Tonkin+Taylor

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Attention: Stephen Collett

Dear Stephen

Brynderwyns Landslide Remedial Treatment Review
Section F Landslip. Letter Report

Executive Summary

Tonkin + Taylor has been requested to undertake a review of the landslide event that occurred in Section F of the Brynderwyn Recovery Works on 30 April 2024 and report on the likely cause and effectiveness of proposed remedial works.

Our inspection has determined that the primary failure mode was a translational landslip involving a layer of residual soils sliding on the interface with the less weathered underlying rock. These materials comprised dry cohesionless sandy silts which is a most unusual product of weathering of greywacke which is the basement rock. These soils were located on the steep vegetated natural face above the road which was largely inaccessible for safely mapping or investigating the ground. These soils, having no cohesive strength, would have been in a critical state of stability. It is likely the slopes would have been sensitive to disturbance by construction works.

Excavation in the highly weathered rock at the toe steepened the face to the design grade that was established for these materials by precedence on this and other slopes. At this location it could have resulted in loss of some support for the upper face, sufficient to progressively mobilise the sandy silts and extend into the forested area to the south of the initial failure.

The remedial works need to be staged to enable plant to safely operate. It is expected this will initially involve the excavation down to the highly weathered rock at the crest of the slope to provide a working platform for removal of the over-steepened head scarp. The work can then progress down the slope removing the remaining residual soils and stepping down the platform. Highly weathered rock is exposed in areas of the scarp which should limit the depth of excavation required to form a stable slope. Once this is removed, we expect the slope should achieve adequate global stability.

Once the upper face is stabilised and deemed safe, the debris may be removed from the roadway and remedial soil nailing installed to secure the steeper lower face cut in the highly weathered rock.

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The debris is surcharging the roadway and planning of works needs to consider effects of further loading by spoil on stability of the area downslope.

No other zones of sandy silt residual soils have been identified on other sections by the project team, but this should be reconfirmed as part of the risk review and works completion procedures.

Introduction

Tonkin + Taylor have been requested by the NZTA to undertake a site visit and provide advice on the proposed remediation works required to address the landslide that occurred on Monday 30 April on Section F of the Brynderwyns Hills Recovery and the associated enabling works project, see Figure 1. In addition, the advice should include a view on the approach taken to minimising the risk of future significant slips for the wider recovery area currently being worked on.

This immediate Report summarises the findings from the site visit and a briefing session held with NZTA, Fulton Hogan and WSP staff. Additional information will be forwarded to us that may have a material effect on the review so this advice should be considered as preliminary only.

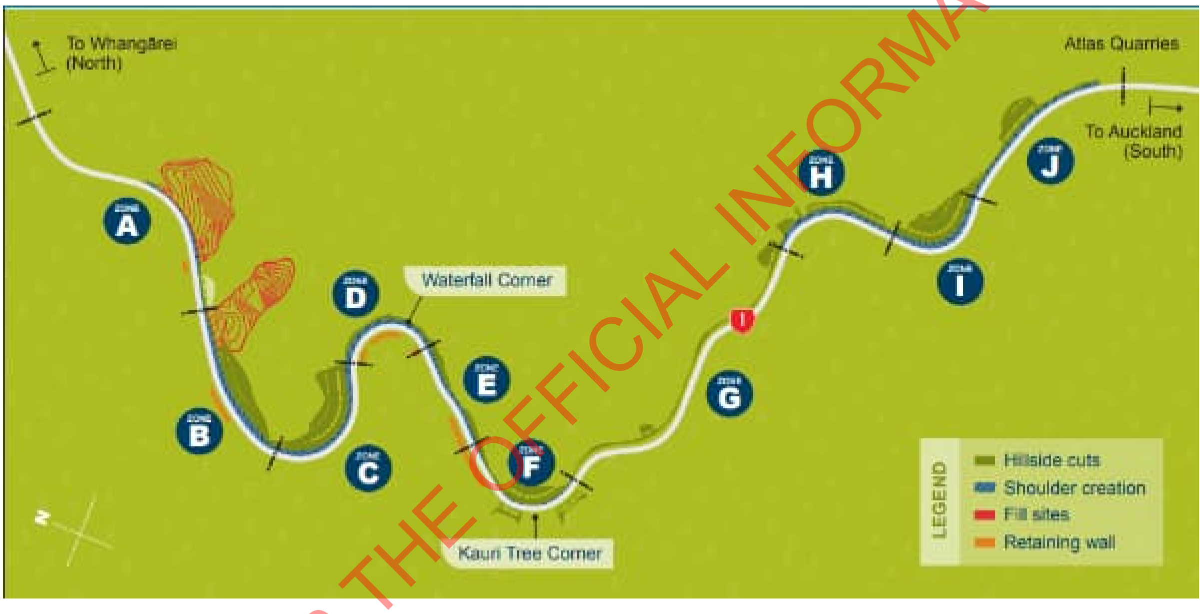

Figure 1: Plan of Brynderwyn Hills recovery works showing sections.

Site description

The Brynderwyns Hills section of SH1 traverses steep terrain that includes steep cuts and sidling fills that have a long history of instability resulting in frequent road closures. The Brynderwyns Hills recovery project was initiated as emergency recovery works following storm damage caused by the Cyclone Gabrielle event in February 2023. We understand the scope of work was changed following an early assessment of high residual risk to the road if works were limited to addressing the immediate areas of storm damage.

The strategy adopted is described in the Design Philosophy statement[1] and includes widening to form a 12.5m wide three lane carriageway to provide increased availability in any reasonably foreseeable event to at least 1 lane for 2-way traffic while the third lane was available for remedial works. This would apply to both instability of the faces above the road as well as access for potential loss of support below the road.

[1] Design Philosophy statement. Brynderwyns Recovery work – SH1 RS 303 RP11.46-13.79. Draft 05 October 2023.

Design Philosophy and Methodology

The revised scope as described by the WSP geologist has been designed based on the "Observational Approach". This is an established design method which is often applied for stability of road construction works in areas of complex geology and where the amount of geotechnical data from drilling and mapping is limited by access (and time). The project has involved extensive earthworks on the section south of the "summit" where a series of hillside cuts have been made.

We understand the primary design slopes have been determined using a collaborative process involving the designer, contractor (including experienced earthworks subcontractor) and NZTA Subject Matter Experts (SMEs.) It is largely based on precedence supported by some back analysis of existing slopes as described in The Design Philosophy Statement[2].

The design for a nominal 10-year life has adopted the following generalised profile based on the observed performance of slopes along the existing road and within the Atlas Quarry site immediately to the south in similar greywacke geological conditions. A Factor of Safety for static stability (FOS) > 1.5 is not expected in all cases. The resultant design provided for:

- 70° cut faces in the moderately to highly weathered rock where exposed at the toe of the excavated faces.
- battering back the completely weathered and residual soils to 45° in the upper sections
- a series of benches and drainage swales formed at the material interfaces. Acceptance that these may progressively erode but primarily required until vegetation is established.
- Where issues of high residual risk have been identified in the exposed faces by mapping and local instability, and landslips may result in a lane closure of more than 2 days, the HW rock faces have been soil nailed while upper CW/residual soil slopes have been remediated at shallower grades.

The design was developed to 80% design stage and drawings completed by WSP, and work packs were prepared by FH for each cut face which included a series of hold points to review and update the design. In practice full supervision of the works (CM5) was provided by WSP with daily site meetings to review progress and update work plans.

The cooperative design approach has enabled the work to progress at pace, and to minimise the time to complete the works. Once this phase of the work is completed and the road reopened, we understand a more detailed assessment of residual risk is proposed and additional works may be undertaken from the "third lane" to address high risk areas identified.

Geology

The Brynderwyn range is formed by uplift and erosion of the Waipapa Greywacke basement rocks comprising interbedded indurated siltstones and sandstones that have been complexly deformed by tectonic movement. The rock mass has been subject to weathering with a distinct change from structural controlled rock behaviour to soil behaviours at the transition from highly weathered to completely weathered stage. Residual soils generally include cohesive component to strength and will develop perched water tables. A feature of the residual soils at Section F, where the failure occurred, is they comprised dry sandy silts. These are unusual and suggest leaching or aggregation of the clay size particles. These materials appear to be local to the zone of failure.

The exposed rock mass, although looking chaotic in nature, contains persistent defects (joints and crushed zones) which are mappable features. These defects are likely to extend into the weathered rock mass a relic defects, see Figure 2.

[2] Design Philosophy statement. Brynderwyns Recovery work – SH1 RS 303 RP11.46-13.79. Draft 05 October 2023.

Figure 2: Section F in foreground and Section F beyond showing the recent failure in this section. Sections are on the west facing slope on north trending spur ridge with a series of steeply incised gully features (see Figure above, the recent slip is on the right of the photo).

Site Visit

A site visit was made by section 9(2)(a) (Geotechnical Engineer) and section 9(2)(a) (Engineering Geologist) on 02 May 2024. An initial briefing was provided and a site induction before the group was joined by other site staff for an inspection of the site and works. This comprised an approach to the southern extent of the recent landslips at Sections F before circuiting through the Atlas Quarry to the northern end of the landslips. An exclusion zone was in place at the slips, but they were able to be adequately observed from a distance. Closer inspection of adjacent zones provided an appreciation of the materials and structure of the geology.

On return to the site office the videos of the landslip as it occurred was reviewed and a workshop was held with site staff. We greatly appreciated the open conversation and the degree of cooperation which we infer reflects the strong culture and focus of the team.

Landslip Events 26 – 30 April

Section F extends around a south trending spur ridge which includes Kauri Tree Corner. An earlier slump had occurred in the upper slope where Section E transitions to Section F of the route. This had resulted in a scarp feature some 30m long that had been dressed and hydroseeded as part of the works. A moderate size slump of material (about 200m^3) is reported to have occurred in the lower face in Section F north of Kauri Tree Corner on 30 April.

An access track was formed down the ridge line above the slump to enable unloading of the head of the slope at this location~~.~~

Video footage shows the first signs of large movement was at the northern end of Section F and adjacent to a cut and hydroseeded area of the upper face in Section E of the slope. Spoil was expelled indicating compression as the material above started to mobilise. This was followed quickly by slumping of highly weathered rock (gravel size fragments) at above the toe of the slope. This is likely the result of compression by the mobilising soils on the slope above which then gained momentum as the ~~toe~~ support was lost and developed into the mass landslide. The landslide then extended to the south to include a forested area of the face. The estimated 40,000m^3 of material is deposited on the road which both buttresses the slip debris and surcharging the road platform, see Figure 3 and 4. It is also clear from the video, and observing the material involved in the slip, that this area of the slope was in a critical state of stability, where any disturbance was highly likely to trigger movement. The team had already cut back the toe at the base of the slope to widen the road and were in the process of installing soil nails to stabilise the exposed highly weathered rock, but this was not able to provide sufficient buttressing to prevent mobilisation of the cohesionless soils above.

Figure 3: Failure scarp showing over-steepened rear scarp at crest and cracking circled behind the crest where it is exposed in the adjacent side face of the earlier landslide in Section E.

The material that has evacuated the upper face is reported to be dry cohesionless sandy silts derived by weathering (and leaching of minerals) of the greywacke rock to residual soils. The frictional strength of these materials is expected to be in the range of 32-35^0, i.e., below the slope angle and stability would have been critical, FOS=1.0.

The recent landslips have occurred following an extended period of dry weather. The lack of cohesive (clay) components is unusual in the greywacke derived residual soils and the dry state would have likely made them increasingly susceptible to mobilisation. We note the face before the landslip was vegetated with native bush. Some of the tress on the lower slopes appear to exhibit leaning that would suggest creep movements of the slope had been ongoing.

The landslide is likely to have been a translational event, primarily involving the completely weathered/ residual soils and shearing at the interface with the highly weathered rock beneath. The progressive movement would have loaded the highly weathered rock exposed at the base of the cut slope probably causing the breaking out that occurred in the early stages of the landslip.

The spoil is covering the lower slope, see Figure 4, so it is not possible to assess the extent of damage to the rock, but it is important to note that early video showed rock being expelled over a section and some disturbance to the remainder of the face should be expected.

Figure 4: Landslip showing debris at road level and evacuated face above. HW rock exposed in foreground and hydroseeded face of earlier failure in Section D above with cracking evident at crest. HW rock is present at mid-height of the evacuated scarp.

We observed exposures of highly weathered rock in the evacuated upper face that indicates that much of the residual soils have now evacuated form the face. There remains an over steepened head scarp of residual soils at the crest of the ridge (see circled feature below). We understand Goodmans (Experienced earthworks sub-contractor) has excavated a trench at the crest and confirmed highly weathered rock at about 3m depth in the vicinity of the digger in the photo.

Landslip remediation

The site team are developing options for remediation, and we understand the current proposal is to cut down the ridge to HW rock to form a platform from which the remaining residual soils at the headscarp can be removed. The work will then progress down the slope maintaining a bench to operate safely from. We consider this would be a safe approach to securing that face but would delay access for the removal of spoil as it is buttressing the toe of the slipped materials.

We note that HW rock is likely to be encountered at a relatively shallow depth on much of the exposed face, as evident in exposures of HW rock in the scarp, see Figure 4, and there may be options to limit the extent of further excavations, initially removing material at the crest to make safe and scaling the remaining loose soils on the middle section, sufficient to enable plant to operate on removal of the spoil at road level. The initial phase for both options is the same and it may be possible to target the latter while retaining the more extensive works if the lesser works cannot be safely achieved.

It may be difficult to remove all the remnant residual soils from the face. Options that may be considered include drag net, washing and leaving it for weather to erode.

Additional Comments on The Recovery Works Project

We provide some further comments on the design processes and other works observed on the site.

Stability of the Road loaded by Landslip debris

The spoil from the landslip has been deposited on the roadway including a section where sidling fill has been formed on a steep face and retention works are currently being strengthened. The stability of the roadway may be impacted by the surcharge of spoil. Monitoring is recommended and the spoil removal methodology should consider potential for instability.

Geological structure

We note that there are a number of major geological features that extend across the project area. The significance of these features should be further assessed as part of the stage 2 risk assessment that is proposed.

There has been detailed mapping of the site, but we understand this data has not been analysed to identify if there are prevalent and pervasive joint clusters that may impact on stability. There is some potential for persistent jointing to have had a secondary contribution to the instability at Section F and when the spoil is removed remedial soil nailing is likely to be required for the highly weathered rock in the base cut.

There has been logging of the completely weathered rock and residual soils above the MW rock interface as construction has progressed, but we did not sight any maps of the completed slopes to record these. This should be completed to ensure as-built data is available before revegetation to assist in identifying future risk and informing planning of remedial works in the event of landslippage.

Uncemented Residual Soils

We would recommend mapping/ investigations to assess the potential for further zones of uncemented residual soils where this may present a risk to the slopes above (and below) the road. As noted earlier, this product of weathering is unusual in our experience of greywacke rock where residual soils usually have significant clay components and higher water contents. It is likely that leaching of minerals has occurred during the weathering processes.

Section E

The cut in Section E is high and the faces have been excavated using the general approach. Some spalling of the lower face has occurred below the bench compromising future access. Soil nails are expected to be required. The upper face cut in the CW/residual soils is high and large trees are present at the crest. We note that any rock fall/ slumping/ loss of trees will not be captured by the bench and rock fall will likely encroach on the carriageway. Consideration to a catch fence at the bench may be necessary as well as more specific assessment of stability of this face. Specific investigation and stability assessment of this face is recommended as the potential volume of debris is large, see further note below.

Stability Analyses

Stability analyses for finished cut slopes on the project had been undertaken by WSP[3,4] . However, these do not include Section F which was still under construction. We observed that the strength parameters used in these reports for the materials are consistent with our experience of these materials except the cohesive components would not apply to the sandy silts in Section F.

We also note that only circular failure analyses have been reported, whereas the failure at Section F and the adjacent earlier failure in Section E included translational mechanisms. We recommend that translational mechanisms be included in the proposed risk assessment.

Once the remedial works are advanced and debris removed to expose the failure surface, back analysis of the failure should provide parameters for these uncemented soils. It would be useful to compare these, and other back analyses undertaken with published test data on weathered greywacke materials (Grant Taylor[5], Pender[6], and Martin and Millar[7]).

Summary

The landslip that occurred on 30 April 2024 in Section F is likely to have been initiated as a translational failure of the completely weathered/ residual soils in the upper section of the slope. These materials comprised dry cohesionless sandy silts which is an unusual product of the weathering processes of the greywacke rocks (which usually contain cohesive clay components). The failure occurred above the interface with the highly weathered materials that daylights in the base of the cut slopes and exhibits rock strength characteristics.

The steep upper slope was likely to have been in a state of critical equilibrium prior to the works due to the unknown presence of the zone of sandy silts and their lack of cohesive strength. It was likely accelerated as a result of the disturbance when removing the “buttressing” provided by the highly weathered greywacke rock at the base of the slope and potentially to a lesser extent by earthworks at the crest.

[3] WSP.”Brynderwyn SH1 Recovery Works. Upslope Stability Design Assessment Report”. Project 1-11264.00, 13 March 2024

[4] WSP. “Issue Memo 11 – Section E North End Upslope Hazard report”. Memorandum to Project Recovery Board. 27 March 2024 (First Raise 03 November 2023)

[5] Grant Taylor T L. “Stable Angles in Wellington Greywacke”. New Zealand Engineering, Vol 19, Issue 4, April 1964, pp129-130

[6] Pender M J. “Some Properties of Weathered Greywacke.” 1st Australia – NZ Conference on geomechanics. Melbourne 1971

[7] Martin G R and Millar P J. “Joint Strength characteristics of a weathered rock. “ Proc. 3rg Congress Intl Soc. Rock Mechanics. Denver. Vol 2, Part A pp263-270. 1974

The progressively mobilising soil above the HW rock at the bench level has transferred load and caused local failure of the highly weathered rock in the lower face causing local failure of these materials. There is also potential for exposure of unfavourably oriented jointing in the HW rock to have been involved resulting in loss of support at the toe. The primary cause is considered to be the unusual weathering product comprising cohesionless sandy silts in the steep slope aided by the drying out of the material from a dry summer.

Remedial works will require reshaping of the face to a stable batter of the upper slope and potential strengthening of disturbed rock at the toe. An over-steepened rear scarp remains at the crest of the slope, and this will need to be removed by access from the crest. The exposures highly weathered rock in the failure scarp indicate much of the completely weathered soils have evacuated the slope and this may provide the opportunity to limit the extent of further excavation to adequately stabilise the face. A trial excavation at the crest has also encountered highly/moderately weathered rock that provides a platform to work from. Further loading on the road platform by spoil during the remedial works should also be considered in staging the works.

The presence of cohesionless sandy silts was not evident from the limited investigations and site mapping possible on the steep face and this is an unusual product of the weathering processes in greywacke rock. We note that the instability associated with the uncemented sandy silts in Section F is likely to be isolated, but this should be confirmed by review of the site mapping. There are also features of the high face in Section E that may present a landslip risk which could impact on the road.

The design of the cut slopes for the Brynderwyn Recovery works has been primarily based on precedent using the performance of existing slopes on the road and in the Atlas Quarry to identify slope angles expected to achieve the short-term design objectives. An observational approach has been applied using close supervision, mapping of the exposed faces and applying additional mitigation measures (reprofiling and soil nails) where unfavourable conditions were identified. This is a widely used practice, well suited to this project but limitations of access, and the unusual nature of the materials, has meant the risk of instability was not detected.

While we have not reviewed the project stability analysis reports in detail, as they do not specifically include Section F, the parameters applied to the analyses are generally consistent with our experience for the weathering grades of greywacke. However, the cohesive strength component used for completely weathered rock would not apply to the sandy silts encountered at Section F. The mechanism of failure at Section F is primarily a translational mode while the analyses have only considered circular modes. Translational models should be included in any future analyses for this section and other sections where the interface of the completely weathered and highly weathered rock provides potential for a translational mechanism of failure.

Limitation

This immediate report is based on a site visit and initial review of selected information provided by the project. No close inspection was possible, and we have relied on data and information disclosed. We note that other information may be available and more detailed investigation may affect the conclusions and they should be used for guidance recognising they are based on experience but limited information.

Yours sincerely

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