



## Memorandum

To	s 7(2)(f)(ii)
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Office	Tauranga
Date	1 March 2023
File/Ref	2-9B559.00
Subject	TCC Slip Inspections for Council Reserves

Dear s 7(2)(f)(ii)

This letter relates to our recent site inspections of landslips affecting Council Reserves in Tauranga City. The geotechnical inspections are to inform TCC of any immediate risk to people or property and to provide recommendations for further work to remediate the sites. As part of our assessments, the following sites have been inspected.

- Mauao Campground
- McLaren Falls Park – Road slump and Hamilton Point
- Te Auhi Pa – slips above properties at No. 33 & 37 Bateleur Cl
- Wharepai Domain – slip down onto the Waikareao walkway

The subject sites are discussed below, and outline the findings of our inspections, risk assessment and recommendations. Inspections were carried out from 31.01.23 to 7.02.23.

## 1 Mauao Campground

### 1.1 Site Description

This site is located at the western end of the Mauao campground on the corner of Pilot Quay and Adams Avenue at the foot of Mauao. The slope comprises an approximately 5m high grassed bank with a slope gradient of approximately 40 degrees above the camp site with a swale drain running along the toe of the slope which contained surface water at the time of the inspection. The crest of the slope is flat with a walking track located above and an approximately 50-degree slope above the track. A tension crack has developed along the crest of the slope. The length of tension cracking is approximately 17m long with a vertical offset ranging from 120 to 170mm. The crack was measured to be 600mm deep. There was no evidence of bulging at the toe of the slope, however a Nikau palm located on the slope had a curved trunk which suggests soil creep is occurring over time.

The site location is indicated on figure 1&2 below.



Figure 1: Grassed slope above site.



Figure 2: Tension crack along track

**1.2 Failure Mechanism**

Based on our site inspection, it appears that there is an overland flow path which ponds above the site. This, along with saturation of the slope from rapid and persistent rainfall over the slope would have likely resulted in an elevated groundwater table resulting in increased pore pressure in the slope and reduction of the shear strength of the soil. As a tension crack has developed, there has been some shear displacement, however the slope has not completely failed.

### 1.3 Initial response works

Following our initial site visit on 31 January 2023, WSP recommended that the site area was cordoned off below the track, including camp sites H72 – H70 followed by monitoring the site. We also recommended that the tension crack above the slope was filled with bentonite clay to prevent water from infiltrating through the slope and that additional drainage measures were implemented above the slope, such as installing an additional culvert above the slope with an appropriate outlet to prevent water ponding above the slope.

### 1.4 Slope Risk Assessment

We consider the slope to be currently stable under dry weather conditions, however the failure may be re-activated during a high rainfall event (e.g., 100-year storm event) if excess water pressure develops in the slope. The consequence of failure would be moderate for structures situated immediately. However, as the slope is of limited height, we anticipate a potential slump failure would be limited to the toe of the slope.

### 1.5 Recommendations

Based on our initial appraisal of the site, we recommend that additional hand auger testing is undertaken at the site along with the completion of a topographical survey to enable the accurate development of a ground model, from which slope stability modelling can be undertaken. We anticipate that 3 hand augers drilled to depths of up to 4m would be required.

This would enable assessment of the existing stability conditions of the slope and its sensitivity to the build-up of pore water pressure. The stability assessment would also enable development of mitigation options to improve slope stability which may include, cut or regrading of the slope, building restriction line or possible retention. The results can be detailed in an options assessment including mitigation options and associated rough order costs.

## 2 McLaren Falls Park – Road Slump

### 2.1 Site Description



Figure 1: Site Location

The road slump site within the park is located on the access road which leads to McLarens Falls Waterfall Loop track within the park. The straight section of road is bound on the east by a steep escarpment and to the west by swampy ground and small river below the road level. The road at this location is 4.3m wide with the slumping affecting 1.3m from the edge of seal to the widest part of the slump.

The site is characterised by an arcuate tension crack (13m long) in the road pavement and seal, from which the tension crack then leads to a straight section (9m long) along the edge of seal. There has been slumping and lateral movement towards the stream. Site measurements indicate the tension cracking is approximately 50mm wide with a vertical drop of 80 to 100mm at the maximum location. There is also approximately 50mm of settlement in a localised area of the road on the opposite side of the road. The downslope side of the road drops in elevation by approximately 1.7 to 1.8m over a horizontal distance of approximately 5m (i.e., 1V:3H).

Based on our correspondence with TCC, we understand a crack initially appeared after prolonged rainfall and increased in size over a day. Observations would indicate that little or no further movement has occurred over a period of about a week.



Figure 2: Arcuate section of slump and tension cracking in pavement



Figure 3: Straight section of tension crack.

## 2.2 Failure Mechanism

Based on our recent site observations and brief desk top study, we consider that the slumping has been caused by the rapid and persistent rainfall, combined with the potential flow of stormwater over the slope which has likely resulted in an elevated, short-term elevated groundwater level.

The rise in the groundwater table would have resulted in increased pore water pressures resulting in a reduction in shear strength of the soil, resulting in slope displacement and slumping. The soil may also may have comprised low strength filling, soft alluvial or reworked volcanic materials which can be prone to failure as the location is below a large escarpment which has evidence of previous failures at the toe and the site has likely been filled as part of the original road construction.

## 2.3 Initial response works

Following our initial inspection, WSP advised that the road could remain open, provided it was monitored each morning for any further slope movements. However, it was advised that the road should not be used during and shortly after heavy rainfall in case of potential further failures.

## 2.4 Slope Risk Assessment

Currently we believe a future failure is possible as there is a well-developed tension crack, however as the slope is not overly steep or high, we anticipate it would require a very high rainfall event to initiate failure. We anticipate the failure would develop at the current tension crack location leaving an exposed scarp. We therefore consider the risk to be moderate however, a failure may develop in a high rainfall event.

## 2.5 Recommendations

Based on our initial appraisal of the site, we recommend that additional hand auger testing is undertaken at the site along with a topographical survey. We anticipate that 4 hand augers drilled to depths of 4m would be required.

The hand augers would enable the development of a ground model for the site which would assist in developing remedial options. An options report could then be prepared which would detail possible options and rough order costing for each option to remediate.

### 3 McLaren Falls Park - Hamilton Point Slips

#### 3.1 Site Description

The subject site comprises two slips that have occurred at the western end of the Hamilton point campground at the edge of Lake McLaren. The site locations are indicated on Figure 1 below.



Figure 1: Location of slips at Hamilton Point.



Figure2: Slip site 1



Figure 3: Slip Site 2

The exposed headscarp at site 1 is approximately 8m across and 3.5m high. The slip has occurred at the edge of a relatively flat terrace below the Hamilton point campsite. The scarp is subvertical to vertical for a height of 3.5m where the slope below flattens to about 18 degrees down to the lake edge. Material exposed in the scarp comprise orange -brown silty clay (ash) material with a sub horizontal coarse sand layer noted at 1.5m below the crest. The failure is indicative of a rotational slip surface.

Slip 2 is located to the southwest of slip 1 also on the edge of the terrace and as also failed down to lake level. The geometry of the failure surface is similar with a sub vertical to vertical head scarp. The materials exposed in the head scarp from the top down comprise orange, brown clay material overlying sandy layers which are underlain by a brown organic silt and grey/ light orange clay layer. Seepage was observed at the toe of the slope during the inspection. The sequence of ashes is the same for both slip sites with the slips separated by a intact promontory containing tree stumps.

At both slip locations, the original walking track which was cut into the toe of the original slope has been destroyed. An intact section of the track has rafted into the lake by some 15 to 20m. The slip debris runout at both locations extends well into lake McLaren below.



Figure 4: Photo of section of track in lake.

### 3.2 Failure Mechanism

Based on our observations we anticipate that the failure at both locations is due to the sustained and heavy rainfall which has led to high pore water pressures developing within the slope. There is also evidence of highly permeable sand layers between lower permeability ash layers which could lead to confinement and porewater pressure build up along permeable sand and silt layers. This resulted in reduced effective stresses in the soils and loss of shear strength. In addition, the existing slope had its toe support removed from the original track formation.

### 3.3 Initial response works

Following our initial inspection, WSP advised to cordon off the campsites above due to the current falling hazard and potential for further slippage. WSP understand these sites are currently closed to the public.

### 3.4 Recommendations

Based on our initial appraisal of the site, we recommend hand auger testing is undertaken at the site along with a UAV survey to create a surface and obtain aerial images. We anticipate that up to 3 hand augers per slip site would be required.

The hand augers and survey data would enable the development of a ground model for both of the sites which would assist in developing remedial options. An options report could then be prepared which would detail possible options and rough order costing for each option to remediate. We anticipate options to improve the stability of the slope could involve benching and battering the slopes at a suitable angle by undertaking bulk earthworks or alternatively an MSE wall structure, however this would be confirmed in an options assessment.

## 4 Te Auhi Pa – Welcome Bay

### 4.1 Site Description and Landslide Geomorphology

The subject site is located below Te Auhi Pa at 37 Osprey Drive in Welcome Bay and is shown on Figure 1 below. Below the Pa site, the topography slopes to the south east at an average gradient of approximately 28 degrees relative to horizontal and then flattens to approximately 14 degrees towards the east near properties at 33 and 37 Bateleur Close. The slope flank is concave and arcuate in shape and is the location of a relict slip according to TCC Mapi. There are two large pine trees located just below the Pa site at the crest of the slope.

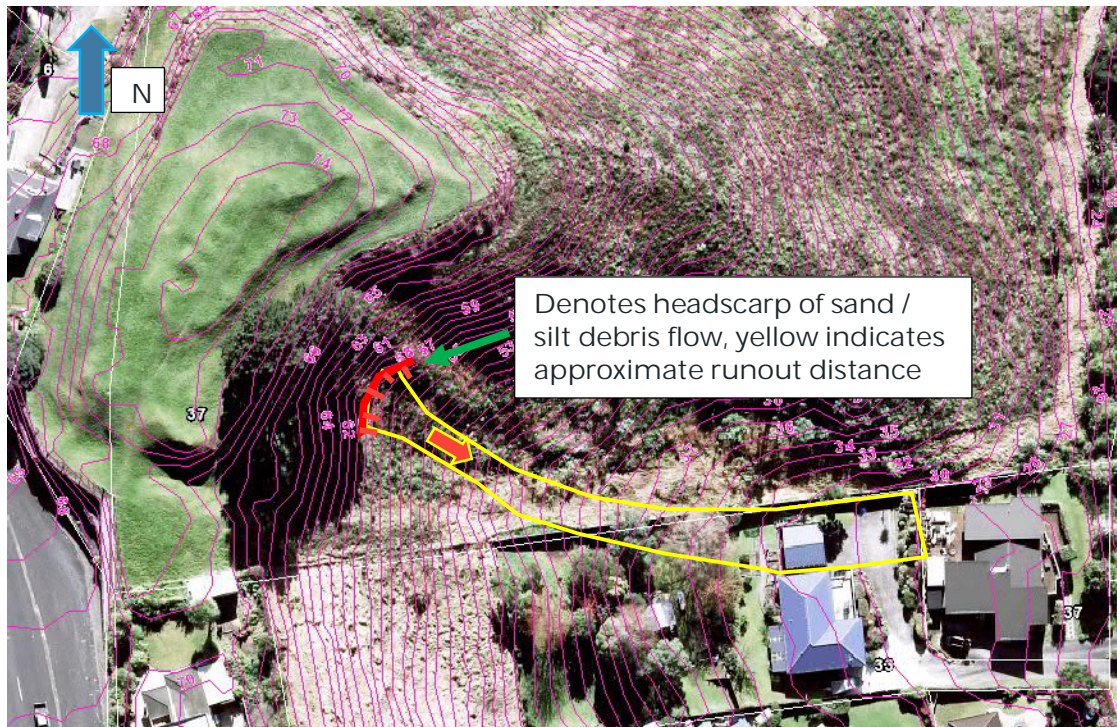


Figure 1: Site location and direction of slip.

Based on our inspection of the slope, a silt/sand debris flow has occurred midway up the slope. The headscarp is approximately 6m wide with a runout length of approximately 70m which has inundated a portion of the property and the garage at No. 33 Bateleur Close with sand and silt. The slip failure is up to 1.2m deep at its margins and has affected the topsoil and underlying ash/ ignimbrite deposits. The debris is saturated and there are numerous mounds of soil up to 600mm high which have rafted down the slope.

The failure has impacted the boundary fence at several locations which has damaged the fence with sediment making its way below the fence onto the property and down between the garage and the house. The garage has been inundated with silt and sand to a depth of approximately 300mm. The slip debris has also affected the boundary of the property located at No.37. Figure 1 above shows the extent of the inundated area.

Some of the soils are likely to be highly sensitive to disturbance from rainfall induced porewater pressures which is common in some tephra units in the Tauranga region. Several metres down from the main head scarp, active seepage was noted from the slope indicating that the soil units have been charged with groundwater. The soil in the failure debris comprises dark brown to orange, brown silty clay and grey to pinkish grey pumice sand and fine gravel.

The published geology of the area indicates the site is underlain by the Waiteariki Ignimbrite; however, the site is likely overlain by younger ashes such as Hamilton and Rotoehu Ashes that have likely eroded as the site is steep.



Figure 2: Path of debris flow



Figure 3: head scarp/ origin of failure

## 4.2 Failure Mechanism

Based on our observation we anticipate that the failure is due sustained and heavy rainfall which has increased pore pressures and seepage within the slope. This has led to a large drop in effective stresses resulting in loss of shear strength. Given the fluidised nature of the failure it is likely the material was at its liquid limit resulting in the large run out length. The geomorphology of the original slope has channel shape depressions which run perpendicular to the slope including hummocky ground which is evidence of historic debris flows and soil movement.

## 4.3 Risk Assessment

As the geomorphology is steep at the site with evidence of historic failure in addition to the current failure, we consider the likelihood of instability to be high below the reserve in a future high rainfall event such as the event that triggered the subject debris flow. Our review of rainfall records indicates that 178mm of rainfall fell in Tauranga within 48 hours on 27 and 28 January (Source Metservice). The location of a future failure is difficult to predict, however we anticipate it could occur anywhere within the slope below the reserve if there is sufficient rainfall to trigger a failure. Based on our desktop review of TCC mapi, all properties at the toe of the Te Auhi Reserve are in the 4:1 inundation zone so consideration needs to be given to the wider risk of slips during inclement weather conditions. Therefore, we consider a future slip event is likely within the remaining design life of the structures (say 50 years) with moderate to major consequences to properties. Therefore, we consider properties below the site to be at high risk of inundation in a future landslide event without any mitigation installed.

# 5 Recommendations

## 5.1 Initial response works

In the immediate short term WSP would recommend removing the debris and any large spoil heaps to waste and plant out the landslide scar and reinstate the fence if this is feasible from a planning and cultural perspective. The debris may become a hazard if the site experiences a future high rainfall event, and it becomes saturated as it could slip down towards the property boundary causing more damage to the property.

It may also be possible to remove the heaps and find a suitable area on site to stockpile but this would require confirmation of the suitability of the foundation conditions and drainage installed below the stockpiles (e.g., drain coil). This could be done by inspecting the foundation prior to placement of material. However, as the material is saturated and likely sensitive, it may not be suitable for compaction so constructing a bund or stable stockpile may be problematic. If this option is pursued, then we would recommend that a standard compaction test is undertaken on the slip material to assess its suitability for compaction.

Regarding the large pine trees on site, we would recommend that the stability of the trees is assessed by an arborist in conjunction with a geotechnical engineer as the trees may be incorporated into landslide debris if slippage occurs at the crest of the slope which can cause a large amount of damage if an impact occurs. The trees can also serve to apply torque to the slope which can promote failure in some cases.

The recommended works are indicated on Figure 4 below.

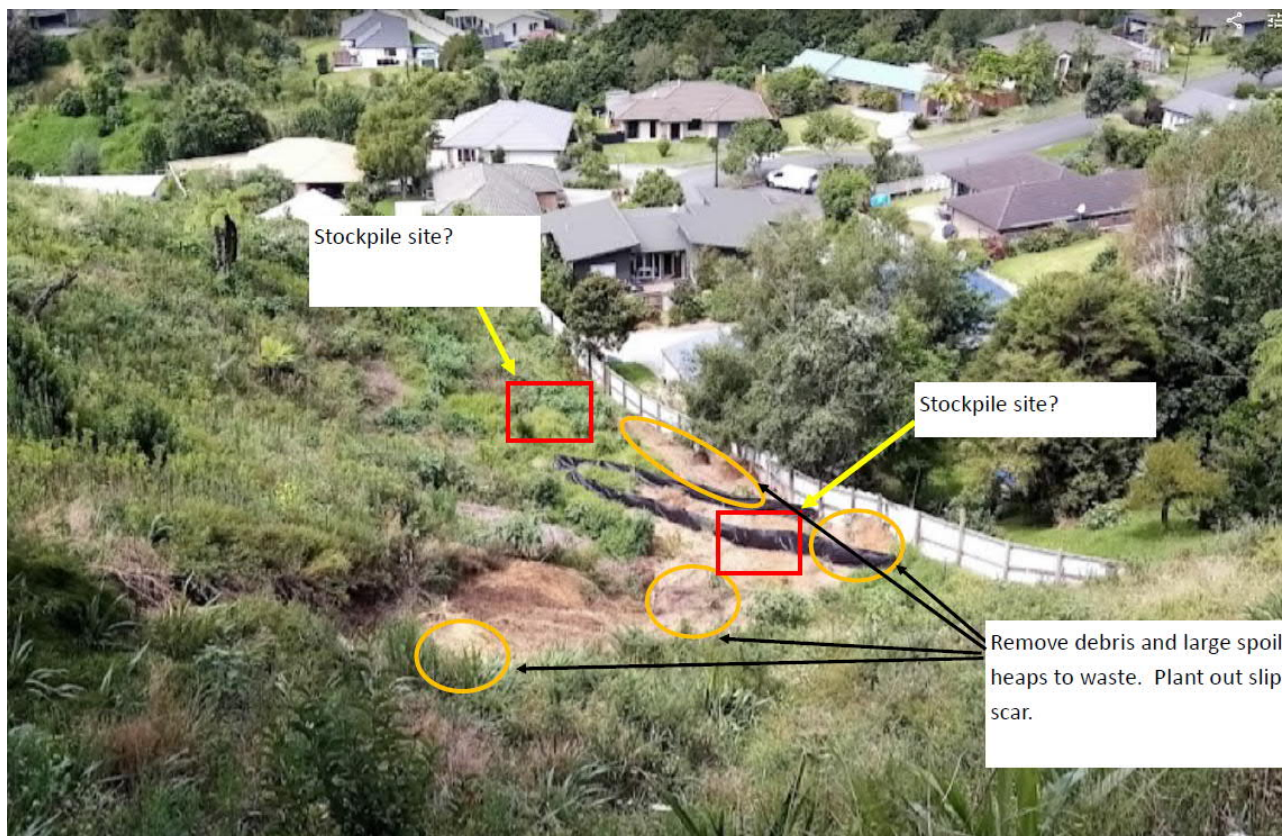


Figure 4: Recommended initial works concept

## 5.2 Further Work

We anticipate that an earth bund will have limited effectiveness in a future debris flow (landslide) as it may flow over a bund depending on the size and velocity of a flow.

A potential long-term option may be to construct a specifically designed debris barrier fence which would require specific design, but the extent would need to be carefully considered as areas outside (those damaged by the debris flow) would be just as vulnerable in the long term as the inundation risk is similar on the entire slope surrounding the site. We believe that it would be very costly and not practical to stabilise the entire slope, however the slope stability may be improved by installing horizontally bored drains and appropriate planting of the slope. We therefore consider it would be more cost effective to protect the dwelling with a specifically designed debris barrier fence rather than stabilisation of the entire slope. We recommend that this option is explored by either the land owner or TCC depending on legal obligations. However, in the short term we would recommend removal of debris and planting as discussed above in section 5.1 to reduce the risk.

# 6 Wharepai Domain

## 6.1 Site Description and Landslide Geomorphology

The subject site is located at the western end of the Wharepai Domain, in an area prone to slippage, as indicated on Figure 1 below. At this location, a landslide has occurred at the crest of the slope beyond the existing fencing. The landslide is approximately 12m wide at the top with a runout zone extending out to the guardrail at the edge of Takitimu Drive – State Highway 2 below approximately 20m across. The height of the slope at this location is approximately 8m high.

The debris from the slip comprises orange brown silty clay soils with a large amount of concrete fill material up to 0.5m in diameter. The volume of evacuated material is estimated

to be approximately 25m<sup>3</sup>. At the time of our inspection, there was fill material lodged midslope behind a tree.

The published geology in the area indicates the site is underlain by Matua subgroup deposits which are typically overlain by (from oldest to youngest) Hamilton ash, Rotoehu ash and younger (post Rotoehu) ashes.



Figure 1: Slip failure with fill material below.

## 6.2 Failure Mechanism

Based on our inspection and desktop study, the failure was caused by sustained heavy rainfall which saturated the slope resulting in high porewater pressures which reduced the shear strength of the soil which was already standing at a steep angle. The presence of fill material on the slope would have also added to the weight of the slope increasing the potential driving forces of a potential failure.

## 6.3 Risk Assessment

Regarding possible further failures of material, we consider the risk to be moderate to high track users due to the presence of fill material and rubble lodged in behind the tree mid slope which may be undermined if further heavy rainfall occurs. We consider the risk to SH2 to be currently low, however there is the possibility of silt runoff during a heavy rain event.

# 7 Recommendations

## 7.1 Initial response works

Regarding immediate actions, WSP recommends that the top of the slip is fenced off with a 3m no access zone be marked out as per the below sketch. We also recommend the track is closed until the debris has been removed, loose material on face cleaned up and concrete blocks stuck behind tree and up slope are removed. When this has been completed, we would recommend installing fencing on the slip side of the track to prevent access into the slip area and allowing track to be re-opened.



Figure 1: Initial response works

## 7.2 Further Work

To further enhance the stability of the slope we would recommend that the current fence is removed to allow regrading of the slope to remove any overhanging material. Once the crest of the slope has been regraded this would allow the placement of erosion protection matting (e.g. Macmat R) and either planting the slope or hydroseeding.

We trust that this is suitable for your current needs, although if you do have any questions in relation to the above, then please do not hesitate to contact the undersigned.

Regards,

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