30 November 2020

Holmes Solutions LP
7 Canterbury St
Hornby
Christchurch 8042

Attn: Ben Glossop

Dear Ben

RE: High Level Geotechnical Assessment for Proposed Zipline - Conical Hill, Hanmer Springs

(Our Reference: 17990.000.001_01)

1 Introduction

ENGEO Ltd was requested by Holmes Solutions LP to undertake a geotechnical assessment for a zipline which is proposed to be constructed on Conical Hill, Hanmer Springs. This work has been carried out in accordance with our signed agreement P2020.002.460 dated 30 October 2020. The purpose of the assessment was to provide high level advice on foundation conditions and potential construction methodology for the proposed zip line development. At this stage of the design development it is intended that this high level assessment will inform preliminary design for initial pricing and planning purposes. As a consequence, our scope of works does not include any detailed design and this letter should not be relied upon for design purposes.

2 Site Description

The site is located within the Conical Hill Reserve approximately 500 m north of the Hanmer Springs township. The Conical Hill Reserve is bounded to the east, north and west by commercial forestry and to the south by a residential area. The Chatterton River is located approximately 300 m to the west of the site. Conical Hill Reserve is well vegetated but has several tracks cut within the hillside for recreational walking and mountain biking. The peak of Conical Hill is located in the middle of the reserve as indicated by the location of the lookout. From the lookout a broad ridge extends to the north.

2.1 Development Proposal

It is proposed to construct a zipline on the western side of the Conical Hill Reserve as indicated in Figure 1 (see Appendix 1 for more detailed plan). The western side of the reserve slopes to the west at a gradient of approximately 20 - 30°.

Figure 1: Site Location Plan

Image sourced from evalu8. Not to scale. See Appendix 1 for detailed plan

The proposed zipline will begin on the ridgeline approximately 100 m north of the lookout. As shown on Figure 2, the first cable span will run to the south to the first post before it zig-zags down the slope to the west for the next three cable spans (2 – 4) and posts. After the fourth post, cable spans 5 – 8 run to the south in a slight curve as the zipline follows the shape of the hill and finishes near the southern property boundary on the south facing slope.

Figure 2: Oblique Concept Plan of Zipline

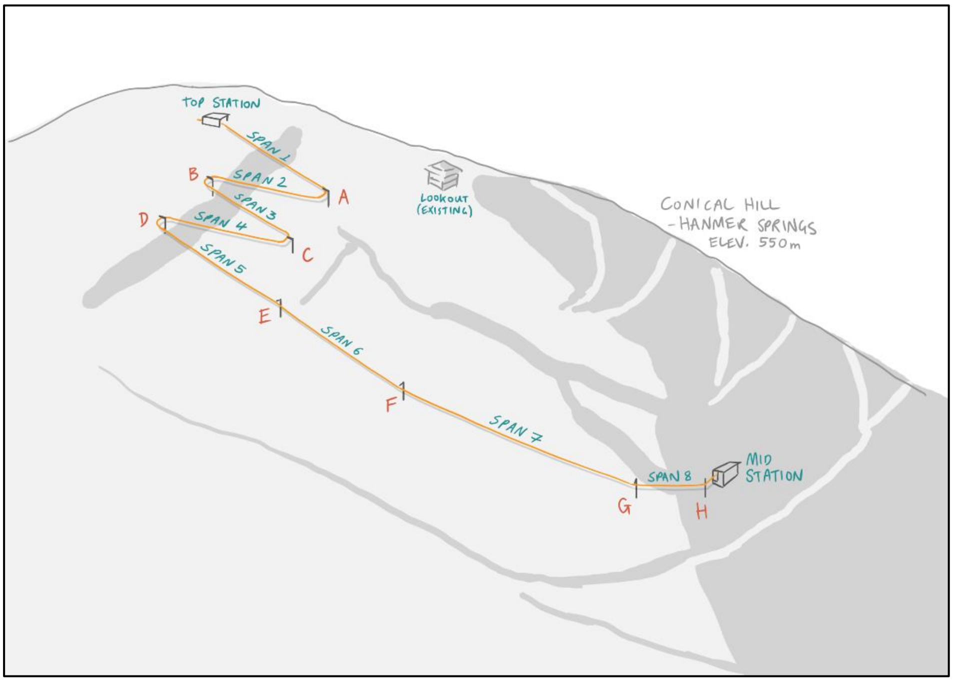
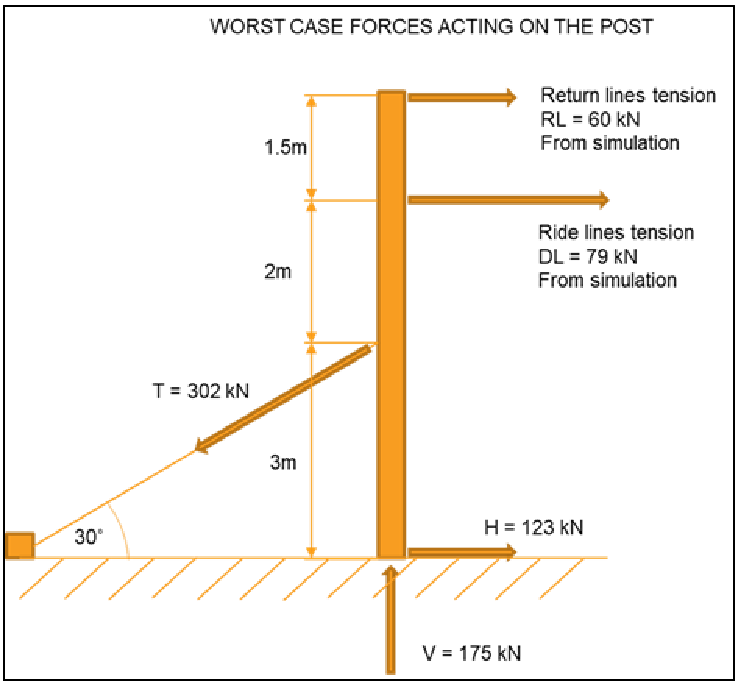


Image sourced from Holmes Solutions.

It is our understanding that the cable for the zipline will be constructed approximately 5 m to 6.5 m above existing ground surface and each cable span between posts will be formed utilising a separate cable span which will be anchored near the top of the post. The posts will be supported on a foundation at the base, additional lateral support will be provided by a guy rope which will be anchored to the ground surface adjacent to each post location. It is intended that the cables will be terminated at the ground surface where the cable will attach to a ground anchor which will provide tensile resistance.

The posts will be formed using 300 mm diameter Circular Hollow Section or similar, the foundation at the base of the post will be designed to resist both compression and shear forces. A concept sketch for the post loading has been provided by Holmes Solutions as shown in Figure 3.

Figure 3: Concept Design for Post Loading Conditions



Sketch provided by Holmes Solutions

3 Desktop Study

We have completed a desktop study as part of our investigation. The main purpose of this review was to understand if any significant geological features exist at the site that would impact the feasibility of the proposed zipline.

3.1 Regional Geology

The site has been regionally mapped by GNS (Rattenbury, Townsend & Johnston, 2006) to be underlain by well-bedded Sandstone and Mudstone, and poorly bedded sandstone of the Pahau Terrane. The Hanmer Fault is located approximately 1.5 km south of the site, while the Isobel fault is located approximately 1.2 km to the north. The New Zealand Active Faults Database[1] indicates that both these faults are active, with the Hanmer Fault having a recurrence interval of less than 2,000 years, while the recurrence interval on the Isobel Fault is not known.

3.2 Aerial Photographic Interpretation

We have reviewed historical aerial photos in stereo pairs from 1950 and 1966. The 1950 aerial photos indicate that at this time the western face of the hillside was relatively free of vegetation. The western face is part of the catchment for the Chatterton River. It is evident that there are several gullies within the face in which small stream channels flow periodically. These stream channels fan out at the head of each on the gullies nearer the crest of the slope and it appears that the area at the head of the gully is over steep and material was loose and eroding as the gully regressed up the slope.

The 1950 stereo pairs appear to show the formation of head scarp within the southern side of the hillside which indicate a potential landslide feature, however, this may just be the landform and is therefore not confirmed as there is no indication of movement having occurred.

In the 1966 photos the gully features are less distinguishable and appear to have become somewhat infilled, however this is an assumption as it is unable to be fully confirmed from these aerial photos. Furthermore, beyond 1966 this area becomes increasingly vegetated such that landforms are unable to be made out within the vegetated areas.

4 Site Walkover

ENGEO visited the site on 4 November 2020 to complete a site walkover with the project team and to observe potential sites for the top and bottom stations and post locations. During the site walkover the following observations were made (see Figure 4 for photos):

- Access to the top of Conical Hill is achievable in a 4WD utility and likely that small machinery would also be able to access this area.

- The slope is heavily vegetated with relatively dense bush and large trees. Access to each post location will require some vegetation to be cleared.

- The Conical Hill Reserve was highlighted as a Rough Gecko habitat which is an endangered species thus requiring consideration as to how construction is completed to protect them.

- Bedrock was observed at the surface along the ridgeline between Conical Hill lookout and the proposed top station location.

- Where tracks have been made within the hillside the cut has exposed the underlying bedrock. The underlying bedrock was described as moderately to highly weathered, grey to light brown, GREYWACKE, weak to strong with very close to moderately spaced defects. In generally the rock appears to be highly fractured.

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[1] https://data.gns.cri.nz/af/

- The exposed cuts indicate that there is a layer of colluvial soil overlying the bedrock typically between 0.2 – 1.0 m in thickness. The overlying soil appears to be completely weathered bedrock described as Gravelly Silty SAND / Gravelly Sandy SILT with some Cobbles, light brown, tightly packed, dry to moist: Silt, low plasticity. The proportional amount of the Gravel and Cobbles varied significantly across the hill side. In general hand digging is difficult due to these particles within the soil matrix.

- Within the southern face of the hillside, near the base station, bedrock was not observed within the cut slopes. This suggests the overlying soil is thicker in this location, and extends to a depth of at least 1.5 m based on the cut face height. This area appeared to be relatively hummocky, however, it appears that earthworks have taken place as part of the forestry works so it was not clear if the hummocks were naturally occurring or not.

- In several areas loose cobbles and boulders (100 mm to 800 mm diameter) were observed on the surface within the vegetation. The materials appeared to have been deposited relatively recently however, the source was not identifiable and may be attributed to the track construction.

- No evidence of groundwater seepage was observed during the site walkover

Figure 4: Site Photos

Photo 1: Looking north from Conical Hill lookout along ridgeline towards proposed top station location.

Photo 2: Observed cut slope above walking track, indicating near surface Weathered in situ Greywacke Sandstone

Photo 3: Example of highly fractured rock that is exposed near the surface

Photo 4: Southern face of hillside in area where base station is proposed.

5 Interpretation

Based on our observations of the ground conditions from our desktop study and site walkover we believe that it is feasible to construct a zipline structure in the proposed location. This is based on the fact that there was no evidence of active slope instability or unsatisfactory materials. The subsoils comprise weathered Greywacke rock or colluvium. It is our opinion that these ground conditions are satisfactory for constructing foundations in order to support the zipline structure, provided the following recommendations are followed.

6 Geotechnical Recommendations

6.1 Foundations

In order to construct foundations for the proposed structure it is preferred to keep the foundations as efficient as possible given constraints such as access, environment, terrain and cost. Whilst in some locations there is shallow rock there are several indicators that the depth and quality of this rock is variable. It is possible that shallow gravity foundations could be designed to form the foundations at the base of the structures and posts, however, due the ground conditions there is a high probability that during construction the founding depth would need to increase. The access and the steep terrain limit the ability make significant amendments to the foundation, as well as limiting options for the temporary support of excavation. Therefore, shallow foundations while feasible, carry significant construction risk and have not been considered further.

The limitations caused by access, environment and terrain also preclude the use of any foundations that require large plant such as piles.

Therefore, it is recommended that the foundations for all of the structures be formed using ground anchors. The plant used to install ground anchors can be relatively small and manoeuvrable as would typically be used for anchor installation on rock faces for rock fall protection structures. Access on this site would likely be reasonably straight-forward, furthermore due to the small size of the drilling rig the amount of vegetation clearance required to operate would be minimised.

The proposed ground anchors would be constructed by drilling a hole that is usually 90 – 100 mm in diameter to a depth ranging between a minimum of 3 m up to approx. 9 m. A threaded steel reinforcement bar is inserted the full depth and is grouted into the hole. It is likely that 'self-drilling' anchors are best suited for this site due to the fractured nature of the material observed. In general terms, 'self-drilling' anchors comprise hollow anchor bars which allow a sacrificial drill bit to be attached to the end and the grout to be pumped down the middle of the bar during installation. The head of grout that is created during drilling reduces the risk of hole collapse caused by difficult ground conditions.

The resistance of the grouted anchor is formed by the bond strength at the interface between the grout and the ground (rock or soil). The anchors at the site are expected to be founded within the moderately to highly weathered Greywacke rock. Based on our experience in similar rock a grout to ground bond strength of between 150 – 250 kPa can be expected. However, given that there is limited ground investigation and no nearby anchor installation or testing results available we consider the lower bound bond strength appropriate at this stage.

6.1.1 Tension Anchors

Ground anchors should either be designed in accordance with FHWA Ground Anchors and Anchors Systems or BS8081:2015. Both standards recommend a Factor of Safety of 3.0 is used on bond strength when anchoring into rock for tension.

Using a Factor of Safety of 3.0 and a grout to ground bond strength of 150 kPa and the loads provided above we have calculated the following anchor requirements in order to support the guy rope.

Guy Rope: 300 kN tension force applied – Two anchors would need to be installed to a depth of 9 m each. A flexible rope connection would form the connection between the anchors and the guy rope.

6.1.2 Compression Anchors

As the base of the post is in compression and shear, anchors for supporting this foundation may be designed as piles in accordance with AS2159:2009. This standard recommends a range of Factors of Safety dependent on information available. Taking a conservative approach this standard recommends a Factor of Safety of 2.5 is used for grout to ground bond strength.

Therefore, using a Factor of Safety of 2.5 and a grout to ground bond strength of 150 kPa and the loads provided above we have calculated the following anchor requirements in order to support the post foundation.

Post Foundation: 175 kN compression force and 125 kN shear force applied – Three anchors would need to be installed to a depth of 3 m each. A small reinforced concrete plinth would form the connection between the anchors and the post base.

6.2 Early Contractor Involvement

It is recommended that a contractor that is experienced in the installation of rock anchors is involved to aid with the design development. The early involvement from a contractor will reduce uncertainty with constructability and cost. Their involvement will also help the design team to better understand the limitations with access vegetation and plant required. Furthermore, it is likely that some further investigations may be required (see following section) and it would be necessary to have a contractor on board to complete this work.

6.3 Further Investigations

Based on the uncertainty at this stage of the ground conditions and the achievable bond strength of the anchors it is recommended that additional investigations are completed.

It is recommended that a contractor that is experienced in the installation of rock anchors completes some sacrificial anchor testing at the site. The sacrificial anchor testing would help to understand construction methodology and get results from grout to ground bond strength. The tests would need to be completed in a range of locations across the site to provide an adequate sample.

As part of this further investigation it is recommended to establish access to each post location and complete additional observations of the ground conditions at each location. Shallow test pit investigations may be completed to try and establish the depth to rock at each location.

It is likely that the rock mass quality will improve with depth and the grout to ground bond strength will also increase. In order to establish if this is the case and to take into account this improvement in the design process a borehole investigation would need to take place alongside the sacrificial anchor testing. However, the cost of this investigation may not outweigh the benefit provided in reducing anchor length. Therefore, it is recommended that a borehole investigation is priced and the cost is compared against the potential savings in order to inform the decision to complete this investigation.

6.4 Further Design

New foundation elements should be designed by a Chartered Professional Engineer practising in foundation design. ENGEO can be engaged to complete the geotechnical aspects of the foundation design.

Prior to the foundations being design the design life and performance requirements of the structure should be confirmed.

7 References

Rattenbury, M.S. Townsend, D.B. & Johnston, M.R. (2006). Geology of the Kaikoura Area 1:250,000. Institute of Geological and Nuclear Sciences.

Institute of Geological and Nuclear Sciences (2020) Active Faults Database. Retrieved November 2020, from http://data.gns.cri.nz/af/

RetroLens (2020) Historical Image Resource. Retrieved November 2020, from http://retrolens.nz/

8 Limitations

i. We have prepared this report in accordance with the brief as provided. This report has been prepared for the use of our client, Holmes Solutions LP, their professional advisers and the relevant Territorial Authorities in relation to the specified project brief described in this report. No liability is accepted for the use of any part of the report for any other purpose or by any other person or entity.

ii. The recommendations in this report are based on the ground conditions indicated from published sources, site assessments and subsurface investigations described in this report based on accepted normal methods of site investigations. Only a limited amount of information has been collected to meet the specific financial and technical requirements of the Client's brief and this report does not purport to completely describe all the site characteristics and properties. The nature and continuity of the ground between test locations has been inferred using experience and judgement and it should be appreciated that actual conditions could vary from the assumed model.

iii. Subsurface conditions relevant to construction works should be assessed by contractors who can make their own interpretation of the factual data provided. They should perform any additional tests as necessary for their own purposes.

iv. This Limitation should be read in conjunction with the Engineering NZ / ACENZ Standard Terms of Engagement.

v. This report is not to be reproduced either wholly or in part without our prior written permission.

We trust that this information meets your current requirements. Please do not hesitate to contact the undersigned on (03) 328 9012 if you require any further information.

Report prepared by	Report reviewed by
W. A. Marshall	
Willy Marshall	**Richard Justice, CMEngNZ (PEngGeol)**
Senior Geotechnical Engineer	Principal Engineering Geologist

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APPENDIX 1

Concept Zipline Plan

Legend

- Base Group
- Zipline Cable Alignment
- Start Of Zipline
- End of Zipline
- Conical Hill Lookout
- Conical Hill Reserve Boundary

100 m

ENGEO

Title: Site Location

Client: Holmes Solutions LP		Figure No: 1
Project: Conical Hill Zipline	Drawn: WM	
Date: 17-11-2020	Checked: -	
Proj No: 17990.000.001		Version: 1.0