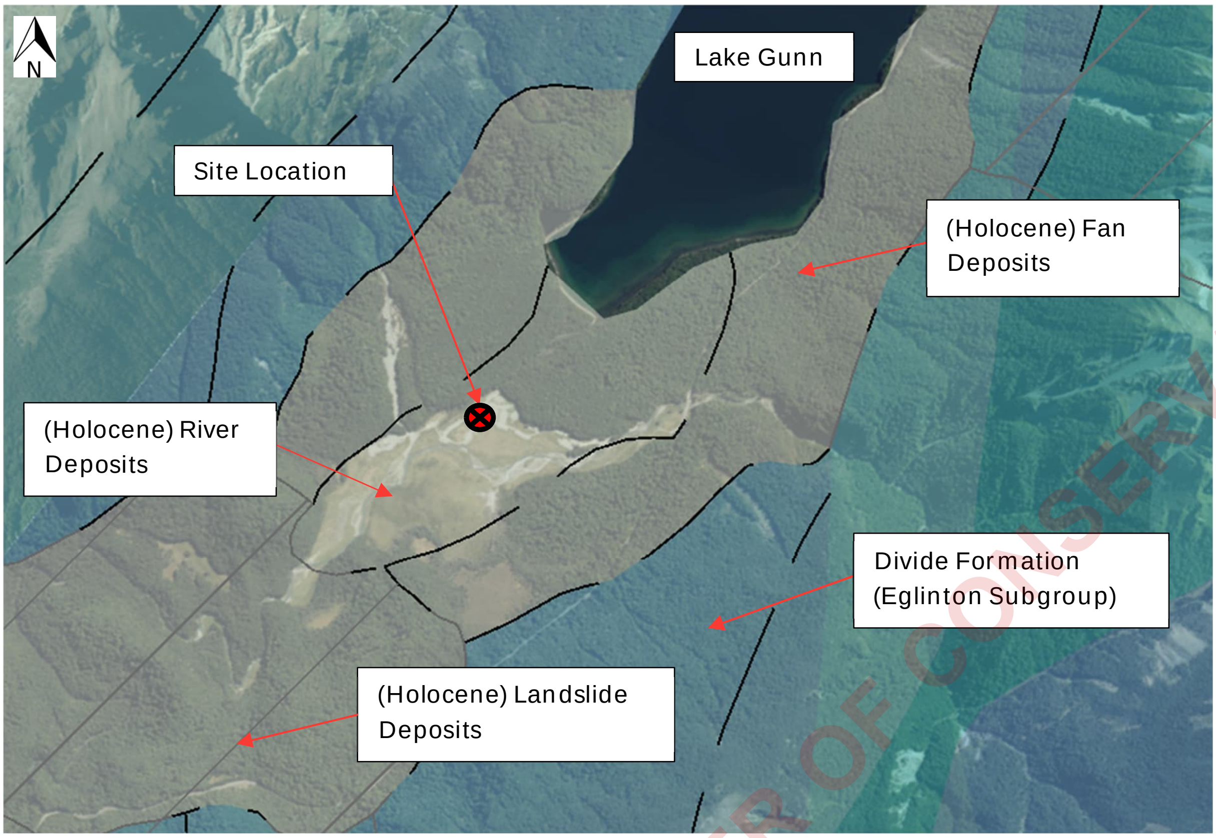


Figure 10: Ōtāpara Cascade Creek – Published Geology

Photograph 5: Ōtāpara Cascade Creek looking south from the existing carpark

2.6.1 COMMENTARY ON FEASIBILITY OF PROPOSED STRUCTURES

The site likely consists of river deposits over bedrock at depth. The river deposits are anticipated to comprise well graded sediment from silts to gravels and cobbles. Based on the distance from the river, groundwater may be encountered at shallow depths. At this stage, based on the available information, the site is assumed to have a medium liquefaction potential. However, geotechnical investigation of the site will be used to confirm the soils onsite and whether groundwater is present at shallow depths and allow for determination if further liquefaction assessment of the site is necessary.

Proposed upgrades to the site include flood protection infrastructure, optimised camping and campervan sites, a bus shelter, toilet facilities and support facilities for kayaking. These are likely to be simple lightly loaded structures and shallow timber piles or shallow strip or spread footing foundations may be suitable.

As with Knobs Flat Te Huakaue, structures may need to be founded on elevated fill platforms to mitigate damage during floods. Detailed design of the foundation will incorporate the site assessment results from other disciplines, such as natural hazards, to determine the final foundation options.

The development as shown in the MOP Masterplan, at this stage, is geotechnically feasible. Additional inputs from other disciplines may alter the geotechnical complexity.

2.7 NODE #5: THE DIVIDE / HINEPIPIWAI LAKE MARIAN

Node #5 has two distinct areas identified as The Divide and Hinepipiwai Lake Marian, which will be dealt with as separate sites.

THE DIVIDE

- The Masterplan structures listed at this site are a carpark and a visitor shelter.
- Elevation: The site is approximately 520 m ASL.
- Closest active fault: Livingstone Fault #8262, located approximately 3.3 km east of the site.
- Geological Map Information: The site is located within the mapped geological unit: Holocene fan deposits (loose, commonly angular, boulders, gravel, sand, and silt forming alluvial fans; grades into scree (upslope) and valley alluvium) overlying Holocene landslide deposits within the Fergus Formation (Eglinton Subgroup) (massive to well bedded greyish-green to grey feldspathic sandstone). See Figure 11 below.
- Environment Southland Liquefaction Risk Map: Low Risk. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.
- A geotechnical investigation was completed by WSP and a report issued in November 2019 for The Divide site[14]. The report provided recommendations for the construction of new facilities at the site which were to include a new shelter, toilets and upgrades to the carpark.
- A design report was issued by WSP in July 2020 to provide a design of a retaining wall to support the carpark upgrade. It is not clear, at this time, if the wall is required or still suitable for the proposed carpark upgrade outlined in the Masterplan. If the wall is required as part of the

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[14] Geotechnical Design Report, The Divide Carpark Upgrade, 14 July 2020, WSP

Masterplan carpark, the design will need to be assessed against the new NSHM 2022 and may require the wall to be redesigned.

- The investigation consisted of 4 Cone Penetrometer Tests (CPT) and were advanced to a maximum depth of 3.0 m bgl.
- Results from WSP's investigation generally align with the published geological mapping. The report noted the presence of gravel fill layer up to 1.0m thick was encountered over the current carpark.
- Site visit and photographs indicate the site soils are likely fan deposits. The site is also likely to have been disturbed during the construction of the carpark and current structures at site and uncontrolled fill may have been placed on the site. See Photograph 6 below.

HINEPIPIWAI LAKE MARIAN TRAIL HEAD

- The Masterplan structures listed at this site are a visitor shelter and toilet facilities, a new Wānanga (living classroom), and carpark upgrades.
- Elevation: The site is approximately 320 m ASL
- Closest active fault: Livingstone Fault #8262, located approximately 5.4 km southeast of the site.
- Geological Map Information: The site is located within the mapped geological unit: Holocene fan deposits (loose, commonly angular, boulders, gravel, sand and silt forming modern alluvial fans; may include debris flow and avalanche deposits) overlying Consolation Formation (Eglinton Subgroup) (pale green to grey, bedded feldspathic sandstone, siltstone, and minor mudstone). See Figure 11 below.
- Environment Southland Liquefaction Risk Map: Site is located on the boundaries of Negligible, Low and Medium Risk zones. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.
- Site visit and photographs indicate the site soils are likely fan deposits. The site is also likely to have been disturbed during the construction of the carpark and current structures at site and fill is likely to have been placed on the site. At this time no records were available for the placement of the fill. See Photograph 6 below.

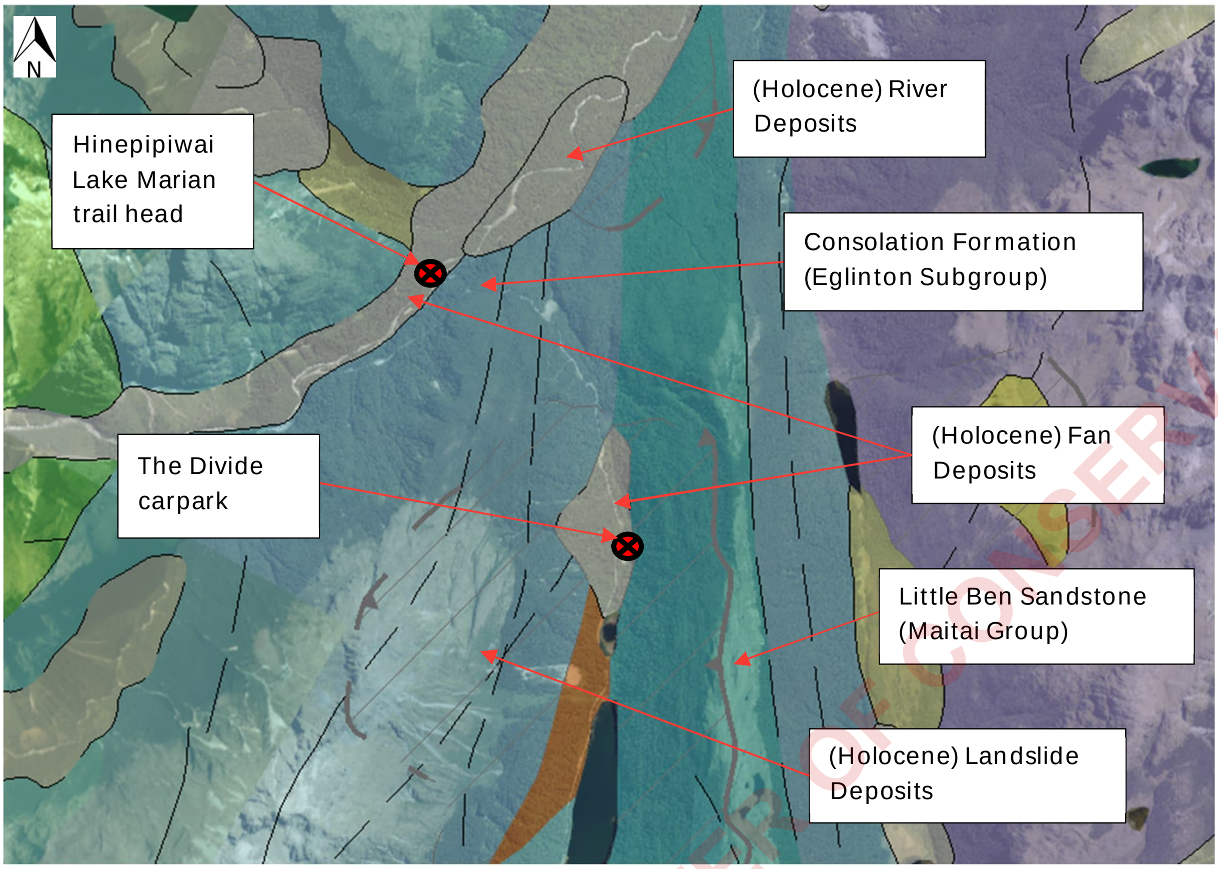

Figure 11: The Divide / Hinepipiwai Lake Marian Trails head – Published Geology

Photograph 6: The Divide carpark (left) and Lake Marian trails head carpark (right)

2.7.1 COMMENTARY ON FEASIBILITY OF PROPOSED STRUCTURES

Both sites likely consist of alluvial fan deposits and debris over bedrock at depth. The alluvial deposits are likely to be angular and well-graded silts to gravels and cobbles. Based on the distance from the rivers in the area, groundwater may be encountered at shallow depths.

WSP's report assessed the liquefaction potential at The Divide site to be a negligible risk. It is noted that the assessment was completed before the new NSHM 2022 was available.

The Lake Marian Trails Head site ranges from Negligible to Medium liquefaction potential. This will affect the type of structure differently and at this stage the site is assumed to have a low liquefaction potential. However, a geotechnical investigation of the site will be used confirm the soils onsite and whether groundwater is present at shallow depths and allow determination if further liquefaction assessment of the site is required.

THE DIVIDE

The WSP reports have recommendations for the site upgrades that were proposed prior to the Masterplan. The report's recommendations may still be valid and an assessment of them should be completed, using the new NSHM 2022.

It should be considered that the proposed upgrades are technically feasible based on the report. However, it should also be noted that additional geotechnical investigation and design maybe required to update or confirm the reports recommendations met the requirements of the new NSHM 2022.

LAKE MARIAN TRAILS HEAD

Proposed upgrades to the trails head include a wānanga (living classroom), visitor shelter and toilet facilities, and carpark improvements. The Importance Level required of the wānanga and visitor shelter in conjunction with the soils present at the site will dictate the recommended foundation type for these structures. At this stage it has been assumed that timber piles or shallow strip or spread footing will likely be suitable for the structures on site. However, if the sites liquefaction potential is higher than anticipated or the structures are a higher Importance Level, more significant foundations may be required.

Upgrades to the carpark are also proposed, these are likely to be feasible with few or no ground improvements given the ground conditions assumed at the site.

Both of the developments for The Divide and Lake Marian Trail Head as shown in the MOP Masterplan, at this stage, are geotechnically feasible. Additional inputs from other disciplines may alter the geotechnical complexity.

2.8 NODE #6: GERTRUDE VALLEY

The following is noted for Node #6:

- The Masterplan structures listed at this site are flood protection infrastructure, visitor shelter, and carpark upgrades.
- Gertrude Valley Walk – Trail Head Facilities
- Elevation: The site is approximately 780 m ASL
- Closest active fault: Unnamed Fault #9214, located approximately 9.5 km northeast of the site.
- Geological Map Information: Site is located on the boundary between the following two geological units, one covering the eastern side of the site and the other covering the western side. See Figure 12 below.
- Western Side: Holocene fan deposits (Loose, commonly angular, boulders, gravel, sand and silt, forming modern alluvial fans; may include debris flow and avalanche deposits).
- Eastern Side: Glacier deposits (Unconsolidated, unweathered, angular, boulder till; mixtures of gravel/sand/silt/clay; in cirque or upper valley moraines).

- Environment Southland Liquefaction Risk Map: Site is located on the boundaries of Negligible and Low Risk zones. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.
- Site visit and photographs indicate that the site is likely to be underlain by glacier deposits, with gravel visible at the surface and a stream reworking coarse alluvial sediments up to cobble sized, see Photograph 7 below.

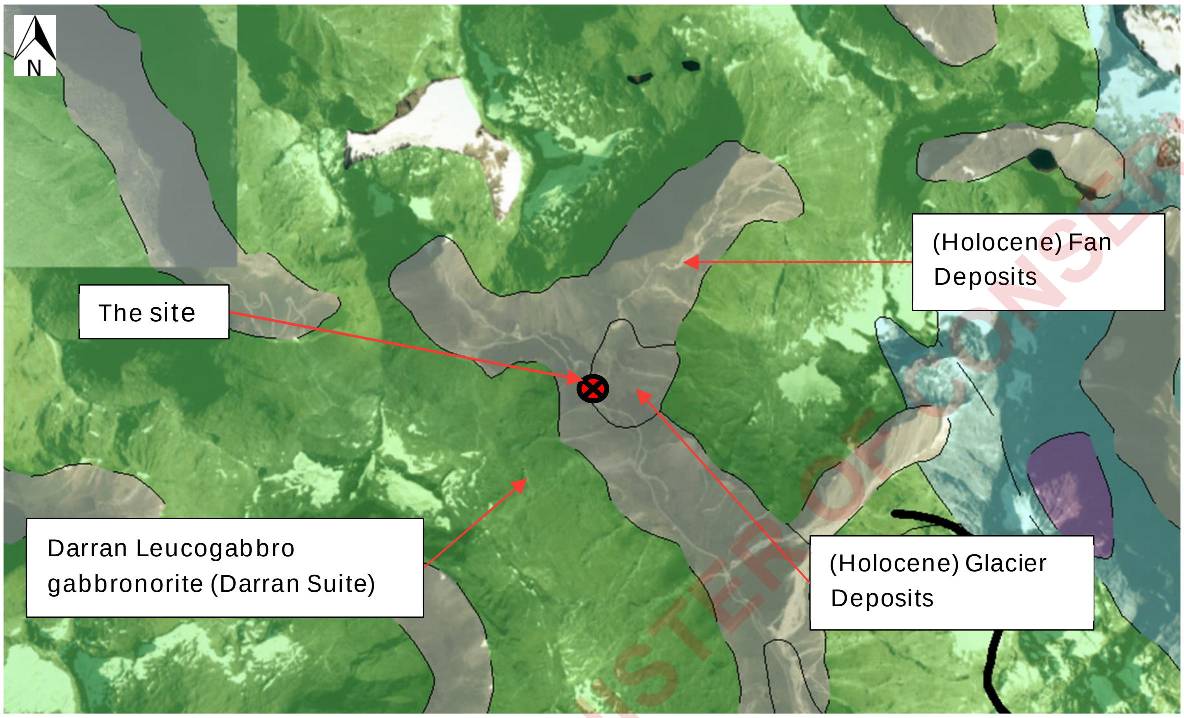

Figure 12: Gertrude Valley – Published Geology

Photograph 7: Gertrude Valley looking southwest from the proposed location

2.8.1 COMMENTARY ON FEASIBILITY OF PROPOSED STRUCTURES

The site likely consists of glacial moraine and alluvial fan deposits over bedrock at depth. Both sediment types are likely to comprise a wide range of grainsizes from silts to gravels and boulders. At this stage the site is assumed to have a negligible to low liquefaction potential. However, geotechnical investigation of the site will be used confirm the soils onsite and whether groundwater is present at shallow depths and allow for determination if further liquefaction assessment of the site is required.

Proposed developments at the site include flood protection infrastructure, visitor shelter, carpark upgrades, trail head facilities. Assuming that structures are simple, and lightly loaded, shallow strip or spread foundations are likely to be the most effective and efficient. Piled foundations would likely be difficult to construct at this site due to the high likelihood of encountering boulders in the near surface soils.

The development as shown in the MOP Masterplan, at this stage, is geotechnically feasible. Additional inputs from other disciplines may alter the geotechnical complexity.

2.9 NODE #7: CLEDDAU CIRQUE

The following is noted for Node #7:

- The Masterplan structures listed at this site are a rockfall refuge and carpark upgrades.

- Elevation: The site is approximately 730 m ASL.
- Closest active fault: Unnamed Fault #9214, located approximately 11.5 km east of the site.
- Geological Map Information: Site is located on the boundary between the following two geological units, one covering the northern side of the site and the other covering the southern side. See Figure 13 below.
- Northern Side: Holocene fan deposits (Loose, commonly angular, boulders, gravel, sand and silt forming modern alluvial fans; may include debris flow and avalanche deposits).
- Southern Side: Darran Leucogabbro gabbronorite (Variably deformed biotite leucogabronorite altered to hornblende diorite in west; trondjemite, pegmatite and quartz diorite dikes).
- Environment Southland Liquefaction Risk Map: Low Risk. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.
- Site visit and photographs indicate that the site soils are likely a mix of alluvial deposits and rockfall debris. The site has a rockfall protection bund constructed to protect the road and carpark, see Photograph 8 below.

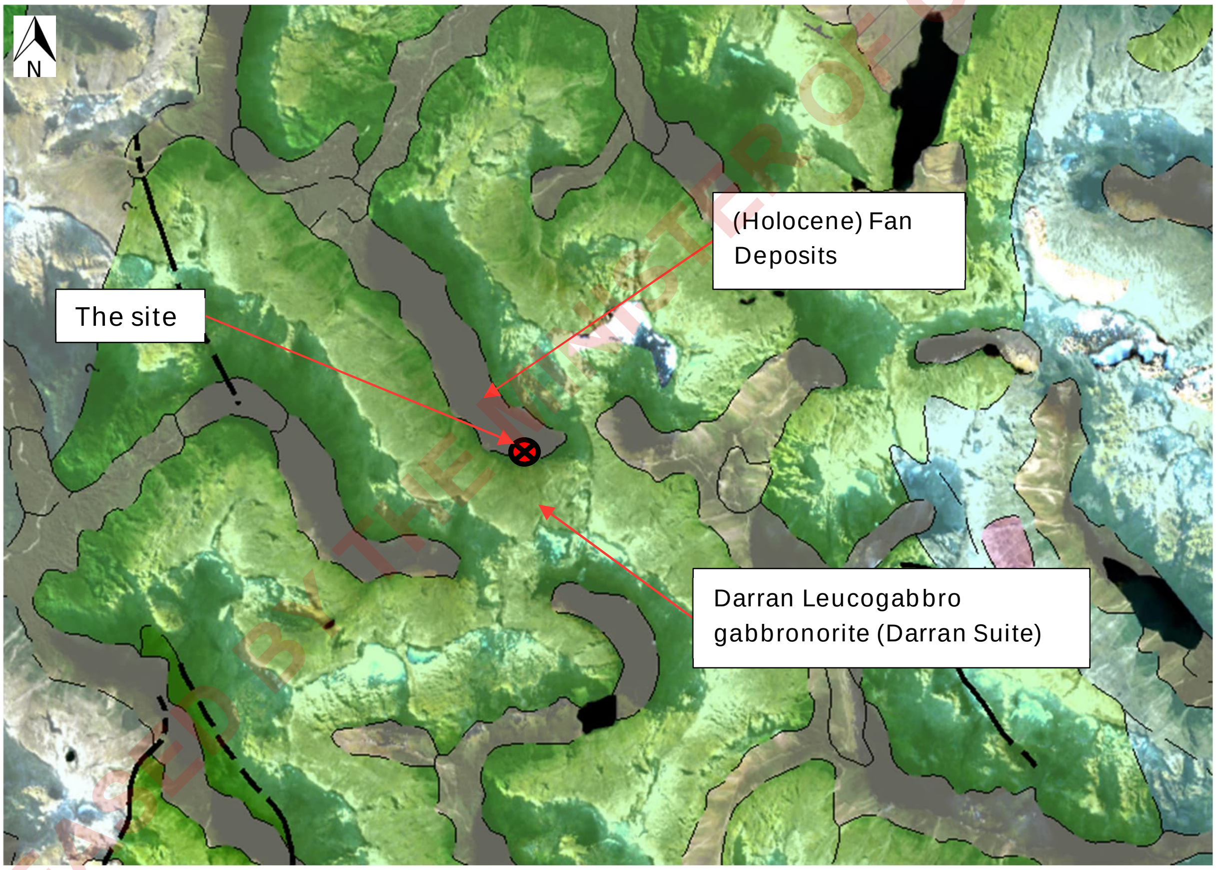

Figure 13: Cleddau Cirque – Published Geology

Photograph 8: Cleddau Cirque looking east from the existing carpark

2.9.1 COMMENTARY ON FEASIBILITY OF PROPOSED STRUCTURES

The site likely consists of alluvial fan deposits over bedrock at depth. Based off site observations, the site is likely to have rockfall debris covering the area. The underlying soils are likely to consist of gravels and cobbles. There is an active stream approximately 30 m to the south of the existing carpark. At this stage the site is assumed to have a low liquefaction potential.

Proposed upgrades to the site include a rockfall refuge, and carpark improvements. The rockfall refuge is assumed to an Importance Level 4 structure and will be a much more significant structure than those proposed at previous nodes (such as toilets and visitor shelters). The rockfall refuge will need to be designed to protect people during natural disaster events such as earthquakes, rockfall and avalanches.

WSP completed the design of the upgrade to the nearby Homer Tunnel Avalanche Shelter which is currently under construction. The avalanche shelter foundations consist of precast concrete pads that are then tied with smaller, poured in-situ concrete elements. This foundation was utilized to reduce construction timeframes and work around tight space constraints. Avalanches and rockfalls result in large and complex loading conditions, which will dictate the type and size of foundation required.

The rockfall refuge will require a site-specific geotechnical investigation to determine the most suitable foundation design. It will have significant costs involved in the geotechnical investigation, design and construction.

Based on available information and development of the tunnel, it is geotechnically feasible to construct a refuge structure at the Cleddau Cirque. Once the final location, structure details are known, investigation and further assessment will be required to confirm the geotechnical feasibility and potential cost implications of constructing this complex structure.

In addition, input from the natural hazard assessment will be critical to understanding the likely loading conditions and performance requirements to allow the design of the refuge.

The carpark upgrades as shown in the MOP Masterplan, at this stage, is feasible from a geotechnical point.

2.10 SHORT STOP: THE CHASM

The following is noted for The Chasm:

- The Masterplan structures listed at this site are carpark upgrades, a bus shelter, and toilet facilities.
- Elevation: The site is approximately 210 m ASL
- Closest active fault: Unnamed Fault #9213, located approximately 12.5 km east of the site.
- Geological Map Information: The site is located within the mapped geological unit: Holocene fan deposits (Loose, commonly angular, boulders, gravel, sand and silt forming modern alluvial fans; may include debris flow and avalanche deposits). See Figure 14 below.
- Environment Southland Liquefaction Risk Map: Low Risk. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.
- Site visit and photographs indicate that the site is likely to be debris flow deposits, with the carpark seemingly built on a cut and fill bank of debris above the floor of the valley.

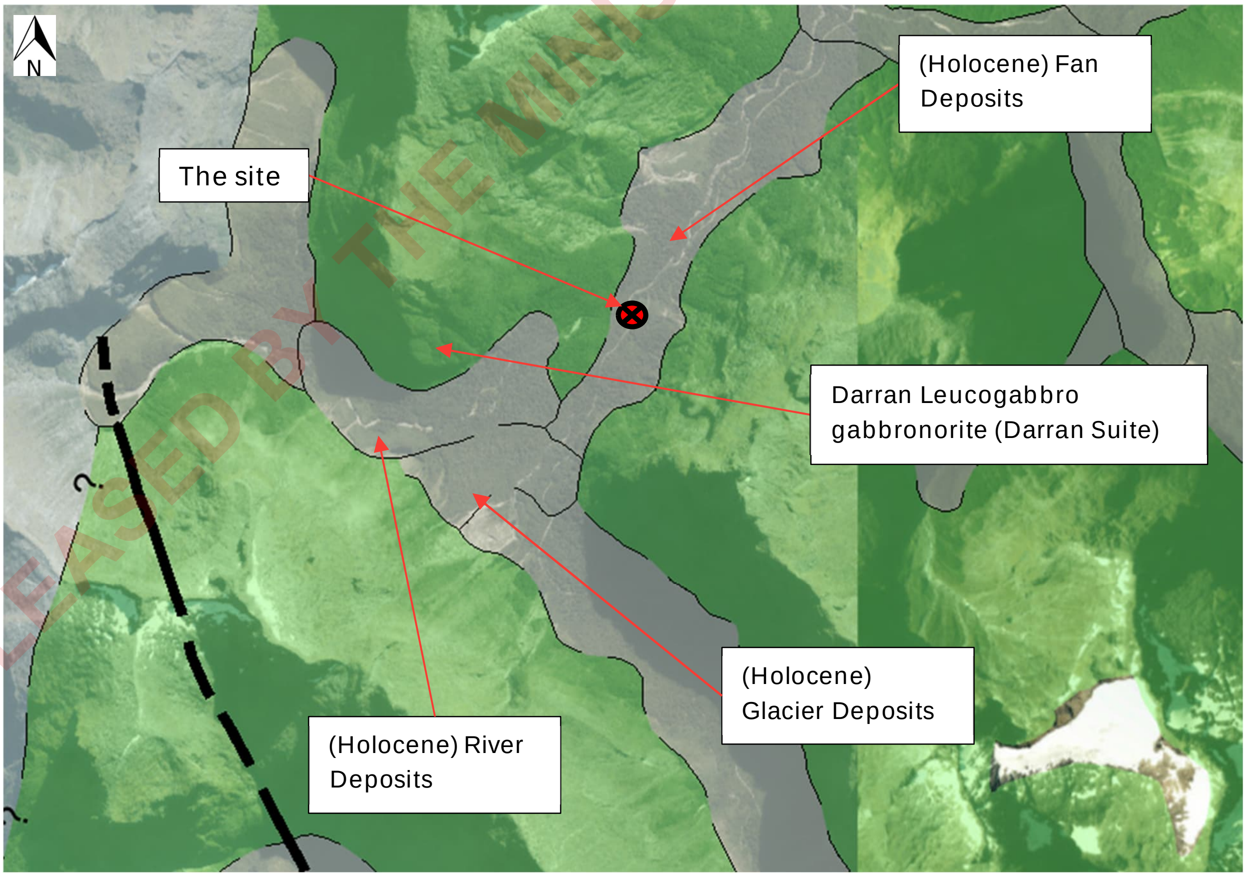

Figure 14: Short Stop: The Chasm – Published Geology

2.10.1 COMMENTARY ON FEASIBILITY OF PROPOSED STRUCTURES

The site likely consists of debris fan deposits over bedrock at depth. The fan deposits are likely to comprise a wide range of grainsizes from silt to gravels through to cobbles and boulders. At this stage the site is assumed to have a low liquefaction potential.

The proposed upgrades to this site include a bus shelter, toilet facilities and upgrades to the carpark. These structures will most likely be lightly loaded and may be founded on shallow strip or spread foundations. The expected soils at the site should have adequate bearing strength at relatively shallow depths to support structures of this type without piled foundations or significant ground improvement techniques. At this stage the upgrades to the carpark are anticipated to require only minor ground improvement. These assumptions should be verified through a geotechnical investigation.

The development as shown in the MOP Masterplan, at this stage, is geotechnically feasible.

2.11 MILFORD SOUND PIOPIOTAHI VISITOR HUB

The following is noted for Milford Sound Piopiotahi visitor hub:

- The Masterplan structures listed at this site are new visitor and staff accommodation, a visitor hub building, a bus terminal, carpark upgrades, a Barren Peak Spur treetop lookout, new covered walkways, and new foreshore engagements (viewing decks). See Figure 15 and Photograph 9 below.
- Elevation: The site is approximately 0 m – 5 m ASL
- Closest active fault: Anita Shear Zone #8756, located approximately 12 km west of the site.
- Geological Map Information: The site is located within the mapped geological unit: Holocene river deposits (Unweathered, loose, bouldery gravel, sand and mud in modern floodplains. Peat and carbonaceous mud bands may be interbedded). See Figure 16 below.
- Environment Southland Liquefaction Risk Map: High Risk. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.
- A preliminary geotechnical investigation was completed by GeoSolve with a report issued in February 2019[15]. The report provided preliminary recommendations to upgrade the current carpark to a multi-storey carpark. The investigation consisted of 4 sonic boreholes completed to a maximum depth of 18 m bgl. Two piezometers were installed to a depth of 6 m bgl for water monitoring at the site. At this stage it is not known if the piezometers are still installed on site or have been decommissioned.
- Results from the GeoSolve investigation indicate that the site is underlain by fill, with deltaic sediment and interbedded organic swamp deposit below, and gabbro bedrock at depth (5 m to <18 m bgl). Groundwater level was encountered between 1.1 m and 1.9 m bgl.
- The near-surface fill encountered in GeoSolves investigation is assumed to be engineered as part of a major upgrade of the Cleddau Flood Protection Scheme completed in the early 2010s. As built records to confirm the level of compaction achieved in the placed fill are not currently available, but may be available through DOC. These records may help to inform detailed

[15] Preliminary Geotechnical Report for Concept Design, 2019, GeoSolve

planning of geotechnical ground investigations and preliminary foundation conceptual design.

- GeoSolve notes that the carpark site has a liquefaction potential of high. It is likely that the surrounding areas also have high liquefaction potential. It should also be noted that this analysis was completed prior to the new NSHM 2022.
- A pavement assessment was completed by Stantec and a report issued in May 2022[16]. GeoSolve was contracted to provide a geotechnical investigation report for Stantec as part of the aerodrome runway pavement assessment report. GeoSolve's investigation included 4 test pits excavated to a maximum depth of 2.4 m bgl. Ground water was encountered at 2.3 m bgl. The investigation scope was restricted to section of runway adjacent to the taxi and fixed-wing parking area.
- Ground conditions encountered beneath the runway comprise asphalt placed onto native soils. The native soils consisted of loose to medium-dense sandy gravel with cobbles and boulders interspersed with woody organic material and some voids. Slumping issues observed in the runway pavement are likely caused by decomposition of buried logs (approximately 1.8 m bgl) in the natural subgrade, causing settlement. In one test pit, a void was encountered which GeoSolve noted was caused by decomposition of organic material.

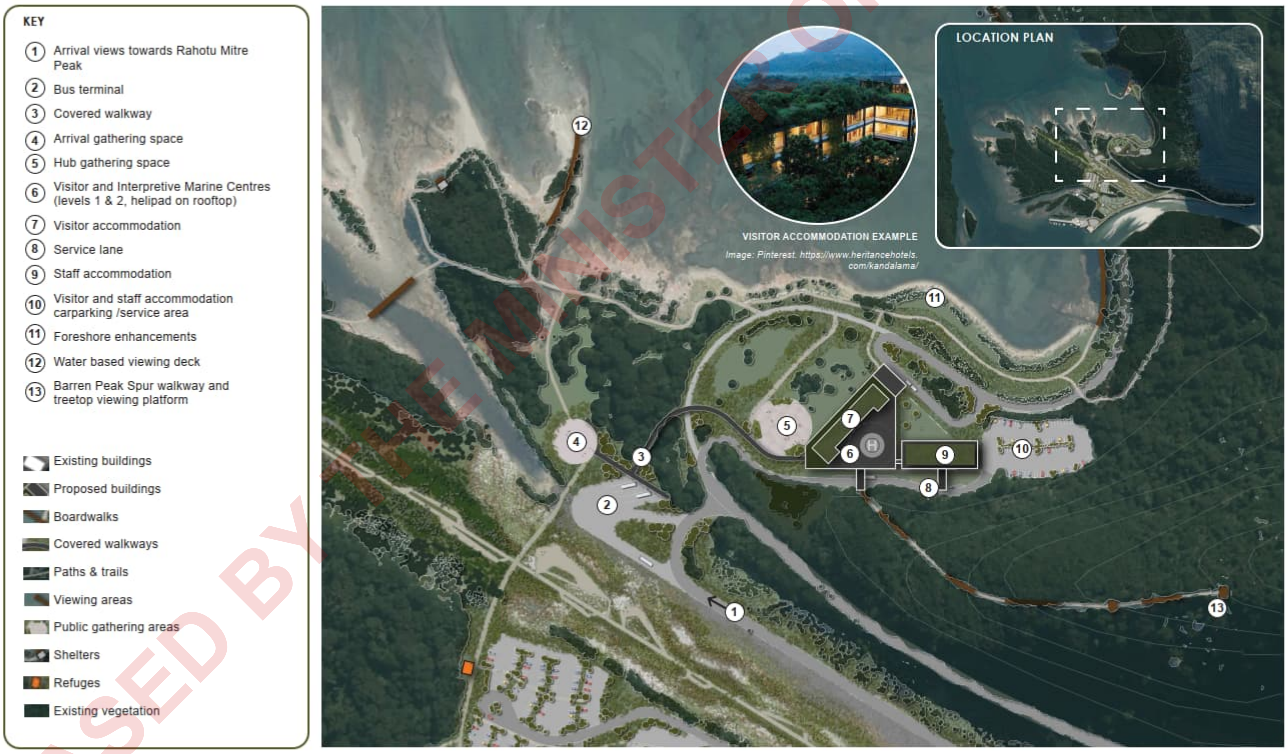

Figure 15: Masterplan Milford Sound Piopiotahi Visitor Hub Concept Layout

[16] Milford Aerodrome Pavement Assessment, 2022, Stantec

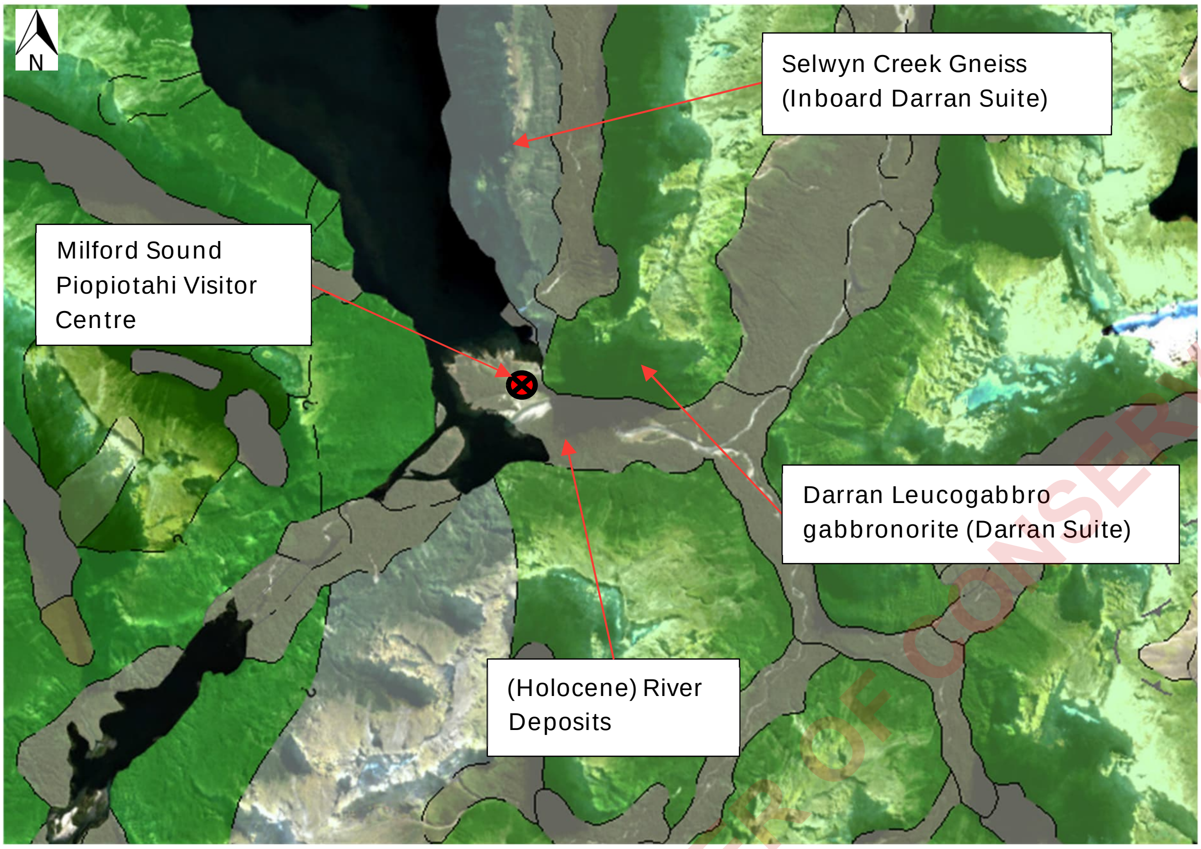

Figure 16: Milford Sound Piopiotahi Visitor Hub – Published Geology

Photograph 9: Milford Sound Piopiotahi (Freshwater Basin) looking northwest from the foreshore carpark

2.11.1 COMMENTARY ON FEASIBILITY OF PROPOSED STRUCTURES

The reports outlined above give some information about the ground conditions at discrete locations around Milford Sound Piopiotahi. Further investigations are required at each of the proposed structure locations to obtain site-specific information for design and to provide further detail on the spatial variability of ground conditions across the area.

Based on the available reports, the site likely consists of unknown depth of fill (engineered and possibly uncontrolled), underlain by interbedded sand, silt and gravels (deltaic sediments) and organic swamp deposits. It is assumed that water is present at shallow depths below the site, fed by the Cleddau River and the Sound. Based on the likely presence of shallow water and the deltaic sediments, the site should be considered to be susceptible to liquefaction at this stage.

Proposed upgrades to this site include visitor accommodation, staff accommodation, a visitor hub building, a marine research centre, bus terminal, carpark relocation, Barren Peak Spur treetop lookout and walkway, covered walkways between critical areas, and new viewing decks / upgrades to the existing foreshore experience.

It should also be noted that lower lying areas are currently affected by tidal changes within the Sound. Variable water levels will need to be considered when designing structures that are in or near the lower lying area.

It is possible that if individual geotechnical investigations of the various sites are completed in conjunction with each other, the amount of investigation can be optimized and will likely lead to efficiencies in investigation costs.

The development as shown in the MOP Masterplan, at this stage, are geotechnically feasible. Due to the proximity of the Alpine fault and refuge status of some structures, it should be expected that more detailed geotechnical investigations, strict design requirements and complex construction will be required for these structures. These buildings will come with a significant cost associated with them when compared to other structures located in regions that experience lower seismic inputs.

Additionally, this report does not consider any of the risks or information that is being developed for the MOP Natural Hazard report. Inputs from this report and others should be used to inform the geotechnical investigation planning to ensure that scoping will include relevant testing.

VISITOR ACCOMMODATION

A new hotel is proposed in an elevated position above the visitor and marine research centres. It will at a minimum be large enough to maintain the existing capacity within Milford Sound Piopiotahi. Based on Stage 2 Infrastructure Report – Appendix 2[17], this hotel is assumed to be designed to accommodate up to 100 visitors in a multi-storey structure with an Importance Level of 4. The structure will need to withstand extreme events and act as a refuge.

Due to the importance of the structure a detailed geotechnical investigation and a site-specific seismic assessment should be completed to enable design of such a high importance structure. To plan an appropriate investigation, a specific site location needs to be selected and some

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[17] Milford Opportunities Project. *Stage 2 Infrastructure Assessment Report*, Appendix 2 (Cost Estimations), Mar 2021, Stantec

building details, such as footprint, and the number of levels be finalised. This will allow determination of the number of investigation points, types and termination depths.

Given the above assumptions, and the likely presence of relatively weak near-surface soils, it is likely that the structure will need to be founded on a piled system. This may include piles socketed into bedrock (if shallow enough), but interpretation of the geotechnical investigation will determine the most suitable foundation type for the proposed structure.

It has been assumed that any carparking associated with the visitor hub will be single storey and simple geotechnical investigations will be able to be provide input to pavement designs.

STAFF ACCOMMODATION

A new purpose-built, multi-storey development has been proposed to replace the existing staff accommodation facility. The location of the staff accommodation has been identified as being located at either the Milford Sound Piopiotahi Visitor Hub or Little Tahiti.

If the staff accommodation is located at the Milford Sound Piopiotahi Visitor Hub, it is proposed to be located adjacent to the hotel. Based on MOP Stage 2 Infrastructure Report – Appendix 2, the assumptions and foundation recommendations for this structure are similar to the above Visitor Accommodation except for an increased capacity of 280 – 320 beds. At this stage it is assumed that the increased capacity will require a large building and as such an increase in the investigation scope will be needed when compared to the Visitor Accommodation.

It is anticipated that the foundation requirements will be similar to the visitor accommodation with the exception of possible increased loadings.

VISITOR HUB AND MARINE RESEARCH CENTRE

The proposed new co-located facilities are to be situated next to the existing hotel site. The ground level has been modified to elevate it above the surrounding area. At this stage it is not clear if the fill was placed in a controlled manner. The proposed building is a multi-storey structure that may double as a large refuge for visitors and staff. A rooftop helipad has also been proposed for the structure.

If this structure is designated as an emergency shelter, then it will require design to an Importance Level 4. This structure will have similar requirements to those for the Visitor and Staff Accommodations.

BUS TERMINAL

A new centralised bus terminal is proposed that utilises the existing aerodrome taxiway, apron and terminal area to optimise the coach services. This terminal is assumed to be a one or two storey structure with open spaces internally and covered outdoor area.

As noted above the proposed bus terminal is near the existing aerodrome runway. Investigations completed by GeoSolve in this area where settlement has occurred, found that the likely cause was due to decomposing organic matter. If areas of soft or organic ground are encountered, they will likely require over-excavation and backfilling with controlled fill to improve the subgrade.

Further geotechnical investigation is needed to determine the sites suitability for the proposed bus terminal. This will include subsoil potential for settlement and assessment of the site's liquefaction potential.

CARPARK RELOCATION

The existing foreshore public carpark is proposed to be relocated to the Cleddau Delta, south of the existing aerodrome runway. The ground in this area is assumed to be a combination of natural and reworked ground, with varying thicknesses of fill possible placed as part of the Cleddau Flood Protection Scheme. Further discussion on the carpark is included in Section 2.13.1.

BARREN PEAK SPUR LOOKOUT AND WALKWAY

An upgrade to the existing track leading up the Barren Peak Spur is proposed to connect to two treetop canopy viewing structures that are carefully configured to minimise the removal of mature beech trees and to screen the built infrastructure of the visitor's hub below.

Based on the available information, it is assumed that the site is covered by shallow soils overlying gabbro bedrock. It is currently assumed that an appropriate foundation type would include an above ground concrete footings anchored into the bedrock.

The liquefaction potential for the site varying from high potential at low elevations to negligible at high elevations where bedrock is assumed to be present.

Due to the sensitivity of the site, to minimise the disturbance to surrounding vegetation the geotechnical investigation will be confined to visual observations and a hand investigation to confirm depth to bedrock. Due to the limited geotechnical investigation, anchor design assumptions will need to be verified during construction.

COVERED WALKWAYS AND FORESHORE ENGAGEMENTS

At this stage the locations of the covered walkways are not known. It is anticipated that these are very lightly loaded structures and can be built with minimal geotechnical investigation and a standard footing detail could be developed for these structures.

2.12 FRESHWATER BASIN NODE

The following is noted for Freshwater Basin Node:

- The Masterplan structures listed at this site are Bowen Falls cable car, Bowen Falls/Valley walk, Bowen Falls viewing platforms, a pontoon walkway to access Bowen Falls, a refuge, and redevelopment of the boat terminal. See Figure 17 below.
- Elevation: The site is approximately 0 m – 5 m ASL.
- Closest active fault: Anita Shear Zone #8756, located approximately 12 km west of the site.
- Geological Map Information: The site is located within the mapped geological unit: Holocene river deposits (Unweathered, loose, bouldery gravel, sand and mud in modern floodplains. Peat and carbonaceous mud bands may be interbedded). See Figure 18 below.
- Geological Map Information: Site is located on the boundary between the following two geological units, one covering the low-lying area of the site and the other covering the elevated ridge that forms Bowen Falls. See Figure 16 above.
- Low Lying Area: Holocene river deposits (Unweathered, loose, bouldery gravel, sand and mud in modern floodplains. Peat and carbonaceous mud bands may be interbedded).
- Elevated Ridge: Gneissic hornblende diorites and garnet-biotite gneiss; intruded by abundant amphibolitic to felsic dikes.
- Environment Southland Liquefaction Risk Map: High Risk. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.

- Existing geotechnical investigation information (as per Section 2.11 Milford Sound Piopiotahi Visitor Hub) indicates that the site is likely to be underlain by uncontrolled fill of varying thickness with deltaic sediment and interbedded organic swamp deposit below, and gabbro bedrock at unknown depth. Depth to groundwater level is assumed to be approximately 2 m. See Photograph 10 below.

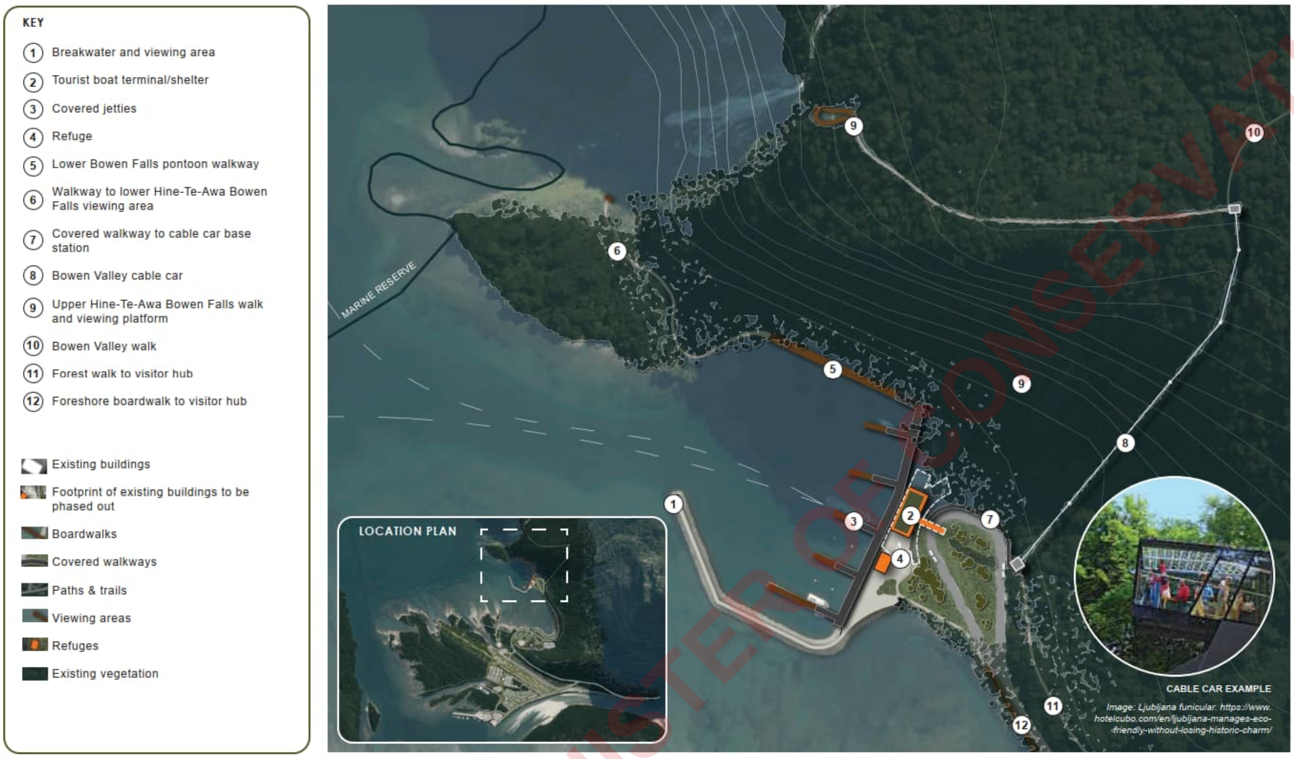

Figure 17: Masterplan Freshwater Basin Layout Concept

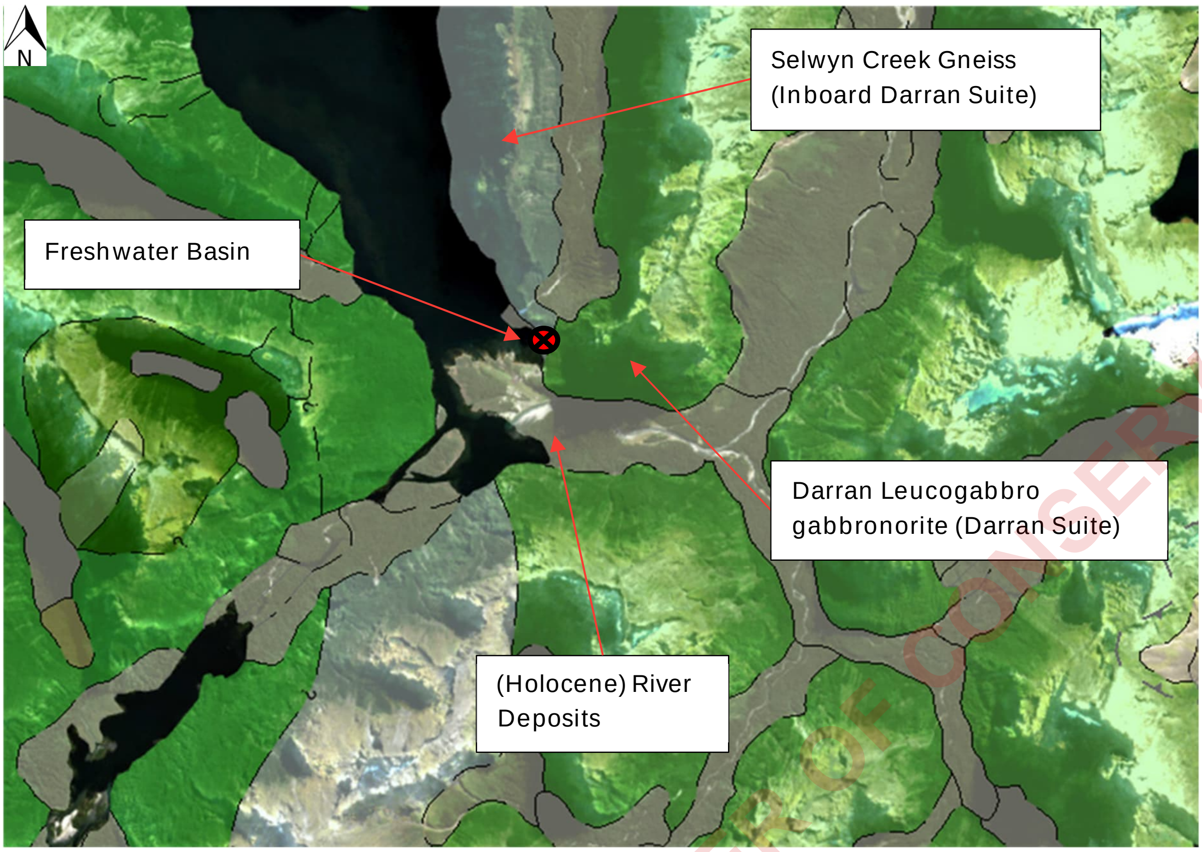

Figure 18: Freshwater Basin – Published Geology

Photograph 10: Freshwater basin looking northwest from the existing carpark and visitor terminal

2.12.1 COMMENTARY ON FEASIBILITY OF PROPOSED STRUCTURES

Foreshore areas of the site are likely to consist of deltaic sediments interbedded with organics over bedrock at depth. It is also assumed that water will be encountered at shallow depths below the site. It is likely that the site will have potential for liquefaction and that lateral spreading may occur in the vicinity to the foreshore. Ground conditions on the hills above the foreshore are likely to be bedrock, overlain by a thin layer of organic matter. At this stage the quality of the rock (strength, fractures etc) is unknown.

Proposed upgrades to this site include a cable car (to access the upper Hine-Te-Awa Bowen Falls), Bowen Falls/Valley walk, Bowen Falls viewing platforms, Bowen Falls pontoon walkway, an iconic natural hazard refuge, and redevelopment of the existing boat terminal.

As with the structures in Section 2.11.1, all significant (IL2 or above) structures proposed in this area will require site specific investigation and design.

It is possible that if individual geotechnical investigations of the various sites are completed in conjunction with each other, the amount of investigation can be optimized and will likely lead to efficiencies in investigation costs.

The development as shown in the MOP Masterplan, at this stage, are geotechnically feasible. Due to the proximity of the Alpine fault and refuge status of some structures, it should be expected that more detailed geotechnical investigations, strict designs requirements and complex construction will be required for these structures.

HINE-TE-AWA BOWEN FALLS CABLE CAR

A new cable car (or other transport system) is proposed to provide access to the top of Hine-Te-Awa Bowen Falls and will include a nature walk. The concept alignment would follow an existing hydro pipeline up a steep incline. The final alignment or transportation system may change due to site limitations (such as slope gradients).

At this stage until further details are available, general comments for a transport system are as follows:

- The base building will potentially be located on deep soft soils. It should be anticipated that foundation design will need to account for settlement. The site may also experience liquefaction and lateral spreading during a seismic event.
- The slope up to the top of Hine-Te-Awa Bowen Falls is assumed to be Gneissic bedrock. Construction will likely include rock anchors as part of the foundations. Anchors into the rock will need to account for the quality of the rock. Based on WSP experience of designing and installing anchors in similar environments, drilling rates will likely be slow given the assumed quality of rock and long anchor lengths may be required due to wide discontinuity spacings within the rock mass. However, development of rock anchor design will require site specific investigation and inspection.
- The top building will need to account for founding into bedrock with similar issues as noted for the anchors.

Foundation recommendations will be highly dependent on the final type of transportation system and the alignment which will determine the slope gradient. In addition, geotechnical investigation of the slope is unlikely to be feasible or cost effective. Geotechnical investigation of the top building will likely be used to inform the design of the foundations on the slope. This will mean that confirmation of assumptions during construction will be required, and provision for additional work (additional anchors, redrilling and lengthening) should be allowed for. A system that avoids construction on the slope maybe more efficient and avoid construction uncertainties. An example would be the Lone Peak Tram at Big Sky Resort, Montana, United States. The tram utilizes a system consisting of only a base and top building to access steep terrain where infrastructure such as towers couldn't easily be built.

Considerable cost is expected to be incurred in the investigation, design and construction of this structure. The Masterplan notes that there is an opportunity to combine the provision of a cable car as part of a planned upgrade to the hydro scheme penstock infrastructure needed to service growing electricity demand in Milford Sound Piopiotahi.

BOWEN FALLS / VALLEY WALK AND VIEWING PLATFORMS

The proposed falls and valley walks include a cantilevered viewing platform to provide views of the top of Hine-Te-Awa Bowen Falls. This assessment will be similar to the Barren Peak spur lookout due to limited access for a geotechnical investigation. The investigation of the site will consist of visual inspections and hand investigation. It is likely that bedrock will be encountered at shallow depths. It is anticipated that rock will be of sufficient quality that the foundation can be anchored into the rock. Assumptions of the rock quality will need to be confirmed during construction.

It is WSP's understanding that the valley walk is not expected to have any structures associated with it and will therefore not require any specific geotechnical investigation. However, design may be needed if any steps and railings need to be built along the alignment.

HINE-TE-AWA BOWEN FALLS PONTOON WALKWAY

A floating pontoon walkway is proposed to provide access from the existing boat terminal to a boardwalk and lookout structure at the base of Hine-Te-Awa Bowen Falls. The proposed offshore pontoon walkway is to replace an old walkway that was closed due to the rockfall hazard posed by the steep slopes above the walkway.

The anchor point located at the southeast end of the walkway is likely to have similar river deposits as those expected at the cable car base location. The proximity to the foreshore may increase the site's liquefaction and lateral spread potential in these softer soils. The northwest anchor point is not well understood currently, but there are some indications that bedrock is present at or near surface. Geotechnical investigation of both anchor points should be undertaken to gain a better understanding of the area to inform foundation selection.

ICONIC REFUGE

A shelter and viewing area that doubles as a natural hazard refuge is proposed on the waterfront alongside the boat terminal to provide protection for visitors and staff during a natural disaster (e.g. rockfall and tsunami). The structure will need to be designed as an Importance Level 4 building to allow it to perform as required both during and post-disaster.

Given the likely ground conditions at the location (liquefiable deltaic sediments with interbedded organic layers and bedrock at depth) suitable foundations are likely to be deep piles. The site will also likely experience lateral spreading due to its proximity to the sound. Ground improvements may also be required (such as deep soil mixing, stone columns) to mitigate liquefaction and lateral spreading effects. A site-specific geotechnical investigation and seismic assessment would be required as with the case of the Visitor Accommodations and other refuges in Milford Sound Piopiotahi.

While technically feasible from a geotechnical point, the ground conditions are not favourable for a structure to function as a refuge. The foundations required for a refuge will likely be prohibitively expensive at this location and it may not financially viable.

Additionally, this report does not consider any of the risks or information that is being developed concurrently for the MOP Natural Hazard report. Inputs from this report and others will be needed to inform the geotechnical investigation planning to ensure that scoping will include relevant testing.

REDEVELOP BOAT TERMINAL

The existing boat terminal is proposed for either downsizing, to act as a covered gateway to boat services, or repurposing for other activities. The scope of geotechnical investigation will be determined by what re-development of the boat terminal will entail.

It is assumed that the site will have similar ground conditions as those expected for the iconic refuge and pontoon walkway and be subject to the same challenges to be mitigated.

2.13 DEEPWATER BASIN NODE

The following is noted for Deepwater Basin Node:

- The Masterplan structures listed at this site are carpark upgrades, redevelopment of the boat ramp, new facilities for kayaking, a refuge, and a heliport. See Figure 19 below.
- Elevation: The site is approximately 0 m – 5 m ASL.
- Closest active fault: Anita Shear Zone #8756, located approximately 12 km west of the site.
- Geological Map Information: The site is located within the mapped geological unit: Holocene river deposits (Unweathered, loose, bouldery gravel, sand and mud in modern floodplains. Peat and carbonaceous mud bands may be interbedded). See Figure 20 below.
- Environment Southland Liquefaction Risk Map: High Risk. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.
- Assessments of the boat ramp, carpark pavement and a shelter were completed between 2017 and 2023.
  - 4 August 2017; Holmes Consulting Group (Holmes) and Wyatt + Gray Architects Ltd (Wyatt + Gray) issued a draft design of a shelter for the site[18]. The Holmes design report was not available at the time of this report. It is not clear if the shelter has been designed to act as a refuge.
  - 7 August 2017; RDAgritech Ltd (now RDA Consulting) issued a bearing capacity assessment report[19] for a proposed shelter for the site. The report is limited to a bearing assessment for a Timber Framed Building as per NZS 3604:2011. The RDA report does not provide any seismic, liquefaction or lateral spread analysis for the structure at the site.

[18] Deep Water Basin Shelter, Ultimate Hikes & Department of Conservation, Milford Sound, August 2017, Wyatt + Gray Architects Ltd, Holmos Consulting Group

[19] Bearing Capacity Assessment for Deepwater Basin, Milford Sound, August 2017, RDAgritech Ltd

– 1 November 2017; GeoSolve issued a pavement design report[20] to upgrade the current carpark. The carpark upgrade proposed by the Masterplan is located in a different part of the site to the current carpark that this report covers.

– 18 January 2018; Opus International Consultants Ltd (now WSP) issued a condition assessment report[21] for the Deepwater Basin Boat ramp. On 11 July 2023 WSP issued drawings[22] for a replacement boat ramp.

- RDA Consulting completed 5 Scala penetrometers for their bearing assessment report of the proposed 2017 shelter site. The Scalas were advanced between 0.25 m and 2.10 m bgl. The location for the 2017 proposed shelter is approximately the same as that proposed by the Masterplan for refuge to be located at site.
- GeoSolve completed 57 Falling Weight Deflectometer (FWD) test points along 4 runs for the pavement design report. The location of the 2017 proposed carpark site has been proposed for short term boat trailer storage based on the Masterplan.
- Based on the proximity of the Cleddau River and the likely soils, groundwater is assumed to be relatively shallow at approximately 2 m bgl. See Photograph 11 below.

Figure 19: Masterplan Deepwater Basin Layout Concept

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[20] Pavement Design, Deepwater Basin Road, Milford Sound, Fiordland National Park, November 2017, GeoSolve Ltd

[21] Deep Water Basin Boat Ramp, Milford Sound – Condition Assessment, January 2018, Opus International Consultants Ltd

[22] Department of Conservation – Te Papa Atawhai, Deepwater Basin, Boat Ramp Replacement, July 2023, WSP

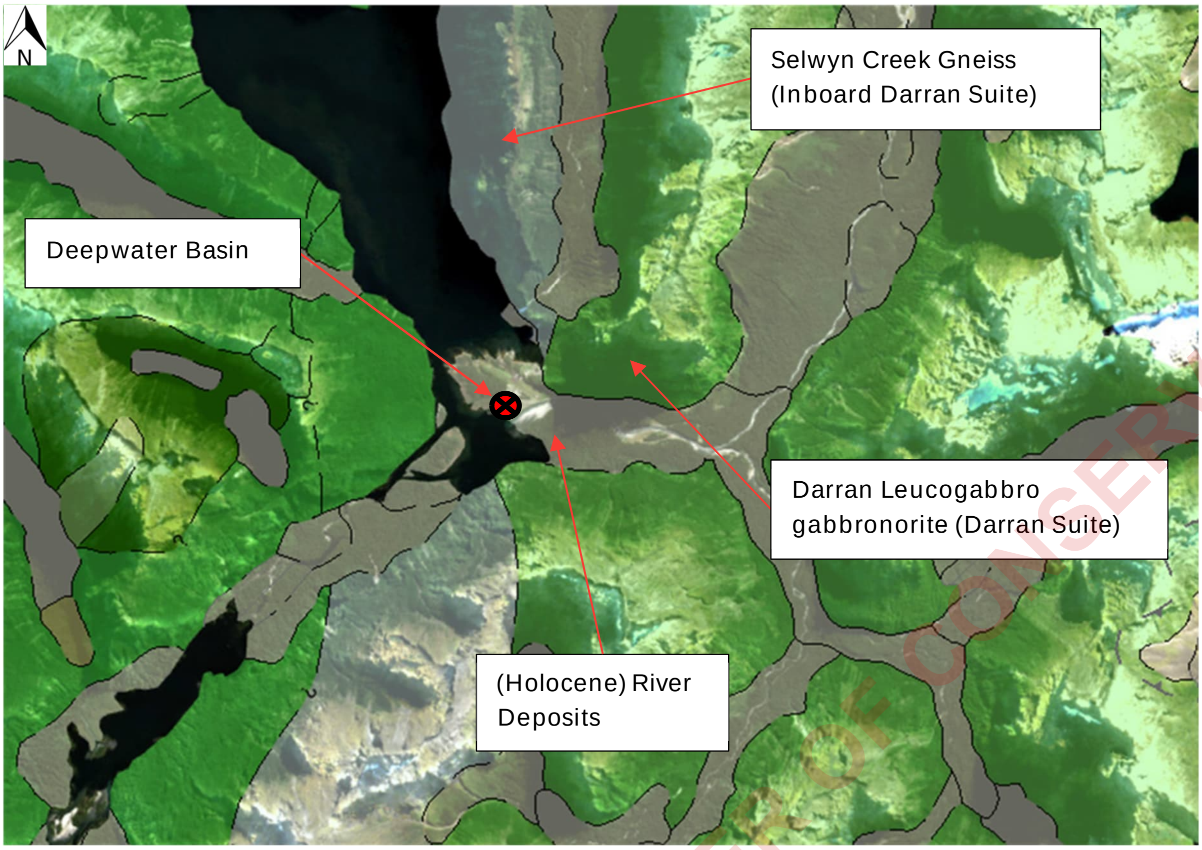

Figure 20: Deepwater Basin – Published Geology

Photograph 11: Deepwater Basin looking southwest from the northern bank of the Cleddau River

2.13.1 COMMENTARY ON FEASIBILITY OF PROPOSED STRUCTURES

The site likely consists of river sediments interbedded with organics over bedrock at depth. It is anticipated that the soils are likely to have layers of finer sediments throughout, and shallow ground water. It is likely that the site will have a potential for liquefaction and that lateral spreading may occur if located near to the foreshore.

RDAgritech's report[19] notes that the proposed shelter site is on reclaimed land and that no fill placement records were available at the time of their report. The GeoSolve report[20] also notes that parts of the site for the 2017 carpark upgrade is located on reclaimed land with fill material likely sourced from the Cleddau River. Some of the fill placed at site was likely placed as part of the Cleddau Flood Protection Scheme. As noted previously, it has been indicated that DOC possesses fill placement and compaction records, but they were not currently available at the time of this report.

Proposed upgrades to this site include a carpark and bus layover area, a boat ramp, kayaking facilities, an iconic refuge, and a new heliport.

It is assumed that the only structures at this node requiring design to an Importance Level above 2 are the iconic refuge and heliport associated infrastructure. The carpark, bus layover area, boat ramp and kayaking facilities are assumed to be simple lightly loaded structures and will not be required to contain or protect people during a seismic event or other natural hazards.

It is possible that if individual geotechnical investigations of the various sites are completed in conjunction with each other, the amount of investigation can be optimized and will likely lead to efficiencies in investigation costs.

The development as shown in the MOP Masterplan, at this stage, are geotechnically feasible. Due to the proximity of the Alpine Fault and refuges status of some structures, it should be expected that more detailed geotechnical investigations, strict designs requirements and complex construction will be required for these structures.

CARPARK AND BUS LAYOVER AREA

A new carparking area and bus layover is proposed to be constructed at the Deepwater Basin Node. It is WSP's understanding that both carpark and bus layover will consist of an open air at grade carpark with associated facilities. This area is currently raised above the surrounding area and ground conditions are assumed to include varying thicknesses of fill, underlain by river sediments and bedrock at depth.

The assumed fill at this location was likely placed during construction of the Cleddau Flood Protection Scheme. As noted previously, records for this fill placement were not available at the time of this report to determine the fill extents or specifications. DOC have indicated that records do exist, and these could be obtained to inform future phases. It is likely that review of the records and a basic geotechnical investigation should be able to determine the subgrades stability for a single-storey carpark. More detailed investigation will be required if the carpark is to be a multi-storey structure.

It should be noted that the proposed carpark area is near the existing aerodrome runway. As discussed in Section 2.11, investigations completed where settlement has occurred, were found to be likely caused due to decomposing organic matter. If areas of soft or organic ground are encountered on site, they will likely require over-excavation and backfilling with controlled fill to improve the subgrade.

BOAT RAMP

The existing boat ramp is proposed to be upgraded to dual lane, with work to optimise the access, manoeuvring and boat parking areas. Depending on the final upgrades, a basic geotechnical investigation consisting of shallow hand investigations (e.g. Scala penetrometer tests and hand augers) may be necessary to support design for the boat ramp upgrade.

KAYAKING FACILITIES

Existing kayaking facilities, comprising a temporary shelter and storage area, are proposed to be relocated to a separate service area at a nearby estuarine inlet. The new facility includes additional boat storage and a dedicated launching ramp. It is assumed that that all new structures are simple, lightly loaded, uninhabited, and single storey.

Basic hand geotechnical investigations are likely sufficient to determine appropriate foundations. This would comprise Scala penetrometer tests and hand augers. The final structure loadings and subsurface conditions will inform the most effective foundation solution.

ICONIC REFUGE

A natural hazard refuge is proposed in the low-lying coastal area near the boat ramp to provide protection for visitors and staff during a natural disaster (e.g. rockfall and tsunami). The structure will need to be designed as an Importance Level 4 building to allow it to perform as required both during and post-disaster.

Given the likely ground conditions at the location (liquefiable deltaic sediments with interbedded organic layers and bedrock at depth) suitable foundations are likely to be deep piles. The site will also likely experience lateral spreading due to its proximity to a free face, where the soil and body of water meet. Ground improvements may also be required (such as deep soil mixing, stone columns) to mitigate liquefaction and lateral spreading effects. A site-specific geotechnical investigation and seismic assessment would be required as with the case of the Visitor Accommodations and other refuges in Milford Sound Piopiotahi.

While technically feasible from a geotechnical point, the ground conditions are not favourable for a structure to function as a refuge. The foundations required for a refuge will likely be prohibitively expensive at this location and it may not financially viable.

Additionally, this report does not consider any of the risks or information that is being developed for the MOP Natural Hazard report. Inputs from this report and others will be needed to inform the geotechnical investigation planning to ensure that scoping will include relevant testing.

HELIPORT

A new heliport is proposed to be located on raised ground off the existing staff accommodation. It is assumed that the heliport will include some above-ground infrastructure (e.g. control building, sheds, etc). The design requirements of the heliport and associated infrastructure (e.g. IL2 or above, specific pavement design), will determine the extent of the geotechnical investigation necessary to inform design.

2.14 CLEDDAU DELTA NODE

The following is noted for Cleddau Delta Node:

- The Masterplan structures listed at this site are water viewing decks and a Delta link bridge, and a refuge.
- Elevation: The site is approximately 0 m – 5 m ASL.
- Closest active fault: Anita Shear Zone #8756, located approximately 12 km west of the site.
- Geological Map Information (as Section 2.11 Milford Sound Piopiotahi Visitor Hub): The site is located within the mapped geological unit: Holocene river deposits (Unweathered, loose, bouldery gravel, sand and mud in modern floodplains. Peat and carbonaceous mud bands may be interbedded). See Figure 22 below.
- Environment Southland Liquefaction Risk Map: High Risk. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.
- Existing geotechnical investigation information (as per Section 2.11 Milford Sound Piopiotahi Visitor Hub) indicates that the site is likely to be underlain by uncontrolled fill of varying thickness with deltaic sediment and interbedded organic swap deposit below, and gabbro bedrock at unknown depth. Groundwater level is assumed to be <2 m. See Photograph 12 below.

Figure 21: Masterplan Cleddau Delta Layout Concept

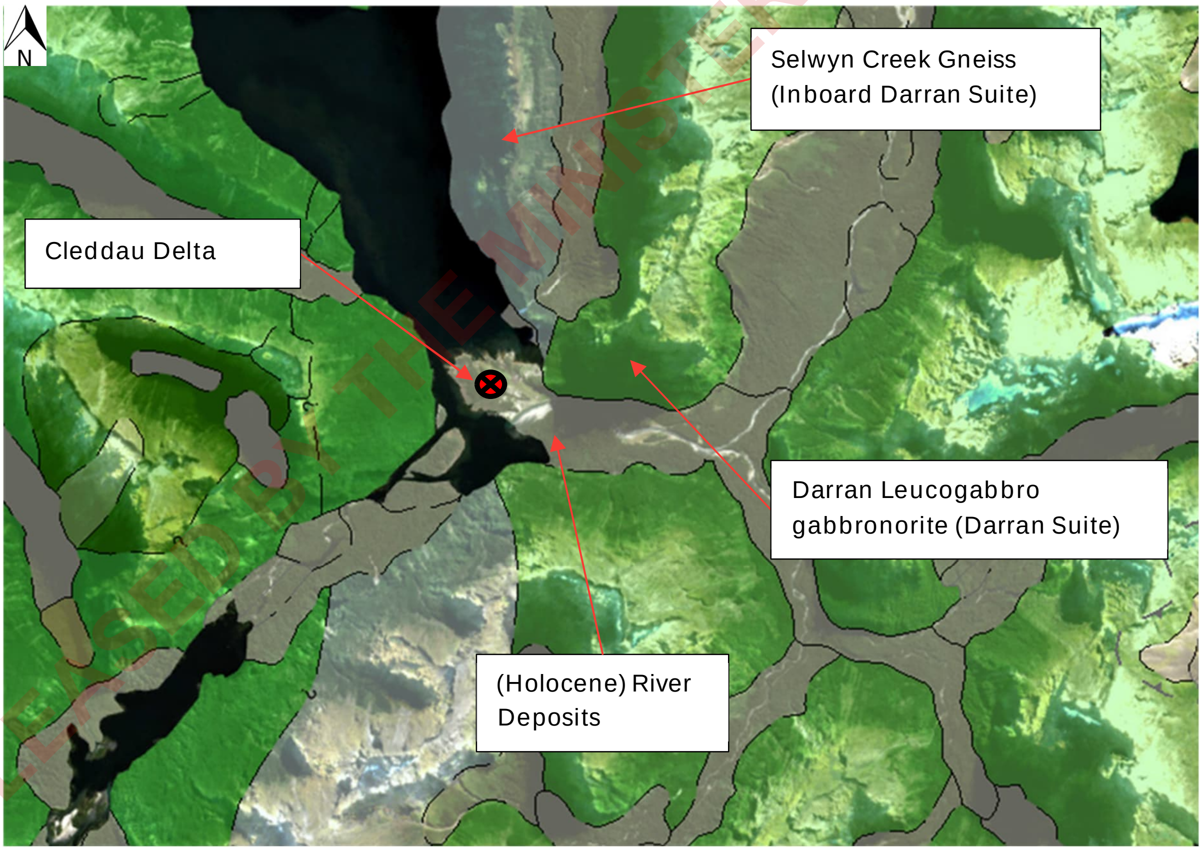

Figure 22: Cleddau Delta – Published Geology

Photograph 12: Cleddau Delta looking west from the existing aerodrome aircraft parking area

2.14.1 COMMENTARY ON FEASIBILITY OF PROPOSED STRUCTURES

The site likely consists of river sediments interbedded with organics over bedrock at depth. It is anticipated that the soils are likely to have layers of finer sediments throughout, and shallow ground water. It is likely that the site will have a potential for liquefaction and that lateral spreading may occur if located near to the foreshore.

Proposed upgrades to this site include removal of the aerodrome runway and addition of more walking tracks including a water viewing deck, two iconic refuges, and delta link bridge.

The water viewing deck and bridge are not assumed to be required to contain or protect people during earthquakes or other natural hazards.

It is possible that if individual geotechnical investigations of the various sites are completed in conjunction with each other, the amount of investigation can be optimized and will likely lead to efficiencies in investigation costs.

The development as shown in the MOP Masterplan, at this stage, are geotechnically feasible. Due to the proximity of the Alpine fault and refuges status of some structures, it should be expected that more detailed geotechnical investigations, strict designs requirements and complex construction will be required for these structures.

WATER VIEWING DECK + DELTA LINK BRIDGE

A water viewing deck (at the NW end of the current aerodrome runway) and a delta link bridge (north of the runway) are proposed as part of the aerodrome nature regeneration and walking tracks.

Given the type of structures, anticipated subsoil conditions, and the potential high volume of pedestrian traffic, a geotechnical investigation and specific design will be required. The scope of the investigation required will be clearer once the loading conditions are better understood. In WSP's experience with structures at popular tourist destinations, these structures are heavily trafficked and design loading is higher to account for this.

TWO ICONIC REFUGES

Two natural hazard refuges are proposed in the low-lying delta area to provide protection for visitors and staff during a natural disaster (e.g. rockfall and tsunami). The structures will need to be designed as an Importance Level 4 building to allow them to perform as required both during and post-disaster.

Given the likely ground conditions at the location (liquefiable deltaic sediments with interbedded organic layers and bedrock at depth) suitable foundations are likely to be deep piles. The site will also likely experience lateral spreading due to its proximity to a free face, where the soil and body of water meet. Ground improvements may also be required (such as deep soil mixing, stone columns) to mitigate liquefaction and lateral spreading effects. A site-specific geotechnical investigation and seismic assessment would be required as with the case of the Visitor Accommodations and other refuges in Milford Sound Piopiotahi.

While technically feasible from a geotechnical point, the ground conditions are not favourable for a structure to function as a refuge. The foundations required for a refuge will likely be prohibitively expensive at this location and may not be financially viable.

Additionally, this report does not consider any of the risks or information that is being developed for the MOP Natural Hazard report. Inputs from this report and others will be needed to inform the geotechnical investigation planning to ensure that scoping will include relevant testing.

2.15 LITTLE TAHITI (ALTERNATE NODE)

The following is noted for Little Tahiti:

- The Masterplan structures lists this site as an alternative location for the new staff accommodation and the heliport.
- Elevation: The site is approximately 10 m – 20 m ASL.
- Closest active fault: Unnamed fault #9213, located approximately 11.5 km east of the site.
- Geological Map: The site is located within the mapped geological unit: Holocene river deposits (Unweathered, loose, bouldery gravel, sand and mud in modern floodplains. Peat and carbonaceous mud bands may be interbedded). See Figure 23
- Environment Southland Liquefaction Risk Map: Medium Risk. Note mapping completed between 2006 and 2012. Data may be outdated under current liquefaction assessment techniques.
- A report completed by e3Scientific[23] indicates that the site is the location of an historical landfill and is known to be contaminated with various substances, including asbestos, and has pockets of landfill waste material distributed across the area to depths of up to 2m. It is understood that the site will be remediated by the Department of Conservation, but it is unknown when this will be completed. Any earthworks at this site (including geotechnical

[23] Little Tahiti Landfill Preliminary and Detailed Site Investigation, Jan 2022, e3Scientific

investigations) must consider the risk of soil and water contamination in their methodologies. Groundwater level is assumed to be 1 m -2 m bgl as per e3Scientific report. See Photograph 13 below.

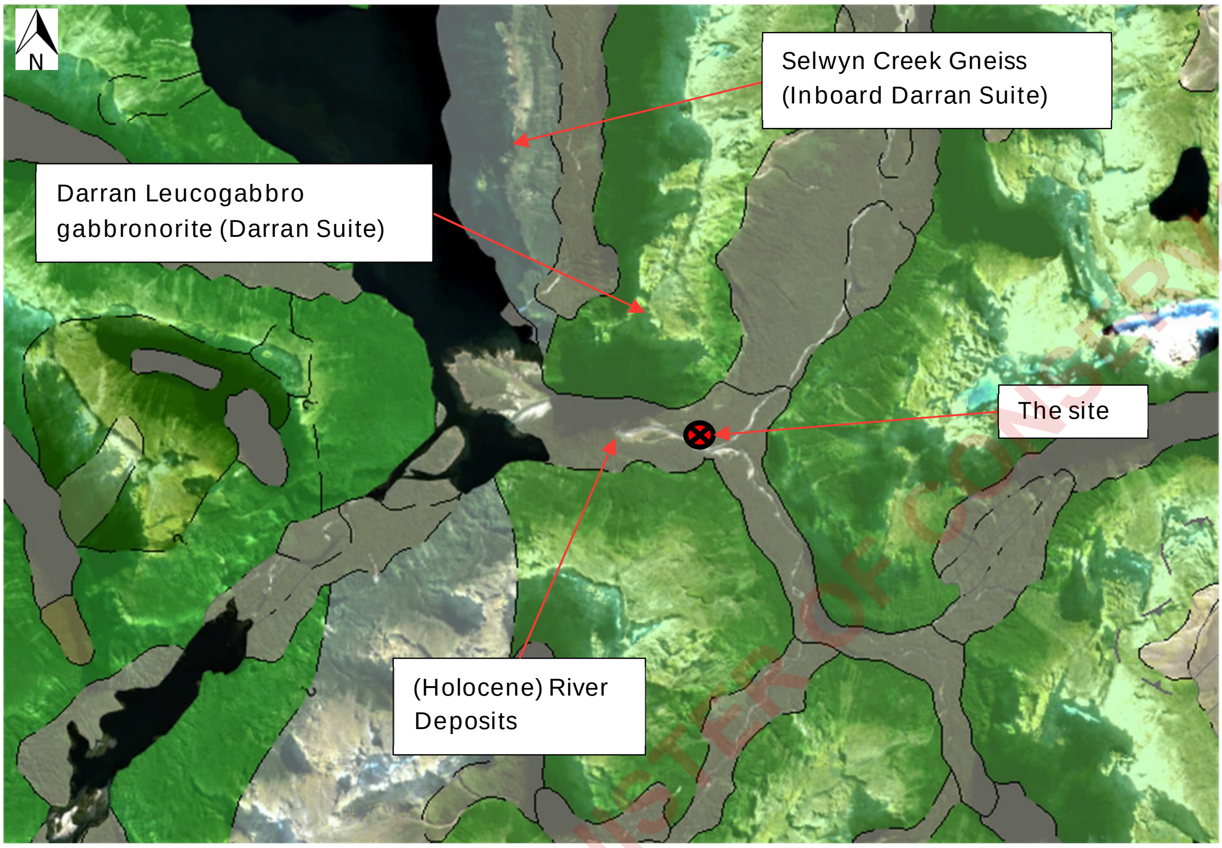

Figure 23: Little Tahiti – Published Geology

Photograph 13: Little Tahiti looking northeast from the southern end of the site

2.15.1 COMMENTARY ON FEASIBILITY OF PROPOSED STRUCTURES

Little Tahiti is proposed as an alternative location for the staff accommodation or heliport discussed in Sections 2.11.1 and 2.13.1.

The e3Scientific PSI and DSI report (2022) found the shallow site geology to consist of river sediments with a shallow organic layer above coarse sands and fine gravels at the north of the site, and cobbles and boulders with a coarse sand / fine gravel matrix in the south. Bedrock is expected at depth.

At this stage the site is assumed to have a medium liquefaction potential. Geotechnical investigation of the site will be used confirm the soils onsite, whether groundwater is present at shallow depths and allow determination if further liquefaction assessment of the site is required.

Any geotechnical investigation of the site will need to consider contaminated land controls, both for the health and safety of workers and for disposal of any disturbed soils, unless remediation of the site is completed beforehand.

The development as shown in the MOP Masterplan, at this stage, are geotechnically feasible. Due to the proximity of the Alpine Fault, it should be expected that more detailed geotechnical investigations, strict designs requirements and complex construction will be required for the staff accommodation building.

STAFF ACCOMMODATION (ALTERNATE)

The requirements for site investigation and foundation design are assumed to be similar for this site to those discussed in Section 2.11.1. However, based on the e3Scientific Little Tahiti report, URS completed 12 test pits up to 2.5m bgl of part of the site in 2013. Review of the logs indicate that the shallow subsoil conditions consist of gravels with varying contents of sand with cobbles and boulders present. This may indicate that the site has more favourable ground conditions than those at the primary location for the staff accommodation. However, a site-specific geotechnical investigation will need to be completed to confirm the ground conditions.

HELIPORT (ALTERNATE)

It is assumed that the heliport will include some above-ground infrastructure (e.g. control building, sheds, fuel tanks). The design requirements of the heliport and associated infrastructure (e.g. IL2 or above, specific pavement design), will determine the extent of the geotechnical investigation necessary to inform geotechnical design. As with the staff accommodations, there are indications that the ground conditions are better than the primary location. However, a site-specific geotechnical investigation will need to be completed to confirm the ground conditions.

3 PRELIMINARY GEOTECHNICAL INVESTIGATION RECOMMENDATIONS

Preliminary geotechnical investigation recommendations for each site described in the preceding section of this report are based on our assumptions of the ground conditions (based on our desk study of published geology, existing geotechnical investigation information, and site tour photos) and assumed structure types (taken from the Masterplan) at each site.

Once the final type and size of structures at each node is confirmed, the following recommendations should be reviewed before undertaking the geotechnical investigation to make sure it is still fit for purpose. Different types of geotechnical investigation are required for structures of different size and use. The main types of geotechnical investigation for seismic design of structures, as prescribed in Earthquake Geotechnical Engineering Practice Module 2[1].

In addition, structures of different size and use may be classified by their Importance Levels (ILs), as defined by NZ Standard 1170.0[24]. The structures IL also has an influence geotechnical investigation that is required to be collected during the investigation.

Liquefaction susceptibility for each node has been estimated based on the Environment Southland Liquefaction Risk mapping[8], and correlates with the expected ground types at each site. Any site with liquefaction risk low - high on the map is categorized as a **yes** (Liquefaction risk considered possible) in Table 4, and any site with negligible risk categorized as a **no**.

The main structure types at each node have been grouped into the categories seen below in Table 4. The geotechnical investigation types mentioned in Table 4 are abbreviated as follows:

- CPT Cone Penetration Test
- BH Borehole
- DPSH Super Heavy Dynamic Probe
- Scala Scala Penetrometer Test
- HA Hand Auger
- MASW Multichannel Analysis of Surface Waves
- TP Test Pit

[24] NZS1170.0:2002 – Structural design actions Part 0: General principles, 2002, NZS

Table 4: Preliminary Geotechnical Investigation Recommendations

Structure Type (incl. proposed IL)	Ground Type	Location (proposed structures)	Proposed Minimum Geotechnical Investigations (Liquefaction considered possible Y/N)
Simple light facilities (e.g. toilets, bus shelters, kayak storage, trail head facilities) *IL1 or IL2*	Holocene Fan Deposits	— Eglinton Reveal (access restriction facilities) — Short stop: Mirror Lakes Waiwhakaata (on slope) — Knobs Flat Te Huakaue & Kiosk Creek (trail head facilities, camp sites) — Hinepipiwai Lake Marian (toilet facilities) — Short stop: The Chasm (bus shelter, toilets)	— Deep investigations (Preliminary Liquefaction Risk: **yes**) Recommended testing is one CPT (to 10 m or refusal) and one BH (to a minimum of 10 m bgl) per site, locating the investigations under two of the most significant proposed building footprints where these are known and where there are multiple simple light structures at one site (otherwise locate both investigations under the one building footprint). CPT testing may not penetrate to great depths due to the likely presence of gravels and cobbles. Liquefaction analysis may be completed using SPT test results. CPT locations would be substituted for BHs. This analysis will be coarser as the SPTs are not continuous.
	Holocene River Deposits	— Ōtāpara Cascade Creek (bus shelter, camp sites, toilets, kayaking facilities) — Short stop: Mirror Lakes Waiwhakaata (flats only) — Deepwater Basin Node (kayaking facilities)	
	Glacial Deposits	— Gertrude Valley – eastern side (trail head facilities)	— Shallow investigations (Preliminary Liquefaction Risk: **no**) Scala penetrometer, DPSH and CPT testing are unlikely to be suitable at this site given the likely presence of near-surface gravels and cobbles. Recommended testing is 2x machine test pits across each building footprint to minimum 3m depth (or 1 m below 2x the footing width). The test pits may be diagonally opposite each other and <2 m outside the building footprint if this is known. If the building location is not known, or the test pits are dug within the footprint, they should be backfilled with aggregate (i.e. AP65 – AP150) compacted in 200 mm layers, otherwise they may be backfilled with spoil and tamped with excavator bucket + tracks.

Structure Type (incl. proposed IL)	Ground Type	Location (proposed structures)	Proposed Minimum Geotechnical Investigations (Liquefaction considered possible Y/N)
Light timber frame buildings <250 m² (e.g. cabins, visitor shelter) *IL2*	Holocene Fan Deposits	— Eglinton Reveal (visitor shelter) — Knobs Flat Te Huakaue & Kiosk Creek (cabins, camping facilities) — The Divide / Hinepipiwai Lake Marian Head (visitor shelter)	— Deep investigations (Preliminary Liquefaction Risk: **yes**) Recommended testing is one CPT (to 15 m or refusal) and one BH (to a minimum of 15 m) per structure. At Knobs Flat piled foundations are anticipated to be founded on Glacial Till ~10 m bgl. CPT testing may not penetrate to great depths due to the likely presence of gravels and cobbles. Liquefaction analysis may be completed using SPT test results. CPT locations would be substituted for BHs. This analysis will be coarser as the SPTs are not continuous.
	Holocene River Deposits	— Deepwater Basin Node (heliport facilities)	— Deep investigations (Preliminary Liquefaction Risk: **yes**) Recommended testing is one CPT (to 15 m or refusal) and one BH (to a minimum of 15 m) with one testing location per structure if there are more than one.
	Glacial Deposits	— Gertrude Valley – eastern side (visitor shelter)	— Shallow investigations (Preliminary Liquefaction Risk: **no**) Recommended testing as per Gertrude Valley trail head facilities above.
Large concrete floor buildings > 250 m² (e.g. visitor hub, transport terminal, Wānanga, cable car base building) *IL2*	Holocene River Deposits	— Te Anau Hub (visitor centre, transport interchange) — Milford Sound Piopiotahi Visitor Hub (visitor hub, bus terminal) — Freshwater Basin Node (cable car top and bottom base buildings, boat terminal redevelopment)	— Deep investigations (Preliminary Liquefaction Risk: **yes**) Recommended testing is two CPTs to 20 m or refusal) and one BH (to a minimum of 20 m) per structure. At Lake Marian wānanga CPT testing is unlikely to penetrate far at this site given the likely presence of near-surface gravels. The geotechnical engineer who plans the investigation may choose to switch one of the CPTs for an additional BH at this site.
	Holocene Fan Deposits	— Hinepipiwai Lake Marian (wānanga)	
Large Accommodation Buildings (e.g. staff and visitor accommodation)	Holocene Fan Deposits	— Knobs Flat Te Huakaue & Kiosk Creek (lodge at kiosk creek)	— Deep investigations (Preliminary Liquefaction Risk: **yes**) Recommended testing is two CPTs (to 30 m or refusal and one BH (5 m into bedrock or a minimum depth of 5x pile

Structure Type (incl. proposed IL)	Ground Type	Location (proposed structures)	Proposed Minimum Geotechnical Investigations (Liquefaction considered possible Y/N)
IL4			diameters below the anticipated toe of piled foundations, or preliminarily 30 m) per 250 m² of building footprint. Site specific Probabilistic Seismic Hazard Analysis (PSHA) to determine the likely size and direction of seismic waves and Peak Ground Accelerations (PGAs). Testing to confirm VS30 values will be required. VS30 can be collected through down hole testing (completed during BH drilling) or afterward at surface level with Multichannel Analysis of Surface Waves (MASW).
	Holocene River Deposits	— Milford Sound Piopiotahi Visitor Hub (visitor and staff accommodation) — Little Tahiti (staff accommodation - alternate)	— Deep investigations (Preliminary Liquefaction Risk: **yes**) Recommended testing is two CPTs (to 30 m or refusal and one BH (5 m into bedrock or a minimum depth of 5x pile diameters below the anticipated toe of piled foundations, or preliminarily 30 m) per 250 m² of building footprint. Site specific Probabilistic Seismic Hazard Analysis (PSHA) to determine the likely size and direction of seismic waves and Peak Ground Accelerations (PGAs). Testing to confirm VS30 values will be required. VS30 can be collected through down hole testing (completed during BH drilling) or afterward at surface level with Multichannel Analysis of Surface Waves (MASW).
Iconic Refuges (e.g. natural hazard refuge from rockfall / tsunami) ***IL4***	Holocene Fan Deposits	— Cleddau Cirque (rockfall shelter)	— Deep investigations (Preliminary Liquefaction Risk: **yes**) CPT testing is unlikely to be suitable at this site given the likely presence of near-surface gravels and cobbles. Recommended testing is two BHs (to 5 m into bedrock or a minimum depth of 5x pile diameters below the anticipated toe of piled foundations, or preliminarily 30 m) per 250 m² of building footprint.
	Holocene River Deposits	— Freshwater Basin Node (tsunami refuge) — Deepwater Basin Node (tsunami refuge) — Cleddau Delta Node (tsunami refuge)	— Deep investigations (Preliminary Liquefaction Risk: **yes**) Recommended testing is two CPTs (to 30 m or refusal and one BH (5 m into bedrock or a minimum depth of 5x pile

Structure Type (incl. proposed IL)	Ground Type	Location (proposed structures)	Proposed Minimum Geotechnical Investigations (Liquefaction considered possible Y/N)
			diameters below the anticipated toe of piled foundations, or preliminarily 30 m) per 250 m^2 of building footprint.
Lookout platforms (e.g. treetop lookout, viewing platforms) *IL2*	Holocene River Deposits	— Milford Sound Piopiotahi Visitor Hub (Barren Peak Spur lookout, foreshore viewing decks) — Freshwater Basin Node (Bowen Falls viewing platform, pontoon walkway) — Cleddau Delta Node (water viewing decks, delta link bridge)	— Deep investigations (Preliminary Liquefaction Risk: **yes**) Recommended testing is one CPT and one BH per structure (both to 15 m or refusal). The type, function and IL of each structure should be carefully considered before applying this proposed testing recommendation, as it may be acceptable to undertake no testing at all for some structures (e.g. the water viewing decks may be assessed to only require standard DOC boardwalk type construction, with no geotechnical investigation). Barren Peak Spur and Bowen Falls upper viewing platform are anticipated to be entirely on bedrock with a thin layer of organic soil, therefore no liquefaction risk and little need for deep investigations, especially if bedrock parameters can be derived from other nearby investigations. Freshwater Basin pontoon walkway will likely require a set of investigations at each end to help with foundation/anchor point design, as ground conditions may vary between shores.
Pavements (e.g. sealed carparks, transport terminal forecourt, heliport) *IL N/A*	Holocene River Deposits	— Te Anau Hub (transit forecourt) — Milford Sound Piopiotahi Visitor Hub — Deepwater Basin Node (carpark, heliport) — Little Tahiti (heliport – alternate)	— Pavement test pits (maximum of 2 test pits per small carpark or 4 test pits per large carpark to a minimum depth of ~600 mm bgl). Test pits should be backfilled with compacted aggregate to ensure no 'soft spots' are created that may impact later pavement construction.

Structure Type (incl. proposed IL)	Ground Type	Location (proposed structures)	Proposed Minimum Geotechnical Investigations (Liquefaction considered possible Y/N)
	Holocene Fan Deposits	— Eglinton Reveal (carpark) — The Divide / Hinepipiwai Lake Marian Head (possibly unsealed carpark) — Cleddau Cirque (possibly unsealed carpark) — Short stop: The Chasm (possibly unsealed carpark)	— Laboratory testing (soaked and unsoaked CBR) to confirm the subgrade soil parameters for pavement design.
	Glacial Deposits	— Gertrude Valley (possibly unsealed carpark)	
Cable Car (IL TBC)*	Darran Leucogabbro gabbronorite (Darran Suite)	— Freshwater Basin Node (cable car)	— Specific geotechnical input is required for the planning of investigations for the Cable Car. It is anticipated that at least two boreholes be completed up to 20 m deep. One at the based where softer soils are expected and one at the top to gather rock parameters. Laboratory testing of soil and rock core samples, will be required per footing location.
Artwork IL2	Outwash Deposits	— Te Rua-o-Te-Moko Fiordland National Park Gateway	— Shallow investigations (Preliminary Liquefaction Risk: **no**) Scala penetrometer testing is unlikely to be suitable at this site given the likely presence of near-surface gravels. Recommended testing is 2x DPSH on either side of the road, within the spread of the proposed pouwhenua locations, to refusal or 5m depth (x4 total tests).
Boat Ramp IL N/A	Holocene River Deposits	— Deepwater Basin Node	— Geotechnical investigation scope to be determined once details are available. Very simple structures may require hand investigations of Scalas and HAs.
Flood Protection Infrastructure IL2**	Holocene River Deposits	— Ōtāpara Cascade Creek	— Shallow + Deep investigations (Preliminary Liquefaction Risk: **glacial deposits – no, river and fan deposits - yes**) Stop banks are assumed to be less than 1km in length. Recommended testing consists of two boreholes and DPSH every 100m.
	Western Side: Holocene fan deposits	— Gertrude Valley	

Structure Type (incl. proposed IL)	Ground Type	Location (proposed structures)	Proposed Minimum Geotechnical Investigations (Liquefaction considered possible Y/N)
	Eastern Side: Glacier deposits		

* The cable car at Freshwater Basin Node does not fit cleanly into one of the IL categories in NZS1170.0. Careful consideration and consultation with the client is required when confirming an appropriate Importance Level for the cable car.

** Flood protection infrastructure should be designed to at least the same IL as the structures it is protecting. In this case IL2 may be suitable given the structures at Ōtāpara Cascade Creek, Gertrude Valley.

3.1 PRELIMINARY COST ESTIMATES FOR GEOTECHNICAL INVESTIGATIONS

Preliminary estimates of costs to complete the proposed geotechnical investigations have been prepared and are summarised in Table 5 below. The costs include an estimate of contractor's and WSP fees to complete the site works and onsite monitoring. WSP costs also include the production of a Geotechnical Factual Report summarising the investigation information for each site.

Indicative contractors' fees are based on a consensus from three different local (South Island based) geotechnical drilling contractors, with support from other investigation contractors where necessary. WSP monitoring fee estimates are based on onsite timeline hours provided by the contractors. WSP factual reporting has been simplified into a small, medium, or large Geotechnical Factual reports and assigned based on the size of the investigation at each location.

Estimated days to complete the proposed investigations by the three drilling contractors ranges from 110 – 193 (excluding any multi-storey carpark investigations) to 238 – 373 (including multi-storey carpark investigations at three sites). This is based on estimates from the drilling contractors where they have assumed that each site would be completed as a separate project. Total timeframe may be reduced by completing investigations concurrently, depending on contractor availability etc.

It should be noted that the costs provided by the drilling contractors are rough order costs for guidance at the feasibility stage. Once structures have been finalised and geotechnical investigation have been scoped, drilling contractors will be able to give more accurate costs to complete. Therefore, it should be expected that final costs may vary when work is commissioned.

Table 5: *Preliminary Estimates of Cost for Geotechnical Investigations of MOP Upgrades*

Location	*Cost Estimates*	
	Sum	*Sum (incl. multi-storey carpark investigations at 3 locations)*
Te Anau Hub	$64,000.00	$486,500.00
Te Rua-o-Te-Moko Fiordland National Park Gateway	$23,000.00	
Short Stop: Mirror Lakes	$23,000.00	
Eglinton Reveal	$61,000.00	$483,500.00
Knobs Flat Te Huakaue & Kiosk Creek	$81,500.00	$504,500.00
Ōtāpara Cascade Creek	$59,500.00	
The Divide	$32,000.00	
Hinepipiwai Lake Marian	$47,500.00	
Gertrude Valley	$49,500.00	
Cleddau Cirque	$98,000.00	

Location	Cost Estimates	
	Sum	Sum (incl. multi-storey carpark investigations at 3 locations)
The Chasm	$27,500.00	
Milford Sound Piopiotahi Visitor Hub	$394,500.00	
Freshwater Basin Node (Milford Sound Piopiotahi)	$235,500.00	
Deepwater Basin Node (Milford Sound Piopiotahi)	$96,000.00	
Cleddau Delta Node (Milford Sound Piopiotahi)	$78,500.00	
Little Tahiti (Milford Sound Piopiotahi)	$345,000.00	
Total	$1,716,000.00	$2,984,000.00

The following assumptions and exclusions should be noted.

- Estimates are based off Table 5 and the proposed minimum geotechnical investigations.
- The estimate is based on WSP's current understanding of the various structures that make up the MOP upgrades. These estimates should be reviewed and reconsidered once the full scope of upgrades has been finalised.
- Costs for each location have been estimated separately. Grouping multiple investigation locations together would provide efficiencies in reducing establishment costs.
- Te Anau will be used as a base for physical works, except for locations in Milford Sound Piopiotahi as it has been assumed accommodation can secured. Estimates include travel costs between site and Te Anau or Milford Sound Piopiotahi for each day.
- These estimates do not include any time for application of permits or resource consent to be permitted to complete investigation work. This includes utility clearances, land access agreements etc.
- Estimates include WSP fees for onsite monitoring of investigations and delivery of a Geotechnical Factual Report for each Location. It should be noted that these reports comprise a summary of factual information only and no interpretive reporting or design has been included in the cost estimate.
- Costs for geotechnical investigations of multi-storey carpark locations cover larger areas than other structures, therefore requiring more boreholes to determine the lateral variability of ground conditions.

4 MOP – WALKING AND CYCLING EXPERIENCE CRITICAL STRUCTURES

In addition to the proposed development to the Milford corridor outlined in Section 2, various walking and cycling experiences are also proposed to be constructed. Southern Land has produced a draft Walking and Cycling Experiences Report[25] which discusses the technical feasibility of providing the experiences identified in the MOP Stage 2. The proposed locations of the walking and cycling experience are shown in Figure 24 below that was taken from the Southern Land report. WSP have been asked to provide a high-level geotechnical feasibility assessment of the critical structures identified in the Southern Land report. WSP has not visited the sites of the critical structures to complete our own assessments. As such, the following geotechnical feasibility is based solely on publicly available information and the Southern Land report.

Southern Land identifies 15 critical structures of sufficient size or structure type to require further technical consideration to confirm their feasibility. The geotechnical feasibility of the critical structures is summarised in Table 6 below. This should be read in conjunction with the WSP Structural Feasibility Report[26]. The Chasm Bridge(s) replacement is being considered and investigated separately by the Department of Conservation (DOC) and is only briefly mentioned in this geotechnical feasibility summary table.

The preliminary feasibility summary briefly discusses the likely ground conditions at each site (based on available information), a recommendation of suitable foundation types, and any difficulties likely to affect construction. WSP has not visited the sites, therefore our assumptions of site conditions are preliminary and may change subject to more information being gathered in the future.

[25] Milford Opportunities Project, Walking and Cycling Experiences Report (DRAFT), Dec 2023, Southern Land

[26] Milford Opportunities Project, Critical Structures for Walking and Cycling Construction Feasibility – Draft, Feb 2024, WSP

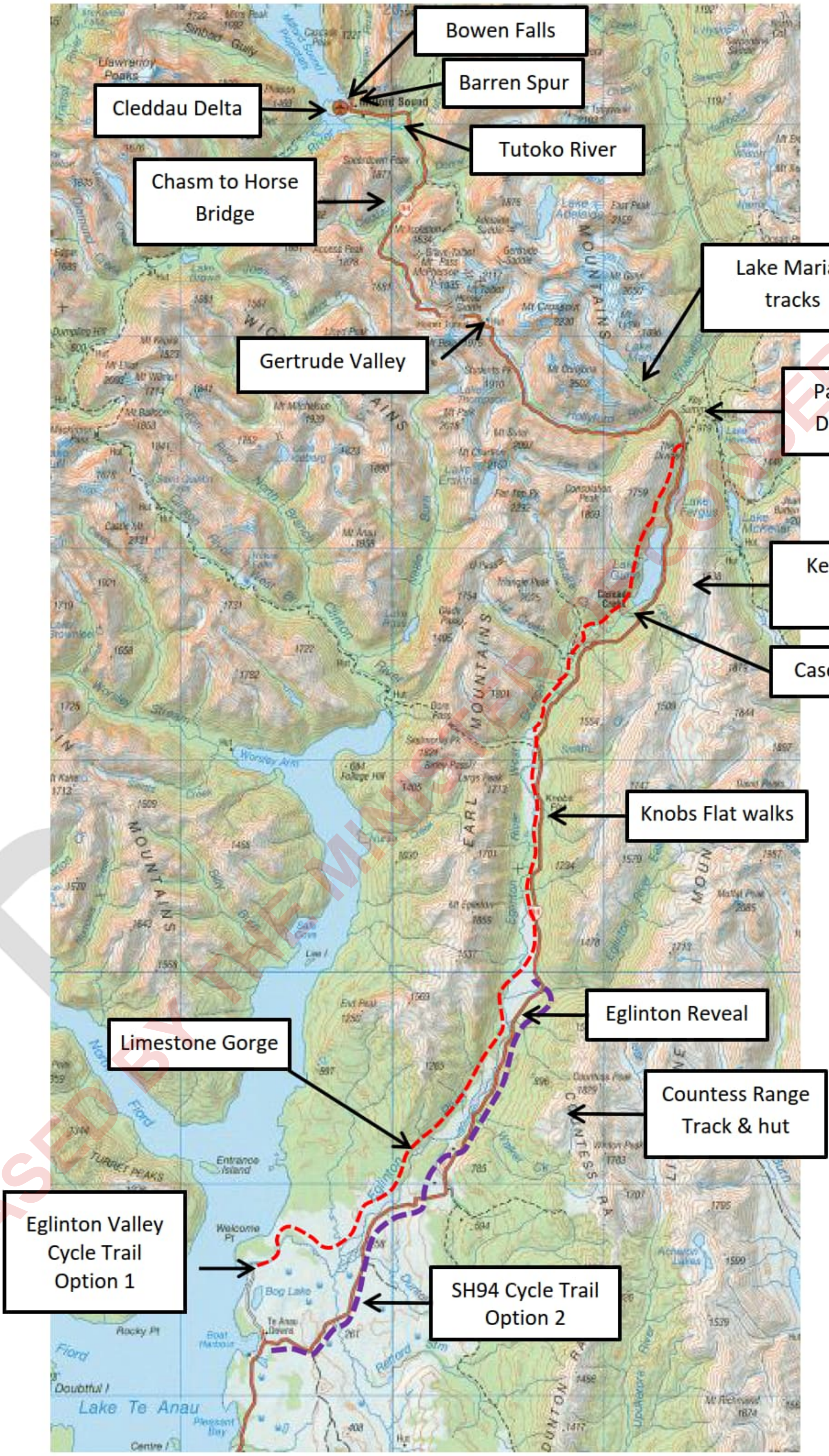

Figure 24: Walking and Cycling Trail Map taken from Southern Land Report[25]

Table 6: MOP – Walking and Cycling Experience Critical Structures Preliminary Geotechnical Feasibility Comments

Item #	Location (Structure Type)	Geological Unit Slope Gradient	Feasibility Comment
1	Lower Eglinton River (Bridge – suspension)	**Late Pleistocene glacier deposits** (generally unweathered, unsorted to sorted, loose sandy gravel, silt and sand (till) in terminal and ground moraines) Low gradient	Geotechnically feasible. Geotechnical Investigation of site required for input into foundation design and assess liquefaction and lateral spread potential of the site. Liquefaction potential at site is currently assumed to be negligible to low based on the assumed soils and Environment Southland mapping. Liquefaction and lateral spread potential of the site will need to be assessed. Depending on liquefaction potential, standard foundation solution may be suitable such as shallow piles + concrete pad under towers and buried cast in place concrete deadman anchors for cables. Suitability TBC after geotechnical investigation and bridge loading is provided. Possible difficulties include liquefaction and lateral spreading of soils, and the presence of boulders in the glacial sediment.
2	East Eglinton confluence (Riverbank scour protection)	**Holocene fan deposits** (loose, commonly angular, boulders, gravel, sand, and silt forming alluvial fans; grades into scree (upslope) and valley alluvium) Low gradient High angle slip upslope of trail	Geotechnically feasible, with ongoing maintenance. Rock armouring may be used to protect the slope from further river scour and as a foundation for the cycle path. Possible difficulties include debris from the slip above continuing to fall to the foot of the slope, especially after high rainfall. This will require frequent (fortnightly/monthly) inspection and maintenance to keep the path clear. A rockfall catch fence or bund could also be used to reduce the volume of debris reaching the path with a maintenance plan to clear debris. This may be costly to install but will require less frequent maintenance. Benching into the toe of the slip should be avoided, if possible, as this will destabilise the slope and lead to increased erosion / rockfall onto the path. If the toe of the slope is modified, retaining structures will be necessary or the slope will need to be regraded.

Item #	Location (Structure Type)	Geological Unit Slope Gradient	Feasibility Comment
3	Eglinton River just above east branch (Bridge – suspension)	From **Holocene fan deposits** to **Holocene river deposits** (unconsolidated gravel, sand, silt, clay, and minor peat of modern to postglacial flood plains, may be terraced) Low gradient	Geotechnically feasible. Geotechnical Investigation of site required for input into foundation design and assess liquefaction and lateral spread potential of the site. Liquefaction potential at site is currently assumed to be low based on the assumed soils and Environment Southland mapping. Liquefaction potential of the site will need to be assessed Standard foundation solution recommended, such as the one described for Lower Eglinton River Suspension Bridge above. Ground conditions on the eastern bank are likely more suitable for driven piles, as boulders are less likely in river deposits, though large cobbles and possibly boulders are still likely in the fan deposits on the western bank. Difficulties include the possible presence of soft, organic, or liquefiable layers below footings. Deeper piles (e.g. screw piles) or other adjustments could be used to combat this, depending on the design requirements of the bridge.
4	Countess Range Hut (Alpine hut)	**Boyd Creek Formation** (discontinuous basal mudstone; thin-bedded graded sandstone, upper part is massive siltstone/mudstone with lenticular massive sandstone) Low to moderate gradient – bedrock / boulder field	Geotechnically feasible. Geotechnical Investigation of site required for input into foundation design. Liquefaction potential at site is currently assumed to be negligible based on the assumed soils and Environment Southland mapping. Standard foundation solution recommended such as concrete pad / strip footings cast into rock. Excavation at some locations, will likely be difficult due to shallow bedrock or landslide debris (significant sized boulders). Given the remote location, it will be difficult to mobilise equipment of sufficient size to carry out excavation in rock, this will need to be considered during foundation design. In addition, soft ground may also be present at some locations and should be avoided to ensure all footings are on solid subgrade to avoid differential settlements. Consideration should be given to locating the hut away from rockfall hazard and unstable ground.

Item #	Location (Structure Type)	Geological Unit Slope Gradient	Feasibility Comment
5	Kiosk Creek bridges (Bridge – land span)	**Holocene fan deposits** Low gradient	Geotechnically feasible. Geotechnical Investigation of site required for input into foundation design and assess liquefaction and lateral spread potential of the site. Liquefaction potential at site is currently assumed to be low based on the assumed soils and Environment Southland mapping. Liquefaction and lateral spread potential of the site will need to be assessed. Standard foundation solution recommended for abutments such as timber piles with concrete capping beam. Pile driving may be difficult if very dense gravels and/or large cobbles are encountered near surface. It should be possible to combat this with the right piles and driving equipment. Stream bed aggradation and avulsion should be expected here. Consideration should be given to the location and protection of abutments and approaches.
6	Mistake Creek (Bridge – suspension)	From **Holocene river deposits** to **Holocene fan deposits** Low gradient	Geotechnically feasible with some site disturbance. Geotechnical Investigation of site required for input into foundation design and assess liquefaction and lateral spread potential of the site. Liquefaction potential at site is currently assumed to be low based on the assumed soils and Environment Southland mapping. Liquefaction and lateral spread potential of the site will need to be assessed. Standard foundation solution recommended, such as the one described for Lower Eglinton River Suspension Bridge above. Earthworks to build ramps for the approaches to the abutment are likely required due almost no difference in elevation between the creek and surrounding ground. The current wire walking bridge has been elevated with a ladder required for access. Photographs of the site at the existing 3-wire bridge show boulders and cobbles in the stream bed. The presence of boulders should be expected during foundation excavations and may make piling difficult. Concrete ground bearing pads may be more suitable depending on specific site conditions and bridge design.

Item #	Location (Structure Type)	Geological Unit Slope Gradient	Feasibility Comment
7	Eglinton River at Lake Gunn (Bridge – suspension)	**Holocene river deposits** Low gradient	Geotechnically feasible with some site disturbance. Geotechnical Investigation of site required for input into foundation design and assess liquefaction and lateral spread potential of the site. Liquefaction potential at site is currently assumed to be low to medium based on the assumed soils and Environment Southland mapping. Liquefaction and lateral spread potential of the site will need to be assessed. Standard foundation solution recommended, such as the one described for Lower Eglinton River Suspension Bridge above. Similar to the Mistake Creek bridge, earthworks for approach ramps may be required. It is considered likely that boulders and cobbles are present at the site, similar to Mistake Creek above. Final foundation type should be decided based on specific site conditions and bridge design.
8	Melita Bluff gantry(s) at Lake Gunn (Bluff bridge/gantry with rock anchors)	From **Divide Formation** (medium to dark green volcaniclastic sandstone with thick beds and lenses of volcanic breccia; siltstone in upper part of formation) to **Gunn Dolerite** (strongly altered, dark, medium to coarse, augite0rich dolerite) Steep gradient - bluff	Geotechnically challenging but feasible, with high natural hazard risk. It is anticipated that the gantry can be fixed to the bluff using rock anchors drilled and grouted directly into the bedrock. These may be designed for high loads as required. Rockfall and treefall are unavoidable hazards for this site and are considered to pose a high risk to the structure and to people using it. Rockfall protection for the entire length of the proposed gantry is considered to be economically infeasible. The construction method of the gantry, including installation of rock anchors, will require challenging access solutions (e.g. helicopter and abseil access). Hand tools can be used for installing rock anchors.

Item #	Location (Structure Type)	Geological Unit Slope Gradient	Feasibility Comment
9	Marian Creek Bridge – Lower (Bridge – suspension)	**Holocene fan deposits** Low to moderate gradient – stream bed	Geotechnically feasible, with some site disturbance. Geotechnical Investigation of site required for input into foundation design and liquefaction and lateral spread potential of the site. Liquefaction potential at site is currently assumed to be negligible to low based on the assumed soils and Environment Southland mapping. Liquefaction and lateral spread potential of the site will need to be assessed. A suitable foundation solution should be chosen based on site specific factors. Possible foundation types may include concrete bearing pads embedded in rock/boulders or fixed using rock anchors. The waterfall area that the site is based around is characterised by very large boulders, deposited by rockfall from the adjacent steep slopes. These boulders may create challenges for installing bridge foundations. Depending on the specific site location, boulders or bedrock may require breaking or blasting to create space for construction of the bridge. Site selection should be made very carefully to choose a site that is suitable for construction, access, stability, and flood/natural hazard risk.
10	Marian Creek Bridge – Upper (Bridge – suspension)	**Late Pleistocene glacier deposits** Moderate gradient – above waterfalls	Geotechnically feasible, comments as above for Marian Creek Bridge – Lower. The challenges are likely event greater for the upper bridge, as boulder size and valley steepness seem to increase.
11	Hollyford River bridge at Homer Hut (Bridge – multi span boardwalk)	**Late Pleistocene glacier deposits** Low gradient	Geotechnically feasible. Standard foundation solution recommended. Depending on the ground conditions encountered at the location, this may be either driven piles or piles embedded in buried concrete footings. Cobbles and buried boulders are likely which may make pile driving or excavation difficult. Some rock breaking or blasting may be required.
12	Chasm Bridge (Bridge – suspension)	From **Darran Leucogabbro gabbronorite** (variably deformed biotite laucogbbronorite altered to hornblende diorite in west; tondhjemite, pegmatite and quartz diorite dikes) to **Holocene fan deposits** Low gradient	Geotechnically feasible. Geotechnical Investigation of site required for input into foundation design and liquefaction and lateral spread potential of the site. Liquefaction potential at site is currently assumed to be low based on the assumed soils and Environment Southland mapping. Liquefaction and lateral spread potential of the site will need to be assessed. Standard foundation solution recommended, such as the one described for Lower Eglinton River Suspension Bridge above. If bedrock or large boulders are encountered at the chosen site, concrete pad foundations embedded into rock or fixed with rock anchors may be suitable. Rock breaking or blasting may be necessary.

Item #	Location (Structure Type)	Geological Unit Slope Gradient	Feasibility Comment
13	Sheerdown Peak gantry (Bluff bridge/gantry with rock anchors)	**Holocene fan deposits** overlying **Darran leucogabbro gabbronorite** Steep gradient - bluff	Geotechnically challenging but feasible. Geotechnical Investigation of site required for input into foundation. Recommendations are similar to the ones for Melita Bluff Gantry above. Extra challenges may arise if the gantry has to cross areas of scree/debris, as this will make drilling and anchoring into the bedrock more difficult. Benching into debris on the slope should be avoided, if possible, as this will destabilise the slope and lead to increased erosion / rockfall onto the gantry.
14	Horse Bridge (Bridge – suspension)	From **Holocene fan deposits** to **Holocene river deposits** Low gradient	Geotechnically feasible. Geotechnical Investigation of site required for input into foundation. Standard foundation solution recommended, such as the one described for Lower Eglinton River Suspension Bridge above. Photos of the existing bridge show the presence of large boulders or bedrock in the stream. Concrete pad foundations embedded into rock or fixed with rock anchors may be suitable. Rock breaking or blasting may be necessary.
15	Barren Peak Spur stairs and viewing platform (Viewing platform and stairs)	**Darran leucogabbro gabbronorite** Moderate gradient	Geotechnically feasible. Factors for the viewing platform are covered in this report in Section 2.11 Milford Sound Piopiotahi Visitor Hub. Recommended foundations for the stairs are piles embedded into concrete footings. These footings may be slightly embedded into shallow bedrock or fixed using rock anchors if required.
16	Lower Bowen Falls access (Pontoon)	**Holocene river deposits** Low gradient	Geotechnically feasible. Factors for the pontoon walkway are covered in this report in Section 2.12 Freshwater Basin Node. Site specific ground conditions should be confirmed before a final foundation design is decided.

5 CONCLUSIONS

At this stage of the MOP there are still many unknowns about the various structures that are proposed. There are significant unknowns for the larger structures proposed and those that will be considered as refuges for natural disasters. Due to this, several assumptions have been made about structures (such as their footprints, and number of storeys) in order to complete an assessment of their feasibility. Feasibility will likely need to be re-assessed as further details are confirmed about the structures. Consideration will also need to be given to the implications of the new Technical Specification TS1170.5 which is currently released as a draft for industry comment.

The seismic hazard of the Milford corridor is dominated by the Alpine Fault. As a result, earthquake design loads are significant when compared to other parts of New Zealand. Greater earthquake design loads result in more complex and costly foundation and structure solutions. In addition, there is potential for liquefaction and lateral spreading of soils at several of the MOP sites which also adds complexity and cost.

The proposed developments at each hub, node and short stop, as detailed in the Masterplan, are considered to be geotechnically feasible at this stage. However, some of the sites and structures will be more challenging than others, requiring more extensive geotechnical investigation and design effort. These more complex sites and structures will have increased costs associated with them including construction costs. Generally, this includes sites where soils have the potential to liquefy and for structures that will act as refuges, large structures (staff and visitor accommodations), or nonstandard structures (cable car). A summary of the structures proposed for each hub, node and short stop and factors that affect feasibility has been included in the Executive Summary.

The proposed minimum geotechnical investigations required for each site has been summarised in Table 4 within Section 3. The investigations summary is based on our current understanding of the proposed structures. No allowance has been made for laboratory testing at this stage. Table 5 provides a cost estimate guidance to complete the geotechnical investigations presented in Table 4. It should be noted that this is based on the information provided in the Masterplan and that the scope of the investigations will need to be reviewed once structure details are confirmed.

Lastly, a high-level feasibility review of the MOP Walking and Cycling Experience critical structures has been completed. All of the critical structures are feasible, but there are some that will pose challenges from a geotechnical investigation, design and construction perspective, whilst others are difficult to get access to be able to complete investigations at all. This has been summarised in Table 6 within Section 3.1.

6 LIMITATIONS

This report ('Report') has been prepared by WSP New Zealand Limited ('WSP') exclusively for Milford Opportunities ('Client') in relation to providing professional engineering advice on the geotechnical feasibility of the Milford Opportunities Project ('Purpose') and in accordance with the Milford Opportunities Project – Transport & Infrastructure Stream Engineering Feasibility Assessment Contract Number SI-O-406 October 2023 ('Agreement'). The findings in this Report are based on and are subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any use or reliance on this Report, in whole or in part, for any purpose other than the Purpose or for any use or reliance on this Report by any third party.

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