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Remediation of flood damage on the Toowoomba Range Railway, Queensland, Australia

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ABSTRACT

The Toowoomba Range Railway is located on the eastern side of the Great Dividing Range approximately 110 km west of Brisbane, Australia and was originally constructed in 1867. This locality in the Upper Lockyer Valley is characterised by steep terrain with surface elevations reaching approximately 600 m above sea level. Following the flash flood events of January 2011, the railway sustained significant damage including washouts of embankments and culverts, failure of upslope cuttings, destruction of a bridge and damage to a gas pipeline. A geotechnical assessment was undertaken along a 25 km length of railway and over 100 failure features were identified as having an impact on operation of the railway. Twenty failure features were considered significant in nature and required engineering input during the remedial design and/or reconstruction phase. Initial estimates by Queensland Rail predicted a 3 to 6 month repair program. Detailed topographic information for selected sites was obtained by an aerial photogrammetric survey from a manned helicopter using the 3DM Analyst digital photogrammetry system. Reconstruction of the flood-damaged earthworks and culverts utilised robust solutions that could be implemented quickly and this typically comprised excavation of failed material and replacement with rockfill, installation of large steel culverts, and at one location the use of pre-cast concrete L-section panels to retain a steep rockfill embankment. A six week program of investigation, pile design and construction was implemented for replacement of the damaged bridge. The first train resumed service on 28th March 2011, about two and a half months after the flood, which was well ahead of schedule.

Keywords: railway, flood, slope stability, bridge, rockfill, culverts

1 INTRODUCTION

This paper presents an account of remedial works completed on the Toowoomba Range Railway in Queensland, Australia following the damage caused by the flash flood events of January 2011. The regional setting and a description of the railway is detailed below, together with a summary of the climatic conditions which led to the event. The nature and significance of damage sustained by the railway is described, along with remedial measures employed for fast-track remediation.

2 BACKGROUND

2.1 Regional Setting

The Toowoomba Range Railway is located on the eastern side of the Great Dividing Range approximately 110 km west of Brisbane, Australia (Figure 1). The Upper Lockyer Valley is characterised by steep and inaccessible terrain with surface elevations ranging from approximately 250 m to 620 m above mean sea level. The basement geology comprises Jurassic-age Gatton Sandstone and Koukandowie Formation (part of the Marburg Subgroup) which are both characterised by labile sandstones (Geological Survey of Queensland 1980). The land surface rises in a westerly direction as the Great Dividing Range is approached and along the escarpment the sandstone is overlain by Tertiary aged Main Range Volcanics, comprising basalt and basaltic ash and tuff. Significant zones of colluvium are also present on the steep slopes.

Figure 1. Locality Plan

2.2 Toowoomba Range Railway

The Toowoomba Range Railway was constructed between 1865 and 1867 and is the earliest railway crossing of the Great Dividing Range. The railway is a single track which provides a vital link between The Port of Brisbane and the region west of the range. The study area covered a 25 km length between the town of Murphys Creek and Harlaxton, a suburb on the eastern margin of Toowoomba (from chainage 132 km to 157 km).

The range section of the railway is characterised by steep cuts, slopes comprising predominantly side-tipped fill (with a high proportion of ash waste from steam train operations) and deep filled gullies. The railway has an approximate elevation gain of 370 m along 25 km, the length being controlled by a maximum 2% grade.

2.3 Flash Flood Event of January 2011

The monthly rainfall recorded during December 2010 for the Toowoomba and Upper Lockyer Valley region was unusually high, with Australian Government Bureau of Meteorology data indicating up to 480 mm, which is approximately four times the historic monthly mean. This higher than normal rainfall can probably be attributed to a prevailing La Nina event in the southern Pacific Ocean.

Higher than normal rainfall continued during the beginning of 2011 and by the 9th January the historic monthly mean of 130 mm had generally been equalled. On 10th and 11th January, daily rainfall amounts equal to between 60% and 80% of the historic monthly mean were recorded and the subsequent surface run-off resulted in flash floods which seriously damaged parts of the Toowoomba Range Railway and settlements such as Murphys Creek downslope of the railway. Extreme flooding and damage also occurred elsewhere in south-east Queensland, including the town of Grantham, located approximately 20 km to the south-east.

3 GEOTECHNICAL ASSESSMENT

3.1 Field Survey

A detailed traverse of the 25 km length of railway between Murphys Creek and Harlaxton in the Upper Lockyer Valley was undertaken jointly by personnel from Golder Associates (Golder) and Queensland Rail (QR) between late January and early February 2011. One hundred and ten features were identified as having actual or potential impacts on safe operation of the railway. Failures included major washouts of embankments and culverts, destruction of Kings Bridge (Figure 2), damage to a gas pipeline near Rangeview station, failure of downslope fill batters (Figure 3) and instability of upslope cuttings including slip failures in weathered rock and colluvium (Figure 5).

Figure 2. View upstream of destroyed Kings Bridge.

Figure 3. Slope failure of carpark at Spring Bluff station.

Twenty sites were identified as major in scale and required geotechnical engineering input for the remedial design and re-construction phases. Initial estimates by Queensland Rail predicted a 3 to 6 month repair program for all remedial works.

3.2 Site Investigation

In general, a non-intrusive visual assessment of failure sites along the railway was undertaken. However, at the Kings Bridge site (chainage 135.5 km) and Rangeview station (chainage 155.75 km) subsurface investigations were required to determine the ground profile and assess material properties in order to facilitate the detailed remedial design.

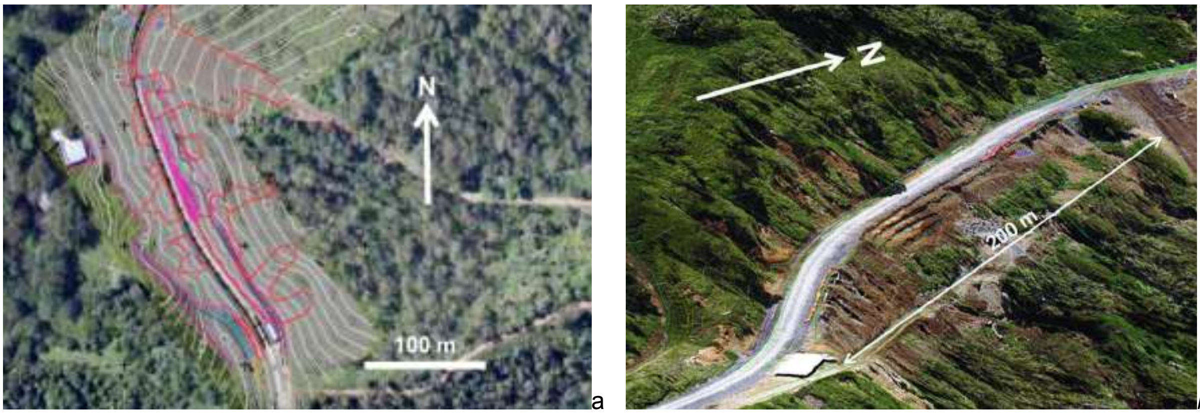
At the Kings Bridge site, borehole drilling was undertaken at proposed pile locations using an air-track drill rig capable of rapidly penetrating deep alluvium and colluvium comprising cobbles and boulders, and which provided information on the depth and nature of the underlying sandstone bedrock by means of measuring penetration rate and recovering drill cuttings. A rotary core drill rig would usually be employed for geotechnical investigations, but due to the limited availability of such equipment following the floods in Queensland and the limited time available for the investigation, an air-track rig was selected.

At Rangeview station, a series of trial pits was excavated on the steep embankment below the railway using a tracked excavator to confirm the depth and nature of the underlying residual soil and basalt bedrock. The weathered basalt was to form the foundation for a proposed retaining wall system comprising pre-cast reinforced concrete L-section panels. Additionally, it was necessary to acquire accurate topographic data for the Rangeview station area, and particularly the downslope embankment to analyse and detail the proposed rockfill slopes and retaining structures. Conventional surveying techniques were not considered appropriate due to time constraints. Subsequently, an aerial photographic survey was undertaken to collect data for the Rangeview site and the entire length of affected railway and this technique is described below.

4 AERIAL PHOTOGRAMMETRIC SURVEY

An aerial photogrammetric survey of the railway line was undertaken using the 3DM Analyst digital photogrammetry system to produce topographic data, a 3D survey of the railway line, buildings and roads, and ortho-photo mosaics of the railway line alignment. 3DM Analyst (by ADAM Technology) is a stand-alone, rapid data extraction software suite. It uses photogrammetric methods to produce high resolution 3D Digital Terrain Models (DTMs) from standard 2D digital photographs, which can be taken with off-the-shelf digital cameras. Typical images produced for the Rangeview Station site, showing topographic contours and the location of landslides, are shown in Figures 4a and 4b. A vertical accuracy of 0.15 m was achieved for topographic contours.

The aerial photography for the survey was undertaken by a specialist subcontractor engaged by Golder. It utilised a manned helicopter as the photography platform, and involved both high altitude



a b

Figures 4a and 4b.Ortho-rectified photographic mosaic from high and low altitude aerial photography, showing topographic contours and outlines of landslide locations (a), and oblique view of a rendered digital terrain model (b) at Rangeview Station.

photography for broad coverage of the alignment corridor and low altitude photography for detailed coverage of selected sites.

5 DESIGN AND REMEDIATION

5.1 A Valued Asset

During normal operation, an average of one 40 carriage train traverses the Toowoomba Range every hour, transporting approximately AU$1 million worth of coal amongst other goods, to the Port of Brisbane on a daily basis. This highlights the valuable nature of this railway corridor and the requirement to remediate damaged sections and resume operation as soon as possible. The nature of the general remediation undertaken is described below, together with a rapid foundation design solution for the Kings Bridge and Rangeview station sites.

5.2 General Remediation

Remedial works were typically completed employing a method specification rather than a strict adherence to standard designs. This was considered necessary in order to expedite the reconstruction works in the shortest time possible. The reconstruction works were completed by QR and its appointed contractor Thiess and critical aspects of the work were supervised by representatives of QR and Golder. Structural design for Kings Bridge reconstruction was provided by Parsons Brinckerhoff.

The majority of failed slopes, including cuts in natural soil and rock above the railway and fill embankments below the railway, were remediated by excavating and removing failed material, reprofiling (including benching) and replacing with a combination of compacted fill and rockfill (Figure 6). At numerous locations Corrugated Metal Pipes (CMPs) were utilised to restore or establish drainage under the railway. These methods proved to be a practical and relatively rapid method for remediating slopes and restoring stability to the railway line and associated vehicle service tracks.

5.3 Kings Bridge

A six week program of investigation, pile design and construction was implemented for replacement of the damaged bridge as described below (Figure 7).

The site investigation at Kings Bridge identified the presence of between 10 m and 13 m thickness of alluvium including boulders, overlying extremely weathered sandstone. The sandstone was typically underlain by mudstone at 20 m depth. Although a driven pile solution was initially considered as an economic solution, bored cast *in situ* piles were selected as the foundation option for Kings Bridge, as the equipment required was readily available and this technique would provide the necessary lateral resistance and reduce potential difficulties associated with penetrating coarse alluvium.

Figure 5. Typical upslope cutting failure.

Figure 6. Failed colluvial slope remediated using typical rockfill construction.

The ultimate axial pile capacity of a single vertical bored pile was calculated using the computer program AllPile (CivilTech, 2009). The pile design accounted for proposed Serviceability Limit State pile loads of between 2000 kN and 2700 kN. Several pile diameters were analysed - a 1200 mm diameter pile with 4 m penetration into the sandstone bedrock was adopted to reduce the socket length and limit loading on the mudstone underlying the sandstone.

The bridge reconstruction was completed in two stages to facilitate rapid restoration. The first stage involved construction of a 5 m thick temporary fill embankment using rockfill, cement stabilised sand and incorporating four 3.5 m diameter CMPs. This temporary structure formed a working platform for the piling activities and the piles were constructed over a one week period during continuous day and night shifts. A total of eight, 1200 mm diameter piles with a typical length of 21 m were constructed. The pile boring and construction was supervised by a geotechnical engineer from Golder and this provided a valuable opportunity to confirm ground conditions and validate the design.

Construction of pile caps and bridge abutments followed soon after, before an additional 1 m thickness of compacted fill was placed on top to complete the temporary embankment. Short term reinstatement of the railway line was then completed on top of the temporary embankment. This initial reinstatement was significant in allowing limited but crucial movements of construction materials to other sections of the railway.

The second and final stage of reconstruction occurred during a subsequent weekend railway line possession in which the temporary railway line was removed and permanent pre-cast concrete bridge deck units were installed. Finally, the permanent railway line was installed and the underlying temporary fill embankment and CMPs were removed (Figure 7).

5.4 Rangeview Station

The railway line at Rangeview Station was originally constructed on a cut slope which has been progressively built out by placement of side-tipped fill, comprising predominantly ash waste. Damage of varying degrees was sustained across a 200 m width of the downslope area and comprised undercutting of the railway line and washouts of the slope and adjacent vehicle track below. Slopes of up to 40° were observed for both the fill material and adjacent natural ground. A gas pipeline located at the northern end of the site sustained damage after backfill material was eroded by flood waters (Figures 4a and 4b).

Figure 7. View upstream of reconstructed Kings Bridge.

Figure 8. L-section concrete retaining wall panels on Rangeview station slope.

In order to remediate the slope and associated vehicle track in a timely fashion several options were considered including: pre-cast, reinforced concrete L-section retaining wall panels; gabion baskets; and concrete mass blocks. All of these options were technically feasible, however in considering the local availability of products, topographic constraints and constructability, the L-section panel option (L x W x H = 2.4 x 1.75 x 3m) was chosen for retaining the toe of reconstructed slopes. Conventional wall stability analyses were undertaken as part of the design and considered sliding, overturning, bearing capacity and loss of overall stability. The design geometry was based on topographic information collected during the aerial photogrammetric survey.

The critical aspect of construction involved removal of ash waste and other side-tipped fill from within a deep natural gully to expose *in situ* weathered basalt. To facilitate reconstruction the gully was then benched and backfilled with cement stabilised sand to provide a foundation for the pre-cast concrete L-section panels (Figure 8). Drainage beneath the foundation and behind the panels comprised 100 mm diameter agricultural drains backfilled with gravel and wrapped in geofabric. Slope reconstruction subsequently proceeded with placement of rockfill behind and above the panels.

Following repair of damaged sections of gas pipeline by the asset owner, rapid reconstruction of the railway line was facilitated by constructing a bridging structure on either side of the pipeline, comprising cement stabilised backfill placed in a benched slope excavation.

6 CONCLUSION

Remediation of flood damage on the Toowoomba Range Railway was completed using a method specification which allowed a rapid and efficient reconstruction program to be implemented. The process was characterised by a flexible approach that allowed progress to be made without compromising critical aspects of the safe running of the railway. It is considered a similar approach has merit for both construction and remediation of certain types of infrastructure and particularly for localities in difficult terrain or prone to natural disasters. The first train resumed service on the Toowoomba Range Railway on 28th March 2011, about two and a half months after the flood, which was well ahead of schedule.

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REFERENCES

Australian Government Bureau of Meteorology, Climate Data On-line, www.bom.gov.au [accessed November 2011].
Geological Survey of Queensland (1980).“Moreton Geology, 1:500,000 scale geological map“.