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LANDSLIDE RISK MANAGEMENT, EAST FRONT ROAD, MANNUM TO YOUNGHUSBAND, RIVER MURRAY, SOUTH AUSTRALIA

Dear Jai

Introduction

As requested by the South Australian Department of Water Land and Biodiversity Conservation (DWLBC) during a meeting (Sanders/O'Toole, 30 March 2010) this letter presents a discussion of options for managing the risk of landsliding along portions of East Front Road, between Mannum and Younghusband in the Lower Reaches of the River Murray in South Australia.

Sinclair Knight Merz (SKM) previously undertook studies of river bank collapses which were described in an *Inspection Report* dated 30 October 2009 and *Geotechnical Investigation Report* dated January 2010. The latter studies included intrusive investigations at two sites (EF1 and EF2) on East Front Road. SKM's 2009 assessment was that the site was '*Almost Certain*' to undergo continued movement and cracking and that the associated Social (Health and Safety) consequences were '*Catastrophic*' and Economic consequences were '*Moderate*'. Following the intrusive investigations the Factor of Safety against slope failure was calculated by SKM to be 1.3 at EF1 and 1.02 at EF2, suggesting significant risk of landsliding at each site (higher risk at EF2).

Golder Associates Pty Ltd (Golder Associates) undertook a peer review of the SKM reports. Review comments were provided to DWLBC in our report (Reference 107662007-002-L-Rev0, dated 10 February 2010). Golder Associates has subsequently provided advice to DWLBC on various matters associated with landslide risk in the Lower Reaches.

Site Observations

Lyndon Sanders, Principal Geotechnical Engineer, visited East Front Road on 9 March 2010 and 30 March 2010 with Jai O'Toole of DWLBC to observe conditions and to discuss various aspects of the site behaviour and landslide risk management with nearby property owners and representatives of the Mid-Murray Council, which has responsibility for the Road.

Sites EF1 and EF2 are close to the crest of the river bank in an area where granite outcrops are present to the east. SKM's investigations suggest that the road runs over fill – up to 6 m deep at EF 1 and 2.8 m deep at EF2. It is possible that prior to road construction the boundary of the river channel was formed by the granite.

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Observations at both EF1 and EF2 indicate ongoing movement of the pavement of East Front Road and some portions of the road shoulders. The River Murray is a few metres to the west. The pattern of movement includes cracking in arcs which generally face concave towards the River, and the development of steps and depressions in the road in the same general pattern as the cracking. There is a site between EF1 and EF2, which we have called EF1a for the purposes of this report, where a similar pattern of cracking and loss of pavement shape is evident.

Similar cracking and unevenness of the road pavement were also observed at the bend in the road around 150 m east of EF2, although the cracks and the unevenness of the road were larger and more prominent there than at the other sites. Again, the pattern of cracks and unevenness were arc-shaped, facing concave to the River which is closer there than at EF2. We will refer to this site as EF3.

There are a number of locations between EF3 and Younghusband where similar patterns of cracking and loss of shape in the road can be observed. Generally, the road at these locations is not directly on the crest of the River bank, but close to the crest of a shorter slope which falls towards the floodplains that fringe the River. It may be no coincidence that some of these locations are close to areas where rock cuts adjoin to the east of East Front Road, which might suggest that fill has been placed to support the western parts of the pavement. There is a least one location between EF3 and Younghusband where the River abuts the toe of the fill slope.

Landslide Risk

Landslide risk is generally assessed (AGS 2007)[1] as the matrix product of the probability of a landslide event occurring and the consequences of the event.

At present it is not possible to reliably quantify the probability of landsliding at any of the sites or the time period in which landsliding might occur. SKM reports a Factor of Safety of 1.02 at EF2, which would suggest incipient failure. The cracking and loss of shape there also suggests that failure has initiated and rupture might occur soon.

The cracking and loss of shape at EF3 suggests a higher probability of landslide there than at EF2. The cracking and loss of shape at EF1 and EF1a suggests a lower probability of landslide there than at EF2.

Generally we assess the probability of landsliding at the other sites to be lower than that at EF2, but there is insufficient data to allow these to be ranked relative to EF1 and EF1a.

The effects of landslide may conveniently be dealt with in groups. We consider that landsliding at EF1, EF1a, EF2, EF3 and any other site where the River abuts the embankment toe could potentially extend for the full width of the pavement of East Front Road. Based on reports of the 2009 landslides at Long Island, in similar geological conditions and embankment geometry, we expect that landsliding might occur quickly and that the ground within the landslide area might drop by up to several metres.

Where the embankment geometry is different – the banks not as high and the River much further away – we expect that size of the landslide would be smaller both in lateral extent and in the depth through which the ground might drop.

The consequences of landsliding are not the same as the effects. Consideration must be given to the population at risk and spacial and temporal effects. The more people passing through an area susceptible to landslide, the higher the risk that an individual will be affected by a landslide event. The bigger the area susceptible to landslide, the higher the risk that an individual will be in that area if it is affected by a landslide event. The more time that an individual spends in (or in this context, crossing) the landslide susceptible area, the higher the risk that they will be involved in a landslide.

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[1] '*Landslide Risk Assessment and Management*', Australian Geomechanics Society MDMP Landslide Taskforce, Australian Geomechanics, Vol 42 No 1, (March 2007)

It is also necessary to consider the vulnerability of the person at risk. Generally in landslide risk assessment it is considered that someone inside a building that is hit by a landslide will be less likely to be hurt or killed (less vulnerable) than someone who is directly by the landslide.

We have estimated the landslide risk to life using the methods described by AGS 2007. Based on discussions with Jon Fry of Mid-Murray Council we assumed 500 vehicles per day pass by EF1, EF2 and EF3 and 100 vehicles per day through the section of road near Younghusband.

Based on these estimates, we assess the risk to life at EF1 and similar sites is most likely to be between 1 in 50,000 and 1 in 100,000. We assess the risk to life on East Front Road near Younghusband to be between about 1 in 250,000 and 1 in 4 million. The risk of injury is assessed to be between about twice and five times higher than the risk to life.

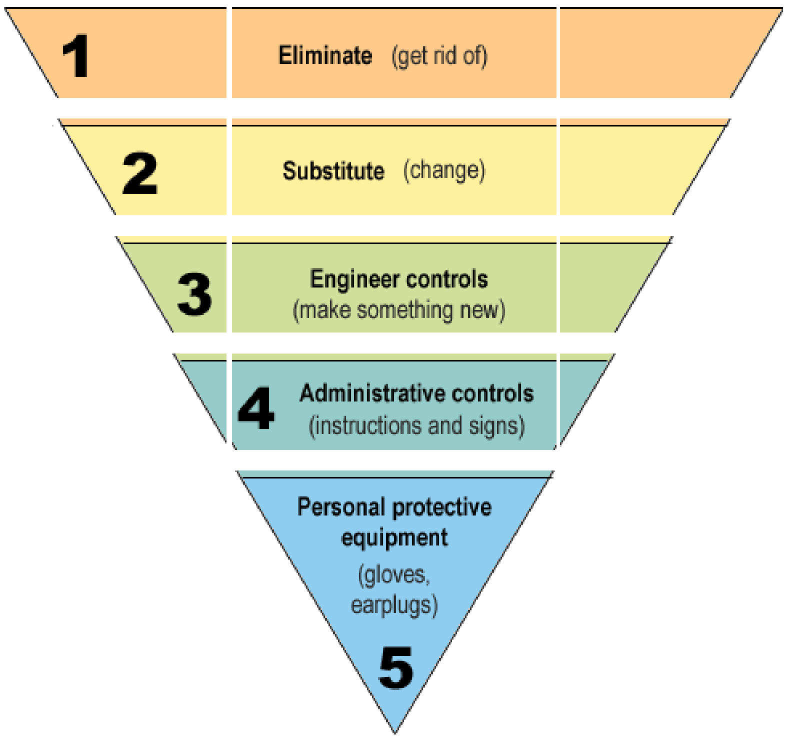
AGS (2007) defines '*Acceptable risk*' as '*risks which everyone affected is prepared to accept. Action to further reduce such risk is usually not required unless reasonably practicable measures are available at low cost in terms of money, time and effort*'.

It defines '*Tolerable risk*' as '*risks within a range that society can live with so as to secure certain benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible.*

AGS (2007) suggests that acceptable landslide risk to life may be taken to be around 1:100,000 for established areas. This suggests that, under feasible conditions, the risk associated with landsliding at the sites near Younghusband, where the slopes are shorter and the River channel further away, is likely to be acceptable. The risks near EF1, EF2 and ER3 might be tolerable although probably not acceptable, implying that the risks should be kept under review and should be reduced if possible.

Landslide Risk Management

The following diagram (taken from the Safework SA website) shows the hierarchy of control for managing practically any risk. The hierarchy indicates which control measures are conceptually more desirable than others.



Some preliminary options for managing the landslide risks along East Front Road are discussed below with reference to the hierarchy of control.

Elimination

It is practically impossible to eliminate the landslide risk at any of the sites as the risk is inherent in the geology and topography.

Substitution

Substitution of the risk would appear to be possible. This would involve changing the alignment of East Front Road to avoid passing through areas of unacceptable risk and closing the existing alignment. That could be done either over short sections or potentially over larger sections.

It may be impractical to close some sections of the existing alignment as these will continue to be required for local access. However, reducing the population exposed would reduce the risk. Therefore it may be possible to provide local access only. It would presumably be necessary to inform the remaining population of the risk and obtain its formal recognition of and consent to the risk it assumes.

Engineering Controls

Engineering controls may also be feasible. These would be aimed at reducing the probability of landsliding. This may be achieved through reshaping the land so that there is proportionately less weight near the head of the slide and more near the toe – either by excavation at the head or placing fill at the toe. Conceptually this is equivalent to make the slope less steep.

It may also be achieved through strengthening of the materials near the slide plane. That might be achieved through, for instance, placing piles (possibly sheet piles) to reinforce the ground. Piling is likely to be expensive and procurement of required machinery and piles of the necessary length is likely to be time-consuming.

Strengthening the soil might also be achieved by replacing some of the potential slide mass with stronger materials. Rock-filled trenches (buttresses) placed parallel to the slide direction are an example. These will not be easily constructed, excavation into a semi-active slide carries certain risks and the nearby presence of the River is likely to affect the stability and ease of excavation of the trenches. However, the machinery and materials required are generally more easily procured than piling machinery.

Stone columns represent an intermediate between these, as piling equipment is required, but the casing driven into the ground is removed during placing of the stone in the columns so the procurement is generally easier. Grouting of the ground might also be possible, but the quality assurance may be difficult.

Section 13 of SKM's 2010 report provides a list of many potential methods for strengthening landslides.

Administrative Controls

Administrative controls would be aimed at reducing the population at risk by restricting access to the site and have been partially covered in the discussion of substitution above.

Administrative control by road closure will eliminate the risk of death or injury to road users because there will be no population at risk. The decrease in risk is directly proportional to the extent to which the population at risk can be reduced.

At present there is an administrative control in place at EF1, EF2 and EF3 with speed restrictions. This may be effective in allowing drivers time to avoid becoming involved in a landslide, but they have little effect on the estimated risk as this depends on the time spent in the risk zone, which is proportionately longer at slower speeds.

Personal Protective Equipment

We doubt that personal protective equipment is a practicable solution to management of the landslide risk, although it would contribute via to use of seatbelts, airbags etc.

The foregoing is not an exhaustive compilation of all feasible management measures, but indicates the framework of an approach that might, under appropriate policy guidelines and protocols, allow continuing access to and use of the sites with presently unacceptable risk.

LIMITATIONS

Your attention is drawn to the document – “Limitations”, which is included in Appendix A of this report. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by Golder Associates, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

CLOSURE

Thank you for the opportunity to contribute to this project. The work has been interesting and presented some challenges. Should you have any queries regarding this letter, or if we can be of further assistance, please do not hesitate to contact this office.

GOLDER ASSOCIATES PTY LTD

Lyndon Sanders
Principal Geotechnical Engineer

LJS/THH/nrd;ljs

Attachments: Limitations (LEG04, RL1)

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