Ardgour Rise Road Safety Review

Alternate Alignment Safety Review

Prepared for:
Santana Minerals Ltd

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Prepared by:
M Smith

Project/File:
310206156

Stantec New Zealand

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Prepared by:

M Smith

Reviewed by:

Signature

M Muirson

Approved by:

Signature

A Metherell

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Executive Summary

This report assesses the road safety and transport matters associated with the proposed alternate Thomson Gorge Road alignment serving the Bendigo-Ophir Gold Project in Central Otago. The assessment considers the existing Thomson Gorge Road environment, the original and revised Ardgour Rise Road design information, site observations undertaken in winter conditions, and the suitability of the proposed route as a remote rural mountainous access road.

Thomson Gorge Road is an existing narrow, unsealed four-wheel-drive route through mountainous terrain. It is characterised by steep grades, constrained geometry, limited passing opportunities, seasonal exposure, and localised issues associated with mud, snow, ice, surface water, rilling and scour. Recent road formation improvements have provided wider and more defined sections of road; however, those works also demonstrate the importance of appropriate drainage, surface material selection, edge definition and ongoing maintenance for this type of road environment.

The proposed alternate route initially follows farmland and existing track formations before climbing through a valley system to the ridge and reconnecting with Thomson Gorge Road near the saddle. The initial design included extended sections of steep grade, including long lengths at approximately 16%. Following site observations and discussions with the project team, the alignment was revised to reduce the length and frequency of steep grades. The revised design generally reduces the steeper portions of the route, increases the use of mid-range grades, and limits the remaining steeper sections to shorter, more isolated lengths.

The key road safety matters for the proposed alignment relate to forward sight distance and passing opportunities on a narrow formation, the effect of steep grades on braking and traction, the suitability and performance of the unsealed road surface, drainage and environmental scour risk, downslope edge protection, and the final road cross-section through steep terrain. The revised alignment is considered more suitable than the initial design and generally better aligned with the intent of guidance for low-volume unsealed rural roads, provided the final design incorporates appropriate operational and safety treatments.

Recommended mitigation measures include confirming localised widening and layby locations during detailed design and construction, providing suitable edge protection where practicable, installing advance warning and advisory signage at road entry points and key hazard locations, providing steep grade and low gear advice before descent sections, considering vehicle escape opportunities where appropriate, and establishing an inspection and maintenance regime suited to the route’s unsealed surface, gradients, drainage conditions and seasonal exposure.

Overall, the alternate alignment can be progressed as a remote rural mountainous road, subject to the revised design principles being carried through detailed design and construction. Particular attention should be given to limiting long steep grades, providing safe passing and recovery opportunities, managing surface water and pavement performance, applying appropriate edge protection and signage, and confirming a maintenance regime that reflects the road environment and intended restricted use.

1 Introduction

1.1 Purpose of this Report

This report sets out an assessment of the existing Thomson Gorge Road alignment, along with a design solution offered by Santana Minerals Limited. The report undertakes an assessment of potential road and operational issues, and the effect that these would have on road user safety.

The area of consideration is generally covered in Figure 1 below.

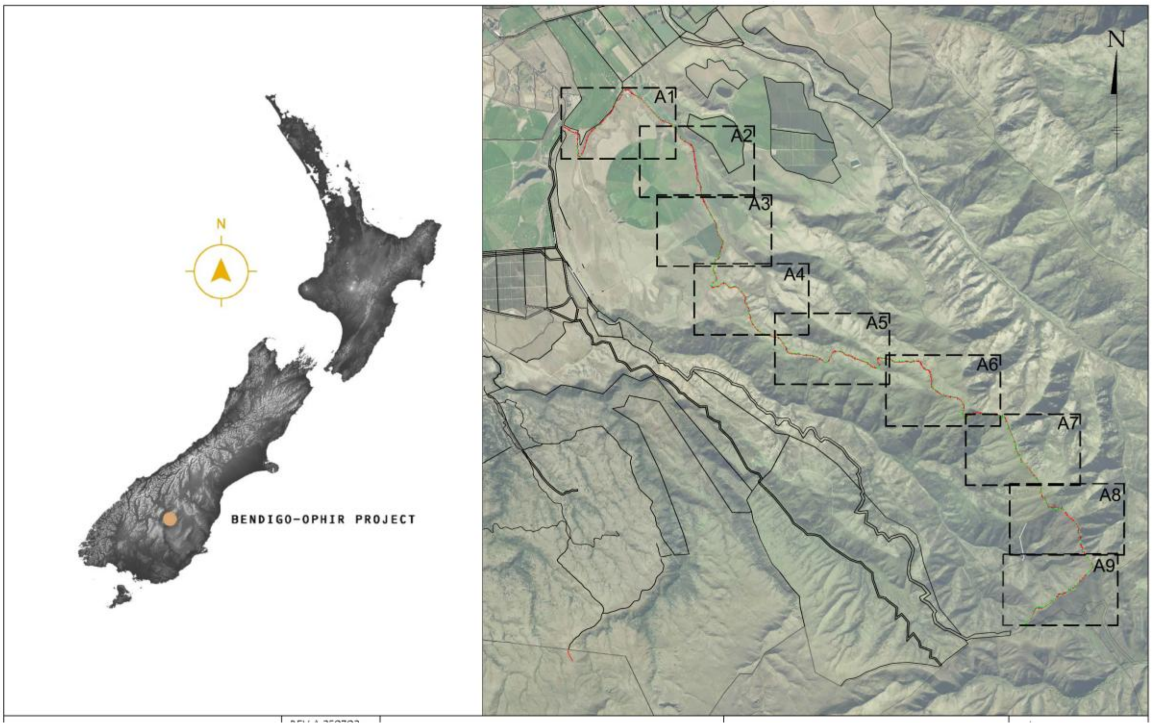

Figure 1: Site location and extents

1.2 References

In preparing this report, reference has been made to the following:

- Ardgour Rise Road Drawing set (V4), comprising of 142 pages (dated 3rd July 2026)
  - Aerial plans with Alignment
  - Long Sections
  - Cross Sections
- Revised Ardgour Rise Road Drawing set, comprising of 142 pages (dated 27th July 2026)
  - Aerial plans with Alignment
  - Long Sections
  - Cross Sections
- Revised Ardgour Rise Road Drawing set, comprising of 142 pages (dated 28th July 2026)
  - Aerial plans with Alignment
  - Long Sections
  - Cross Sections
- AARB: ARRB Unsealed Roads Best Practice Guide_Edition 2
- Central Otago District Council: Engineering and Subdivision Standards Policy

2 Existing Conditions

2.1 Site Description

The proposed Santana mine site is located in the Dunstan Range, Central Otago. The topography is classified as mountainous, and has elevations around 1,000 m. Thomson Gorge Road is a formed 4WD road, crossing from Lindis Crossing, through to Omakau. The road is generally characterised as being a narrow-unsealed road formation, with tight and steep alignment as it ascends from Lindis Crossing, to the Thomson Gorge Road summit (elevation 980m approx.). The existing Thomson Gorge alignment is indicated in Figure 2 below.

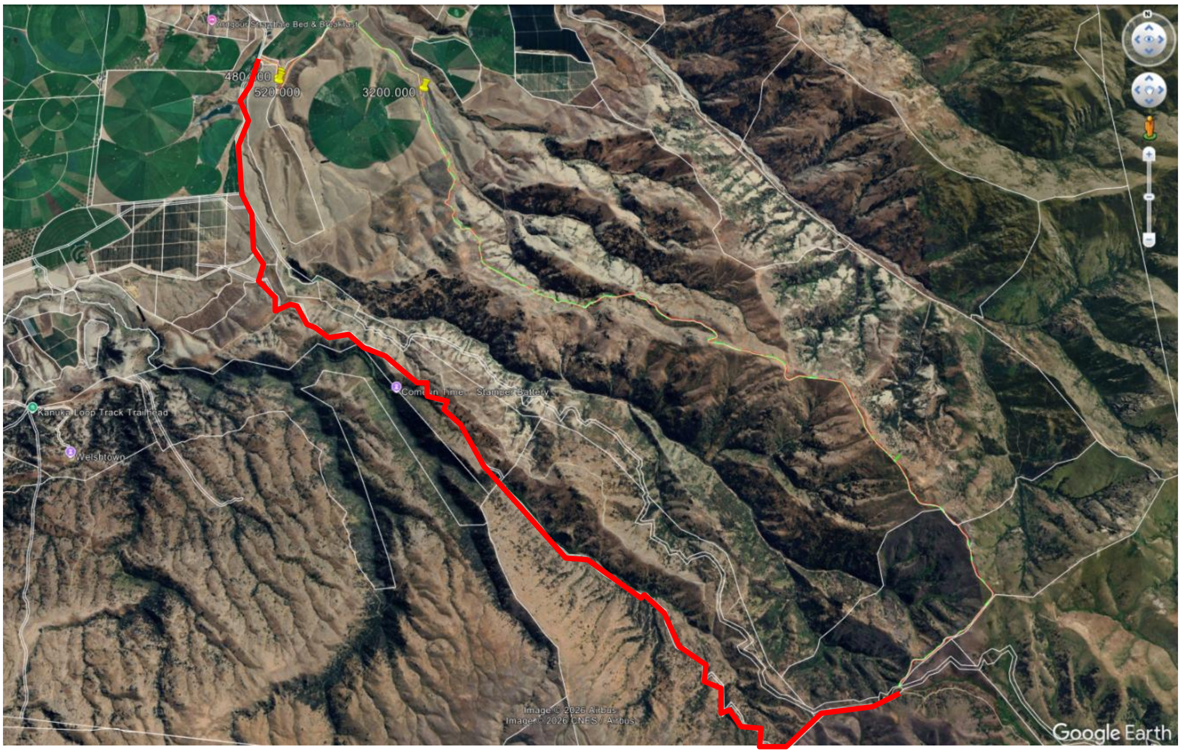

Figure 2: Existing Thomson Gorge Road alignment.

As part of the mine development, an alternate alignment of Thomson Gorge Road is proposed along a valley system north of the mine site. The proposed route generally follows a valley system leading to a ridgeline of approx. 1,000m elevation, before descending to the Thomson Gorge Road saddle.

A drive over inspection was undertaken of the existing Thomson Gorge Road alignment to observe first hand site conditions, formations and existing road safety matters. A further drive over inspection was undertaken with Matakanui Gold staff, generally following the proposed alignment and considering road safety matters associated to that alignment.

2.2 Existing alignment – Thomson Gorge Road

Thomson Gorge Road is signposted as a 4WD, dry weather track only. This inspection has considered the road safety matters that relate to a remote rural 4WD access only and has considered a position that normal road light vehicles would not attempt to traverse the Thomson Gorge Road.

At the time of the inspection (22 July 2026), the initial section of Thomson Gorge Road, from the site access gate (CH0), through to the descent down to the pond (CH6.34), had been modified to a wide gravel surface generally 7-8 metres in width, and well formed with a silty gravel surfacing.

Figure 3: Initial road section – Thomson Gorge Road

Figure 4: Example of modified road section with windrow outer edge of road as protection.

Gradients along this section are typically around 8%, with isolated sections of 12-16% and a maximum recorded gradient of 20%. A large portion of the new formation has a windrow of silt bound material along the outside of the new road formation. This serves as a definition of the edge of road during daylight hours. The windrow also retains any surface water within the road pavement, channelling this along the road rather than off the road.

At the time of the inspection there was evidence of water paths showing in the pavement surface, indicating surface water was travelling along the road alignment, and not shedding directly to the road edge. There were isolated sections where the water channel on the road edge was incised due to water scour, typically because of high velocity, and the lack of culverts to shed the water effectively to a suitable watercourse or gully.

At CH 6.34, the existing road narrows to approximately 4 metres, and commences a steep down gradient to the pond, then flattens to a moderate 6-8% gradient along the valley floor. The steep gradient down to the pond is close to 20% and is in continual shade in the winter months. At the time of the drive over, this section of road was deep mud, with extensive ice and remnants of recent snow falls.

Figure 5: Tight alignment with surface rilling[1]

Figure 6: Surface rilling and road edge scour

At CH 8.5, the road steepens to a typical gradient of 8-12%. At the time of the inspection, recent snow falls was evident from this point, continuing up to the end of the road inspection at CH 11.2. Snow and Ice conditions made travel from CH 11.2 unsafe. From the end of run of the existing Thomson Gorge

[1] **Surface rilling** refers to the formation of shallow channels (rills) in soil caused by the erosive action of flowing surface water.

Road, an inspection of the proposed alignment for Ardgour Rise Road on the opposing terrain was undertaken, with photos being taken using a 400mm lens.

Figure 7: Example of current Thomson Gorge Road alignment[2]

A characteristic of the current alignment is that the majority of the route is on the north flank of the mountain slopes and is typically in sunlight from mid-morning through to late afternoon during the winter months. At the time of the inspection snow and ice was present around the summit area. Shaded portions around the pond were extensively covered in ice, and in shade a high proportion of the day.

3 Alternate Route – New Alignment

A new alignment has been presented for the assessment of road safety elements, and a high-level assessment of risks and potential mitigations or changes as required to address the identified risks.

The route generally commences at the junction of Thomson Gorge Road and the new site access road and follows an alignment initially through flat to rolling farmland, before commencing a steeper incline up a valley system north of the mine site. The proposed alignment is presented in Figure 8 below.

The new road alignment rejoins Thomson Gorge Road at the saddle of Thomson Gorge. The road section eastward of the saddle remains unchanged by this route alteration.

[2] Source Stantec Site Visit Video Footage

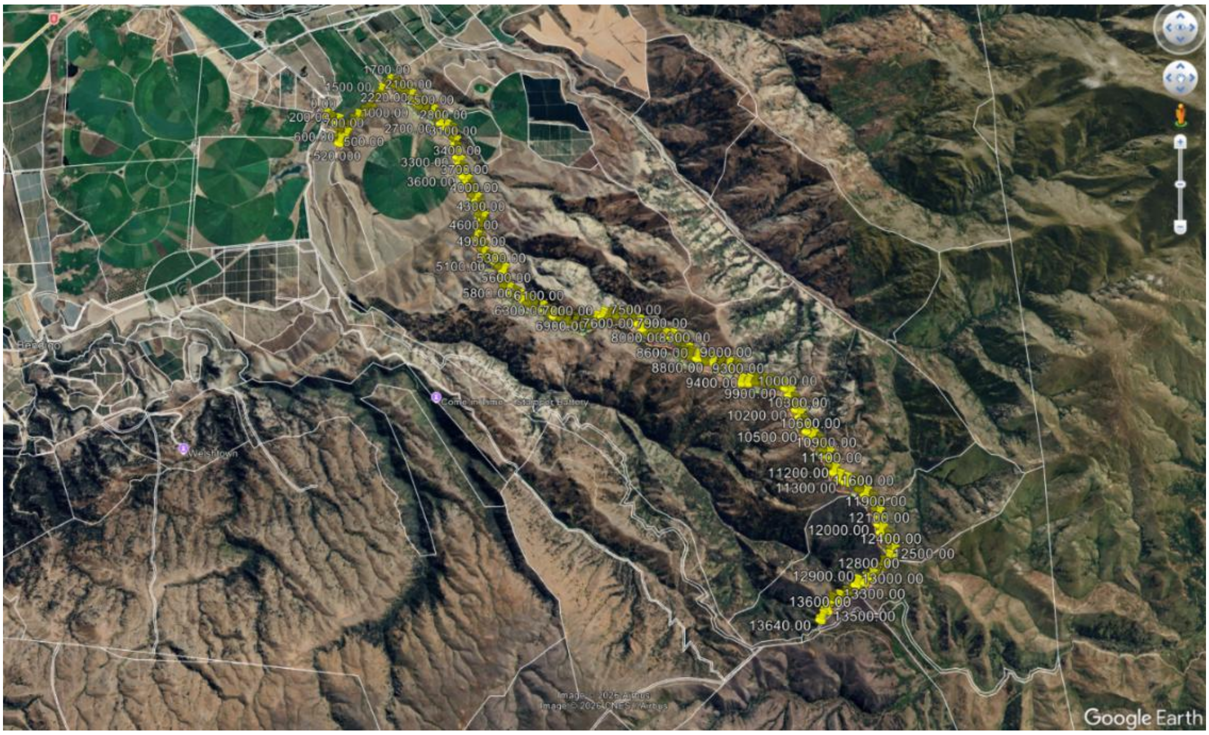

Figure 8: Proposed alignment overview. *Source: Santana KML file*

3.1 Description

An initial design was supplied for the purpose of the assessment. This was considered in the drive over inspection, with discussions and considerations of road safety matters being considered.

The proposed new route commences in and around the current site access gate. For this assessment, it was assumed that this is CH 0m for the new alignment, corresponding to the chainages stated on the supplied design drawings.

The alignment provided for inspection initially traverses across farmland, generally following an existing farm track. While there are short sections of steeper grades, the alignment is considered appropriate for the intended use and does not present any road safety risks. The initial design alignment traverses through to approximately CH 4100. Following CH 4100 the road vertical alignment climbs at increasing grades, to a maximum of 16.6%. The alignment climbs at varying grades to a gate at CH 8580, then generally flattens as it traverses across the ridge and slopes through to the existing Thomson Gorge Road (CH 13640). The initial design alignment has vertical gradients of approximately 16% for lengths up to 1 km. This was assessed on site for suitability, and the combined effects of horizontal alignment, vertical alignment, down slope grade and site topography. At the time of inspection, the team included geotechnical experts to advise of potential matters relating to the geology, and possible road cut / fill formations.

At the time of inspection, we terminated the route at CH 8580 and observed the terrain ahead from outside the vehicle. We did not drive the complete route due to snow and ice on the terrain following CH 8580.

3.2 Design Characteristics

An assessment of the horizontal and vertical gradient has been made, as detailed in the plan set provided.

In summary, the proposed alignment assessed comprises of the following vertical characteristics. For the purpose of this assessment, the description commences at CH 3960, as this represents the steeper elements of the proposed design, leading to the gate at CH 8580.

Table 1: Summary of V4 Ardgour Rise Road alignment – Steep elements

CH Start	CH End	% Grade	Length (m)	Summary of length (m)
3960	4020	16.5	60	
4020	4090	8	70	190
4090	4150	16.4	60	
4150	4520		370	Acceptable grade design
4520	5320	16.5	800	
5320	5410	12	90	990
5410	5510	16.6	100	
5510	6290		780	Acceptable grade design
6290	6330	16.6	40	
6330	6380	12	50	270
6380	6520	16.6	140	
6520	6560	14	40	
6560	6770		210	Acceptable grade design
6770	6840	16.2	70	
6840	6920	14.4	80	
7100	7370	16	270	1280
7370	7415	9.6	45	
7415	8230	16.6	815	
8230	8450	9.5	220	Acceptable relief Grade
8450	8580	16	130	130

This review identified long sections of road alignment that have average gradients around 16%.

The horizontal alignment is considered typical for a remote rural mountainous road, with curve radii typically in the range of 30m to 80m for the tight curves. This alignment has considered the incorporation of horizontal elements, combined with the vertical changes in grade, enabling areas where the combination of both may present risks to users. These are discussed further in the sections below.

Through an analysis of the proposed design, and following observations on site, discussions were held with the project team on potential changes within the design to address the length of steep grades, with an aim to reduce the general gradient below 14%.

A revised design was submitted on Monday 27th July 2026, with further discussions with the designer that same day. This revised design revealed an alignment from CH 4880 to CH 5440 with a gradient on average of below 12.5%. This was achieved through traversing further into gullies, and a general shift utilising a longer distance for the grade change. It is considered that this style of change is demonstration that a redesign of the alignment further in detailed design would result in a more suitable gradient.

A modified design has been undertaken that results in the general elimination of grades above 13%, from CH 3960 through to above CH 8580. This is discussed further in Section 3.3 below.

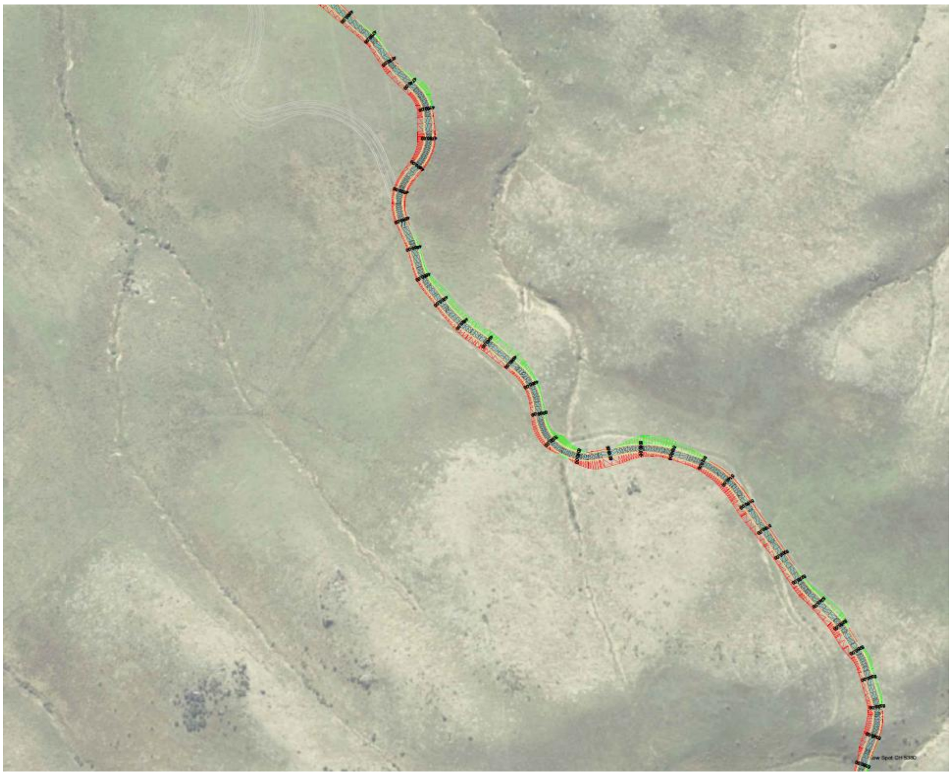

Figure 9: Example of original design

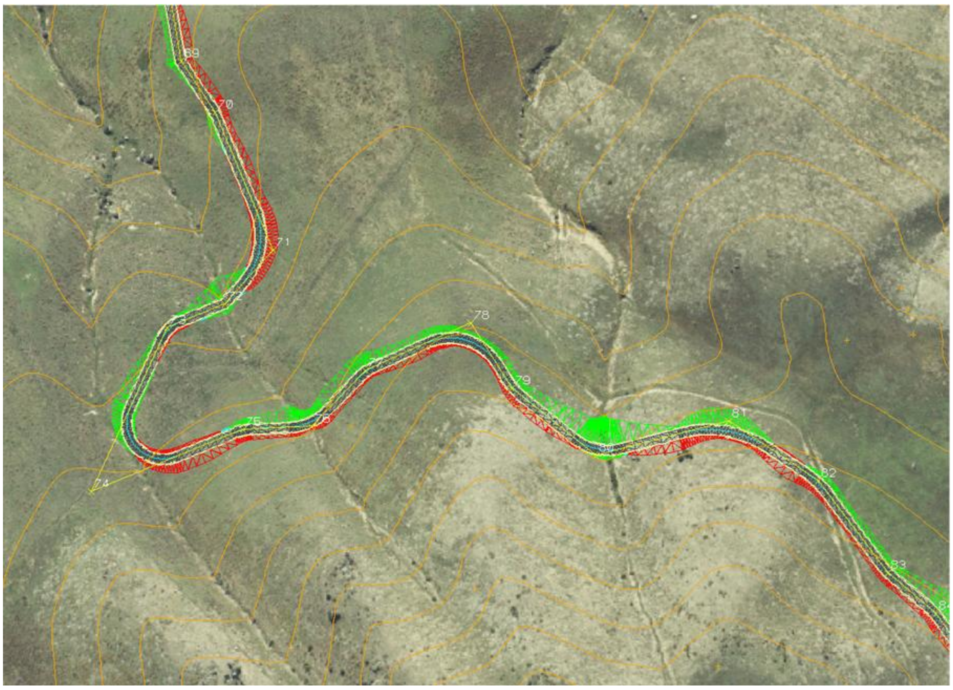

Figure 10: Example of revised design

Figure 11 below details the new road profile (orange), with gradient (blue). The boundary box (green) is the bounds of 12.5% gradient. As demonstrated, there remains isolated sections of road above 12.5%, being the alignment along the highest portion of the proposed road.

For the purpose of this assessment, the vertical scale has been exaggerated to clearly define the changes.

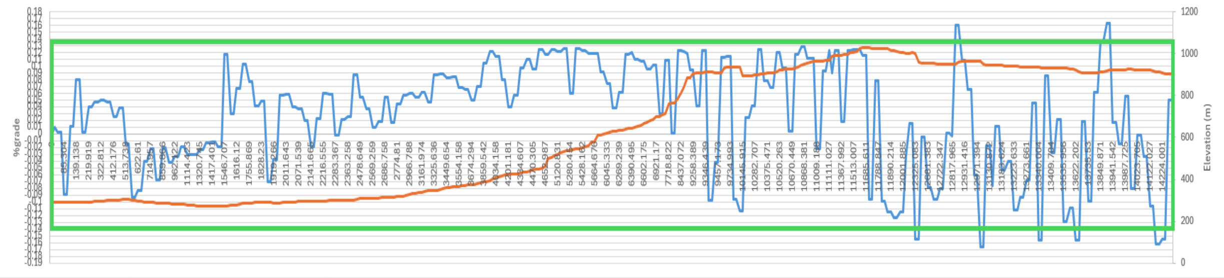

Figure 11: Alignment height / Grade comparison graph.

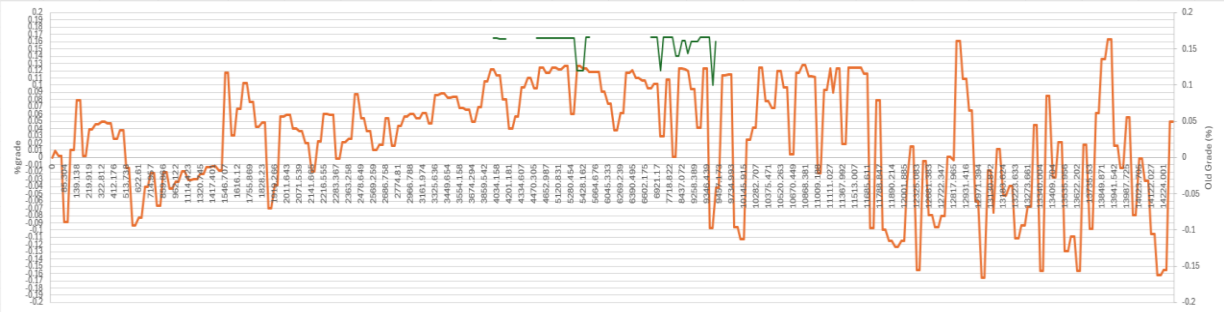

Figure 12: Grade comparison graph.

Figure 12 demonstrates areas where the Revision 4 design steep grade sections (green) have been reduced, resulting in a less steep alignment in Revision 5 (orange). It is acknowledged that there are short sections of steep grade (16%) along the tops, however these are isolated in length, with recovery grades between.

The revised design has been considered within this assessment. Where applicable, a comparison between the original design and the revise design has been given, demonstrating the scale and nature of the changes.

3.3 Design Comparison Summary

Thomson Gorge Road data has been supplied from extracts from a previous report, supplied by Central Otago District Council's Transport Advisor. It is noted that the supplied data does not indicate the start and end location of the route section analysed, therefore it could not be determined as being representative of the full length of Thomson Gorge Road. Discussions with Stantec designers indicate that the analysis of the existing Thomson Gorge Road commenced at Matilda Rise intersection (distance 2.66km) and continued through to a crest (track to Mt Moka) at distance 10.72km.

Measurements from on site, and utilising LINZ BaseMaps© indicate that the distance from the Santana Mine site access (zero point for new designs) to the junction point of the proposed road back onto Thomson Gorge Road is approximately CH 12.1 km. The drive over inspection undertaken as part of this study terminated at distance 11.2 km due to snow and ice.

In undertaking this review, the design data was analysed to understand how the nett effects of the grades compared between all options. The analysis has been undertaken using the absolute value for grade, that it combines positive and negative grades into the same bin ranges.

This has been summarised in Figure 13 below.

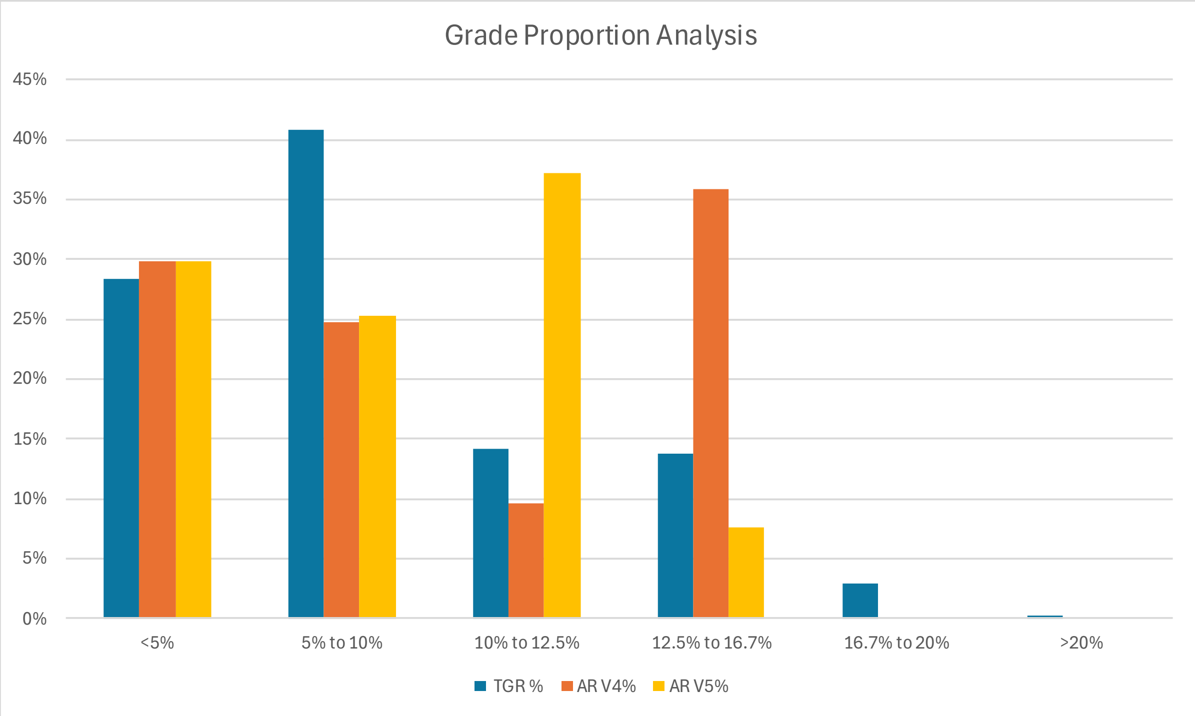

Figure 13: Grade Summary Analysis

The length of both the Ardgour Rise V4 and V5 designs is 13.6 km and 14.3 km respectively. Analysis of the grade data has been undertaken from a start point at the entrance to the mine site, commencing at Thomson Gorge Road, and traversing through to rejoining Thomson Gorge Road at CH 12.1 km.

An analysis of the V4 design as submitted to the hearing had a higher proportion of grades in the 12.5% to 16.7%. The version 5 design has reduced this.

This analysis reveals that the Ardgour Rise alignment (V5) results in a lower percentage of length at the higher grades, with no grades exceeding 16.7%. This is achieved through utilising a higher proportion of mid-range grades (10 to 12.5%).

In summary, the Ardgour Rise V5 alignment generally results in a reduction of steeper grades when compared to the existing Thomson Gorge Road alignment, and is generally compliant with the ARRB guidelines.

3.4 Road Safety Matters

In respect the road safety matters, both the original alignment, and the modifications to alignment following discussions were considered. Many elements below are relevant to all alignment considerations, with the findings being incorporated into the final design for approval by Central Otago District Council.

3.4.1 Alignment – Forward Sight Distance

An essential design element in a rural road with narrow formation is the ability for a driver to observe oncoming traffic and pull over to an appropriate location to enable safe passing. Mountainous terrain, especially where forward sight is gained over valley systems, enables a driver to observe well ahead, and make a conscious choice to stop.

While not indicated within the design, discussions with Santana staff indicate that they could undertake localised widening within the alignment to address this issue.

This would incorporate elements such as:

- Localised widening on ridge curves,
- Localised widening on the alignment across gullies, enabling localised pull off,
- Localised widening at locations of high scenic interest,
- Recovery locations / relief grades for vehicle check / breakdown.

Discussions with the design staff have revealed that the modified alignment generally has clear intervisibility across valley systems. However, despite clear view, the length of travel path through the valley will require additional layby areas for safe passing. Initial reviews of the proposed alignment indicate that these can be formed at appropriate locations as part of the final design.

3.4.2 Gradient – Road Surface

In reviewing the topography on site, along with the initial proposed gradient, it has been identified that there are long sections of gradient between 14% and 16%. An analysis of the supplied design reveals that the longest portion of grade is in the vicinity of 1.28 km (CH 6770 – CH 8230).

The modified design (V5) eliminates these long grades, with grades now under 12.5% for the first 12.6 km of the alignment. This results in grades generally compliant with the ARRB Unsealed Roads Best Practice Guide (Second Edition).

The upgraded road surface on Thomson Gorge Road was observed to be a silt bound aggregate, with a silty surface along its length. It is assumed that a similar product may be used, however, Santana staff identified a large stockpile of crushed rock that was tested as being compliant for NZTA Maintenance Specification (M-Spec). Observations of the stockpile indicate that the product may be AP65 type material, with a high proportion of broken faces. Test results for this material have not been provided, however, given the visual observation of the material, it would generally be appropriate for a rural road.

It is critical on rural roads that the final road surface is fit for purpose and is appropriate for the gradient and shape for the intended formation. As previously stated, the Thomson Gorge Road had a generally smooth-running surface, however it was observed to be prone to rilling.

A successful treatment would be to redesign the road gradient, through utilising the topography more to an advantage of lengthening the distance between two points and providing relief grades where drivers can pull out of the through movement and stop as required.

A typical NZTA M-Spec material has a low proportion of fines, resulting in a surface material that could unravel under wheel traction and descent. It is acknowledged that regular maintenance would address many of these issues, however a typical road grading programme would feather (fluff) the top surface. More successful road maintenance programmes incorporate a towed roller behind the grader; however, it is considered that the length of steep grade would prevent this as a feasible option.

Figure 14: Overseas example of silt rich surfacing in winter months

Corrugations will naturally form after every maintenance grade, as the formation is a function of wheel action, grade, vehicle type and surface composition. The speed at which corrugations form is again a function of use and materials used for the surfacing. It is inevitable that corrugations will form, and most Road Controlling Authorities (RCA) implement a maintenance inspection process to identify periods and locations where additional maintenance is required.

Corrugations within the road surface will have an impact on the performance of a vehicle, especially at higher speeds. At speed, the wheels and suspension will not be reactive enough to follow the road surface and can lead to contact of the wheel on the top of the corrugations only. Research[3] suggests that the maximum contact force is imposed on or near the corrugation crest, with limited or no contact with the trough of the corrugation. This can lead to what is perceived as "wheel bounce" that can affect braking and stability.

At low speeds the tyre and suspension dynamics (resonance) have a greater opportunity to follow the shape of the corrugations, and hence have a longer period of contact, and greater stability

Periodic maintenance grading can take a variety of forms. These include:

1. Light (surficial) grade - a smoothing operation where the loose gravel is redistributed across the road, and does not affect the hard base material.
2. Medium Grade - where the top 25 mm are affected, and the top surface is ripped to allow mixing of the fines in the base and the surface material to create a new top surface.
3. Heavy grade - as for Medium grade, but up to 100mm in depth. This is generally undertaken when major defects in the pavement are required to be corrected.
4. Resheeting - This is the placement of a new top surface with imported material meeting a desired specification, to build up the pavement depth. This is generally undertaken when the top surface is wearing thin through multiple grade cycles and traffic use.

It is recommended that an appropriate maintenance regime be established for the life of the road.

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[3] Corrugation of Unmetalled Roads Part 1: Vehicle Dynamics; G K Misoi and R M Carson; *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, July 1989; vol. 203, 3: pp. 205-214.*

3.4.3 Gradient – Environmental

As identified on the modified Thomson Gorge Road, rilling and water table scour has occurred on the new pavement surface and side drains.

Steep grades increase velocity of water in side drains that can result in localised scour, and loss of trafficable pavement. Poorly shaped road surfaces and gradients can result in shedding of water along the road, rather than into the uphill drain formation. This results in rilling, as observed on the Thomson Gorge Road alignment.

The establishment of a shoulder windrow, if not appropriately designed, causes water to run down road surface, with the steep grades not typically providing short drainage path relief to the drain shoulder.

It is considered that as part of the detailed design, careful placement of side drainage channels, cross-road culverts and downslope discharge will be required.

Utilisation of more cut in the road formation will result in a water channel that is formed within rock, and less prone to scour of the invert. High velocities however may scour the pavement shoulder, causing loss of pavement material.

This is best assessed at the time of detailed design.

3.4.4 Downslope Road Grades

Road gradient is critical when considering appropriate design and is influenced by intended purpose, and terrain. The ARRB document defines the road type based around typical descriptions, as detailed in Figure 15 below.

The functional classification system suggested in this guide has been adapted from the Austroads classification system (Giummarra 2001). The Austroads functional classification of rural ‘Class 4’ roads (Austroads 2019a) has been further subdivided into four categories as listed in Table 3.9 and shown in Figure 3.11.

Table 3.9: Unsealed roads classification system

Road class	Class type	Service function description	Road type description
4A	Main road > 150 ADT	This type of road is used for major movements between population centres and connection to adjacent areas. High traffic volumes occur, and the road can carry large vehicles.	• All weather road, predominantly two-lane and unsealed. Can be sealed if economically justified. • Operating speed standard of 50–80 km/h according to terrain. • Minimum carriageway width is 7 m.
4B	Minor road 50–150 ADT	This type of road is used for connection between local centres of population and links to the primary network. Roads may or may not be sealed depending on the importance and function of the road.	• All-weather two-lane road formed and gravelled or single-lane sealed road with gravel shoulders. • Operating speed standard of 30–70 km/h according to terrain. • Minimum carriageway width is 5.5 m.
4C	Access road 10–50 ADT	Provides access to low use areas or individual rural property sites and forest areas. Caters for low travel speed and a range of vehicles and may be seasonally closed.	• Substantially a single lane two-way, generally dry weather, formed road. • Operating speeds standard of < 20–40 km/h according to terrain. • Minimum carriageway width is 4 m. • May be restricted to four-wheel drive vehicles.
4D	Tracks < 10 ADT	Mainly used for fire protection purposes, management access and limited recreational activities.	• Predominantly a single-lane two-way earth track (unformed) at or near the natural surface level. • Predominantly not conforming to any geometric design standards. • Minimum cleared width is 3 m. • Primarily for four-wheel drive vehicles.

Figure 15: ARRB Unsealed Rural Road Guideline, Section 3.5.5

Thomson Gorge Road fits to classification 4C / 4D. The road has general low use and serves limited access. It is acknowledged that the existing road is classified as a dry weather road only and is signed as such. Environmental conditions limit access along Thomson Gorge Road during high rainfall, and winter months. For the purpose of this assessment, Class 4C requirements have been considered together with the higher portions of the road being more aligned with Class 4D due to the steep terrain.

Table 3.10[4] defines the design parameters for the various road types, as detailed in Figure 16 below.

Road classification	4A Main			4B Minor			4C Access			4D Tracks			Comments
Terrain type	Flat	Rolling	Mountainous	Flat	Rolling	Mountainous	Flat	Rolling	Mountainous	Flat	Rolling	Mountainous	
Minimum stopping sight distance (m)[5]	150	120	70	120	70	30	90	50	30	N/A	N/A	N/A	
Minimum meeting sight distance (m)[6]	290	230	130	230	130	60	180	100	60	N/A	N/A	N/A	
Vertical geometry													
Maximum vertical grade (%)[7]	6	8	12	6	8	12	6	8	12	N/A	N/A	N/A	Avoid steep grades to reduce soil erosion along tracks
Minimum crest vertical curve (K value)[8]	50	30	10	30	10	5	19	8	2	N/A	N/A	N/A	
Minimum sag vertical curve (K value)[9]	11	8	4	8	4	3	6	3	2	N/A	N/A	N/A	

1 *The maximum superelevation value will need to consider the number of loaded heavy vehicles, speed and curve radii.*
2 *In cases where there are a high percentage of heavy vehicles (> 20%) minimum lane widths can be increased by 0.5 m.*
3 *Allows for 1 m verge/table drain width. This must be reviewed based on actual locations where for drainage reasons greater widths may be required.*
4 *Values rounded up. For minimum radius curves, widening on the inside of a curve may be necessary to accommodate longer vehicles.*
5 *Based on a reaction time of 2 seconds and surface coefficients relating to unsealed surfaces. Values rounded up. Values based on flat grades and allowances will need to be made for up and down grades.*
6 *This is mainly a requirement for single lane two-way roads. Values rounded up.*
7 *In some cases, higher grades of up to 20% can be allowed for short sections (about 150 m). Keep grades on unsealed roads lower due to ravelling and scouring of surface.*
8 *Calculation of these values is to be based on information contained in Austroads (2016c). The length of the vertical curve (L) is based on the product of K multiplied by the algebraic difference in grades percentage A (i.e. L = K × A).*
9 *Sag values are based on comfort control criteria.*

Figure 16: ARRB `Table 3.10: Guidelines for the main geometric design standards for unsealed roads

In assessing the modified alignment (Ardgour Rise V5) submitted on the 28th July 2026, it is determined that the proposed vertical alignment generally meets the requirements of Class 4C roads. The ARRB Guide enables isolated sections or road up to 20%, for sections up to 150 m (Refer to footnote 7 in image above). The submitted design (V5) has a maximum gradient of 16.6%, as the road traverses along the tops of the range at the higher altitudes, and does not have any grades in excess of 16.6%.

Long steep gradients are prone to corrugations and traction related damage, especially on the uphill gradients. Typically, this can be addressed with regular maintenance grading, the frequency being determined on observed wear, rather than fixed time durations.

The initial design had areas of identified long uphill gradient with no relief grades that would be suitable for a driver to pull off and address any vehicle related defects should they arise. The modified design incorporates grades that are generally compliant to the ARRB Guide, with relief grades possible within the design. It is acknowledged that the final design could include relief grades to provide a suitable layby area.

A driver undertaking a descent movement is presented with long steep grades still has a high risk of brake fade and loss of control / loss of traction type events. It is critical that drivers select the correct descent gear at a location prior to encountering the steep grade. This can be notified by appropriate signs for descent advice as demonstrated in Figure 17 below.

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Figure 17: Example of Steep Grade: Use Low Gear signs.

User safety is further degraded by corrugations, with a high potential of differential braking and wheel skid being common in older vehicles. While newer vehicles would typically have descent control and ABS, it cannot be assumed that this would be typical for this route.

Corrugations are typically addressed through a schedule of maintenance activities based around grading cycles that consider actual pavement condition, rather than being on a fixed time sequence.

Long steep grades place a high demand on vehicle brakes, with a risk of brake fade and loss of braking capacity. Vehicles can also suffer drive train failure, resulting in an inability to arrest forward movement. This is especially high risk on steep grades. While all scenarios cannot be reasonably designed for, it is anticipated that additional safety measures such as vehicle escape ramps could be formed as part of the design and construction.

Vehicle escape ramps can be achieved though the provision of a steep uphill grade that an errant vehicle can be driven onto to arrest descent, often incorporating an arrest bed material such as loose gravel. These are typically signposted on the approach so that a driver can respond and react safely.

3.4.5 Downslope edge treatments

As presented, the modification of the existing Thomson Gorge Road has incorporated a windrow of material on the outside (downslope) side of the road formation. This ensures that an errant light vehicle is generally directed back into the trafficable lane. An example of the applied edge protection is indicated in Figure 18 below.

The existing Thomson Gorge Road, above the modified sections, has minimal downslope edge protection. While the alignment from the pond initially follows the valley floor, is then rises up the mountain slope, with steep downslope grades that have minimal to no edge protection.

Figure 18: Existing Thomson Gore Road – Edge protection on modified sections

My experience in mountainous roads around the world has indicated that safe and effective edge protection can be achieved through use of appropriate treatments. In Figure 19 below, I give examples of high-level edge protection (left image), along with use of large boulders in more confined locations (right image)

Figure 19: Examples of edge protection, Chile, elevation 2850 m

Considering the proposed road alignment, there will be locations where windrow treatments could be easily established, providing protection for the downslope grade. Tighter sections of alignment, where a wide edge protection could not be formed, could be addressed through the placement of large rocks on the edge. It is acknowledged that panel damage to vehicles may occur if struck, however the vehicle does not penetrate over the road edge, minimising the risk of severe to fatal injury.

Locations where edge protection cannot be installed can be risk minimised through the application of appropriate signs for spot locations, or road lengths.

3.4.6 Road Cross-section

Discussions were held with a Geotech expert while on site to consider the applicable road cross section, especially given the mountainous terrain.

They have advised the following:

> *Cognisant of the nature of this rural alpine road and the restricted use as a 4x4 dry route, the extent of design to accommodate seismic events and ground shaking must be commensurate with it intended use and volume of traffic. To this end, an approbate design philosophy is to exercise more cut into the slope and reduce the volume and footprint of fill embankment on the down slope. This approach is facilitated by the geology of the route's alignment whereby schist bedrock is at or very close to surface. Therefore, rock cuts can be completed at 1H:4V, resulting in a horizontal alignment that can avoid fill embankments that chase down steep slopes. A well excavated rock cut (and bench where >2.5m in height) is much easier to engineer to ensure stability compared to an earth fill embankment on a steep slope.*

It is noted that these comments are made in a high-level form only, and that detailed design should incorporate site specific design comments and be subject to physical on-site evaluation during construction.

Discussions with the designer has resulted in a road formation that utilises a higher level of cut, rather than deep fill. This results in a design cross section that closely resembles that of the existing Thomson Gorge Road.

3.5 Mitigation Treatments

3.5.1 Advance Road Signage – Conditions

It is essential that a driver is fully aware of the conditions ahead. This is typically achieved through the installation of road condition warning signs at the point of entry onto the road. An example of this style of warning is given in Figure 20 below. This sign grouping is installed at the commencement of the Skippers Canyon Road, Queenstown.

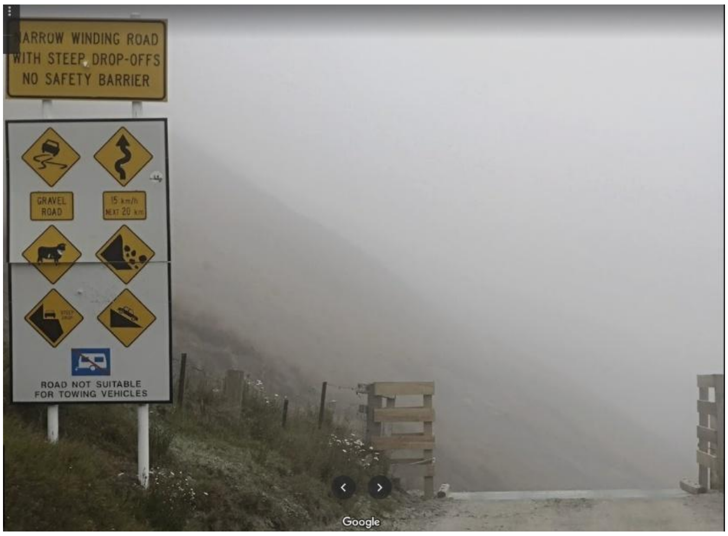

Figure 20: Example of Skippers Canyon Road

Through the use of appropriate signs, along with repeat signs at changes within the alignment, ensures that the driver is made fully aware of the road conditions and hazards ahead. These signs can often deter inappropriate use by strangers unfamiliar with the conditions ahead.

3.5.2 Edge Protection

Edge protection in mountainous road environments is often difficult to form once a road has been cut through the terrain. It is critical that appropriate edge protection be incorporated into the design at an early stage, to determine where suitable levels of protection can be applied.

It is acknowledged that not all sections of the road can have edge protection applied. In these locations appropriate signs and alternate treatments should be implemented. At the lowest form of control is road signs advising of unprotected drop-offs. An example of a sign is given in Figure 21 below.

Figure 21: Road Hazard Sign – French Pass, Marlborough.

It is considered that the style of sign installed on Skippers Canyon Road and French Pass Road is appropriate for the new road alignment.

3.5.3 Localised Widening

As presented, I am of the opinion that appropriate localised widening can be achieved in the final design to ensure appropriate opportunity for safe passing and layby locations can be achieved.

It is recommended that this be addressed in the final design, with the design verified with site inspections prior to, and during construction.

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Stantec New Zealand
Building 2 Hazeldean Business Park
Level 3, 2 Hazeldean Road
Addington, Christchurch 8024
NEW ZEALAND
Mail to: PO Box 13052, Christchurch 8140
stantec.com