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EAST FRONT ROAD, MANNUM, SOUTH AUSTRALIA
OPTIONS FOR REDUCING THE PROBABILITY OF LANDSLIDING

Dear Jai

Introduction and Background Information

As requested by the South Australian Department of Water Land and Biodiversity Conservation (DWLBC) during a site 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, near Mannum in the Lower Reaches of the River Murray in South Australia.

Sinclair Knight Merz (SKM) undertook studies of river bank collapses in the Lower Reaches which were described in an *Inspection Report* dated 30 October 2009 and a *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 East Front Road 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 its intrusive investigation, SK calculated the Factor of Safety against slope failure 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.

East Front Road near EF1 and EF2 was closed in the interests of public safety on 9 April 2010. DWLBC has requested a discussion of options for reducing the risk of landsliding near EF1 and EF2 in order that relative costs of various options, including provision of alternative access routes to this area, can be assessed. Reduction of risk in this case implies reducing the probability of landsliding.

Options for Reducing the Probability of Landsliding

Golder does not have access to details of SKM's calculations and our comments are therefore based on the data and drawings presented in SKM's 2010 report.

The failure surface predicted by SKM at EF2 extends around 35 m from top of scarp to toe. The scarp of the predicted slide cuts into the road pavement. At EF1, the predicted landslide scarp is (only just) outside the road alignment. Between about 5 m and 10 m of the predicted failure surface at EF2 lies within the River channel at (SKM's assumed) water level of -0.8 m AHD, implying that it would extend further into the water at the current -0.5 m to -0.6 m AHD (Mannum Pump Station, SA Water website, 17 April 2010 to 23 April 2010) or higher water levels.

The water level is about 4 m below East Front Road level. The lowest points of the predicted slide plane are at around 10 m depth - well below water level.

Section 13 of SKM's 2010 report *Geotechnical Investigation Report* presents a variety of options for remedial works. We generally endorse SKM's comments on the various options. The following discussion has adopted the order used by SKM for consistency.

The comments presented below generally relate more to EF2 than EF1. The predicted landslide at EF2 is larger and has a lower predicted Factor of Safety than EF1, and would therefore have, we presume, a higher priority. The higher priority at EF2 does not imply that works at EF1 will be simpler or easier - the presence of relatively shallow rock at that location may make construction more difficult and therefore more expensive per metre width of landslide than equivalent works at EF2.

Removal of material from the top of the slope

Removing material from the top of the predicted landslide reduces the destabilising weight which drives the landslide downslope. The 'average' slope of the ground surface in the predicted landslide at EF2 is shallower than 20°. In those circumstances we question whether it would be feasible to achieve the required improvement in stability merely by removal of material from the upper part of the slide.

Removal of material from the top of the slope in the area of the predicted landslide must affect the vertical alignment of East Front Road. Golder does not have the professional expertise to comment on the acceptability of this. We observe that the horizontal alignment of this section of road is curved. The sight lines may be affected if the road surface is lowered.

It would also appear unlikely that the required stabilisation can be achieved without

- increasing the risk of flooding to this section of road;
- compromising the nearby residents' access;
- affecting the subgrade strength and therefore the serviceability of the road by bringing the subgrade closer to water level; and,
- requiring relocation of services along the road reserve.

Removal of Weak Materials

SKM indicates that removal of weak materials is likely to be impractical - it implies digging to not less than 10 m below ground level and 6 m below water level. The removed materials would require replacement with stronger materials at additional cost.

Modifications of the Slope (placing a toe berm)

Removal of material from the top of the slope could be combined with addition of material (a toe berm) to the toe of the slope. SKM suggests that this may be impractical where infrastructure is present on the slide surface. It may also be impractical because it would involve placing significant volumes of fill, a large proportion of which would have to be placed underwater, which could only be supplied to the area via the River or routes that would have to pass over the slide. We question whether management of the associated Occupation Health, Safety and Environmental (OH, S & E) risks can be achieved practically and economically.

Buttressing and Shear Keys

Buttresses are backfilled trenches orientated parallel to the predicted direction of sliding. These penetrate well below the predicted slide plane and are backfilled with stronger materials than those which have been removed. Shear keys are of similar construction placed perpendicular to the slide direction.

The buttress/key is designed to transfer the destabilising slide loads to materials below the slide plane. This is likely to be more applicable at EF1, where there is rock strength material only a few metres below the predicted slide, than at EF2 where there is no distinct increase in the strength of materials within the depths investigated by SKM.

Placing of buttresses or shear keys would involve working progressively into the slide area, which may allow OH, S & E risks to be managed practically and economically. However the difficulties associated with excavation of over 10 m of soil –possibly significantly deeper - with most of it underwater will mean that the work will be costly.

We expect that it will be quicker and simpler to backfill with concrete, or cement-stabilised quarry product, than with ordinary granular materials because of the presence of significant depths of water in the excavations. Material supply would however, be more costly. The cementitious material would have to be tremmied or pumped into place to avoid segregation during placing (similar, although potentially less critical considerations apply to non-cemented materials). It is likely that the quality of the water displaced during placing of new material will require monitoring and management prior to discharge (to the River or elsewhere).

Managing excavation stability is likely to be difficult and costly. We expect that dewatering is likely to be impractical due to the presence of the River over at least 60% of the slide depth and the expected EPA requirements for managing the discharge waters.

Drainage

SKM indicates that it considers that drainage, either surface or subsurface, is unlikely to be effective.

Golder Associates considers that drainage (which would be required to be permanently effective) is exceptionally unlikely to be effective where the River is present over at least 60% of the slide depth. We also pr presume that there would be the difficulties associated with EPA requirements for managing the discharge waters.

Reinforcement or Retaining Walls

Reinforcement of the slide area or retaining walls are similar to buttresses and shear keys in that they transfer the destabilising slide loads to underlying materials. The difference is that the transfer occurs over smaller areas, either distributed across the slide plane (soil nails, stone columns, soil mixing, driven piles) or along specific alignments (sheet piles, retaining walls – possibly soil mixing).

Because the load transfer occurs over smaller areas, we would generally expect the reinforcing members to be required to penetrate deeper into the ground. Investigations to date have not proceeded deep enough to allow reliable estimation of the design length for these members. On the basis of those investigations it is

possible that pile/nail/stone column lengths would exceed 25 m and they may be required to penetrate much deeper, depending on the conditions at depths which have not yet been investigated.

Any such works will require construction over both land and water, although we expect that these will be mostly over water as the larger shear stresses along the slide plane are generally closer to the toe than the scarp.

Progressive construction into the slide zone might allow the associated OH, S & E risks to be managed acceptably.

Soil mixing has not been used in South Australia, to our knowledge. It would require specialist equipment, which we expect would need to be imported and which may not be suitable for other works in South Australia. We expect that there would be a significant requirement for Quality Assurance testing and documentation during and following construction to demonstrate that strength and serviceability requirements were met.

Electro Osmosis

Electro osmosis has not been used in South Australia, to our knowledge. It would require specialist equipment, which we expect would need to be imported and which may not be suitable for other works in South Australia. We expect that there would be a significant requirement for Quality Assurance testing and documentation during and following construction to demonstrate that strength and serviceability requirements were met.

We are not sure whether the efficiency of electro osmosis would be affected by the nearby River.

Grouting

Grouting has been used in South Australia. It requires specialist equipment, but this may be available from Downer EDI Works (John Adamson is our contact within that organisation). We expect that there would be a significant requirement for additional investigations to demonstrate the viability of the system. We also expect a significant requirement for Quality Assurance testing and documentation during and following construction to demonstrate that strength and serviceability requirements are met.

We presume that there would be some OH, S & E difficulties associated with the requirement to work close to, or probably over, the River waters.

Summary

In summary, Golder Associates considers that buttressing/shear keys or soil nailing/stone columns/sheet piles/driven piles are likely to be the most viable options to reduce the probability of landsliding on East Front Road near sections EF1 and EF 2.

We expect that there will be significant difficulties associated with the River side (or over water) construction. We anticipate a significant commitment to risk management to allow construction to proceed within acceptable OH, S & E considerations.

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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

Attachments: Limitations (LEG04, RL1)

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