19 February 2010 Reference No. 107662012-002-L-Rev0

Mr Peter Slee
Department of Environment and Heritage
GPO Box 1047
ADELAIDE SA 5000

ASSESSMENT OF LANDSLIDE RISK
NGAUT NGAUT CONSERVATION PARK , SOUTH AUSTRALIA

Dear Peter

INTRODUCTION

Golder Associates Pty Ltd (Golder Associates) has undertaken an assessment of landslide risk at Nguat Nguat Conservation Park, just south of Nildottie on the River Murray in South Australia. Our services were provided in general accordance with our proposal (P07662012) to the Department of Environment and Heritage (DEH) dated 2 February 2010. We were commissioned to proceed by Mr Peter Slee of DEH via email on 2 February 2010.

We understand that DEH has been provided with a copy of an October 2009 Inspection Report prepared by Sinclair Knight Merz (SKM) on behalf of the Department of Water, Land and Biodiversity Conservation. The report indicates that SKM considers the presence of cracking at the base of the cliff at Nguat Nguat Conservation Park to be an indication of potential landsliding. SKM reports that this might pose '*Catastrophic*' risk to users of the park. On that basis the report classified the situation as '*Critical*'. DEH sought advice from Golder Associates to clarify the landslide risk at Ngaut Ngaut and to recommend risk management measures.

FIELD ACTIVITIES

Field work was undertaken on 5 February 2010. Lyndon Sanders, Principal Geotechnical Engineer, attended site with Mr Barry Furniss of DEH and Cynthia Hutchison, a representative of the traditional owners of the park.

Photographs and notes taken during field work are retained on our project file.

SITE DESCRIPTION

Nguat Nguat Conservation Park is on the left bank of a left hand bend in the River Murray. In this area the river flows approximately east-west. At the eastern end of the Conservation Park the River is bounded by limestone cliffs. The *Renmark* geological map sheet[1] indicates that these comprise Morgan Limestone or Mannum Formation materials and that they are overlain by deposits of the North West Bend Formation.

[1] Scale 1:250,000, Firman, JB, (971)

Towards its western end, the Conservation Park includes alluvial flats. The geological map sheet indicates that these are of the Coonambidgal Formation, comprising "*fluviatile clays, silts and sands. Light grey alluvium of the River Murray System.*"

SITE OBSERVATIONS

At the eastern end of the Park there is a boardwalk which has been placed to facilitate access to places of historical interest including an Aboriginal camp site under a cliff overhang which archaeological evidence suggests is at least 6,000 years old. We understand that the boardwalk also protects the ground against erosion by visitors.

At the eastern end of the boardwalk the ground includes limestone cliffs, the lower part of which are vertical to overhanging. There is what we judge to be a scree slope between the base of the cliff and the River. The boardwalk is founded on the scree slope. We measured the slope angle of the scree slope generally to be around 30° but the slope is highly irregular and the measurement is considered indicative only.

The surface of the slope is littered with rock fragments and boulders up to about 1.5 m in nominal size (maybe 10-tonne). A proportion of the rock fragments and boulder appear to be recently detached from the cliffs, although the presence of mature river red gum trees on the scree slope suggests that the slope has generally been stable over at least several decades.

We observed a crack between the head of the scree slope and the face of the cliff. We understand that this is the crack that was observed by SKM in September 2009. During our site visit it was visible for several tens of metres centred approximately on the archaeological dig area under the cliff overhang. Cynthia Hutchison informs us that previously it had been visible for a greater distance towards the west but this is apparently obscured at present. We observed crack widths up to about 50 mm but the width of the cracks may have been affected by animals digging along the crack.

To the west, the ground opens up from the base of the cliff/scree into alluvial flats stretching to the River. The flats are several hundreds metres wide at their widest. While generally flat, they include what we judge to be natural levees up to about 1.5 m high running parallel to the river. On the river frontage there is a mooring area for riverboats which lies to the east of a separate landing area for canoes which are regularly used by school visitors to the Park.

We observed cracking of ground near the crest of the river bank behind the canoe landing area. The crack was up to about 50 mm wide and was at least 50 m long. It was not possible to confirm the full extent of the crack as towards the ends it was generally obscured by vegetation. It appeared to be generally straight without, as sometimes occurs, turning towards the river at its ends. There was another smaller parallel crack up to about 10 mm wide near the middle of the larger crack and around a metre away. We understand from discussions with Cynthia Hutchison that this cracking has become apparent since the last canoe visit of the 2009 school year in mid-to-late November 2009.

We also observed the river boat mooring area. There were no apparent signs of cracking in the river banks at this location. We understand that as the river level drops the river boats are having greater difficultly obtaining access to the Park as they have to moor further from the banks then previously and this has necessitated the use of extensions to the gang planks.

DISCUSSION AND RECOMMENDATIONS

There are three main areas of concern with respect to landslide risk. These are rock fall in the cliffs, land sliding of the scree slope and land sliding of the canoe landing area.

Cliff Rock Fall

Rock fall is a practically universal feature of the cliffs of the lower reaches of the River Murray. Firman[2] suggested that the course of the Murray is affected by structure in the underlying bedrock. Often defects in the rock run near-vertical and parallel or sub-parallel to the River with rock fall being associated with the cliff face parting on these defects, the base of the cliff having been undermined by River erosion. We did not observe defects in the overhang above the aboriginal camp, which may explain why there has apparently been overall stability at that part of the site for many thousands of years. However, defects with orientation parallel or sub-parallel to the cliff face were observed in other areas, and the generally blocky shape of the detached fragments suggests that the rockfall mechanism at this site is likely to be similar to that described above.

We have estimated the risk to life associated with the rockfall using the methods described in AGS (2007a)[3] and compared these to the guidelines set out in AGS (2007b)[4]. We varied input parameters to the risk estimates to allow assessment of the potential range of risk, having regard to the paucity of the available data. We assumed annual probabilities of rock fall between 0.02 (one in 50 years) and 0.2 (one every couple of months), visitor numbers between 20 and 200 daily and that the visitors would spend between 30 and 90 minutes in the potential rockfall zone. We assumed that anyone hit by rockfall would die.

On that basis, we estimate the risk to life associated with the rockfall to be between about 1:2,400 and 1:720,000. AGS (2007b) suggests that acceptable risk may be taken to be around 1:100,000 for established areas, but that tolerable risk in '*established areas where specific landslide hazards have existed for many years'* may be up to around 1:10,000. That suggests that, under feasible conditions, the risk associated with rockfall at the Ngaut Ngaut site might be tolerable.

The inference from the evidence of extended occupation of the site is that the risk of rock fall in this area has been tolerated by the site owners during that time. However, that should not be taken to imply that the risk is tolerable in the present situation. The decision to accept or tolerate the landslide risk rests with the owners and operators of the site having regard to the acceptability or tolerance criteria that might apply to visitors to the site.

If the site is to be used, we suggest that it might be prudent to erect signs warning people approaching or on the site of the risk of rock fall.

Scree Slope

The development of the crack at the head of the scree slope may be an indication of landsliding occurring - certainly the possibility could not be ruled out on the present evidence. However, it is also possible that this is the result of settlement of the scree slope as the water level in the River has dropped over the past few years.

Based on recent reports of land sliding in the banks of the River Murray since the water level dropped, it is reasonable to expect that the onset of landsliding could be sudden. The consequence is potentially life-threatening for any person on the boardwalk or elsewhere towards the base of the cliffs at the time.

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[2] Firman JB *Structural lineaments in the Murray Basin of South Australia* Quarterly Geological Notes No 35, Geological Society of South Australia (1970)

[3]Australian Geomechanics Society Practice note guidelines for landslide risk management Australian Geomechanics Vol 42 No 1, March 2007.

4Australian Geomechanics Society Australian GeoGuides for slope management and maintenance Australian Geomechanics Vol 42 No 1, March 2007.

We have estimated the risk to life associated with landsliding of the scree slope using the methods previously described and compared these to the AGS guidelines. We varied the input parameters to allow assessment of the potential range of risk. We assumed annual probabilities of landsliding between 0.1 (one in 10 years) and 0.5 (one every two years), 30 to 50 visitors on the boardwalk at the time of landsliding and that the landslide would pose a threat for a 15 to 20 minute period. We assumed that the risk of death was 0.02 (about 1 person in 50 in this situation would die).

On that basis, we estimate the risk to life associated with the potential for scree slope landslide to be between about 1:15,000 and 1:100,000. This suggests that, under feasible conditions, the risk associated with scree slope landslide at the Ngaut Ngaut site might be tolerable although we would generally expect that it would not be.

However, this analysis relies critically on the assumption that landsliding will occur at some time or another. We do not have sufficient data on which to reliably base an assessment of the probability of landsliding. On that basis we must recommend that the boardwalk should be closed until it can be demonstrated that the scree slope on which it is founded is acceptably stable against landslide. The underlying assumption is that the situation with respect to rockfall would permit access to the boardwalk.

We recommend monitoring of any movement of the boardwalk relative to the cliff to allow assessment of the potential for landsliding of the scree slope. We recommend that this should be undertaken at 10 m or closer intervals along the boardwalk. It would be most convenient to do this from marked points on the cliff, measuring from these to nails or other semi-permanent references on the boardwalk itself. We recommend that the distance between these points should be measured twice weekly or more frequent intervals. The measurements should be compared with previous measurements in order to identify trends. If measurements indicate no movement over an acceptably long period we consider that it might be feasible to reopen the boardwalk.

Based on previous experience with similar monitoring we expect considerable “noise” in the measurements and that it will take some considerable time to demonstrate ‘stability’, if indeed it is possible to demonstrate stability. Popper’s position was that *no number of positive outcomes at the level of experimental testing can confirm a scientific theory, but a single counterexample is logically decisive: it shows the theory, from which the implication is derived, to be false* (Wikipedia article on Karl Popper), meaning that an absence of apparent movement does not demonstrate stability, merely a (potentially temporary) absence of instability. If the measurements indicate accelerating movement then we recommend that no personnel should access the boardwalk, even for measurement.

Canoe Landing

There are clear indications of the onset of land sliding near the canoe location and of ongoing movement in this vicinity. The area potentially subject to landsliding is relatively large – tens of metres along the river and around 20 m perpendicular to it. As indicated earlier we expect that if landsliding were to occur its onset would be sudden.

We have estimated the risk to life associated with landsliding of the canoe area using the methods previously described and compared these to the AGS guidelines. We varied the input parameters to allow assessment of the potential range of risk. We assumed an annual probability of landsliding of 1 (one landslide in the next year), 30 visitors on the landing area at the time of landsliding and that these people would be in that area for between 20 and 60 minutes period. We assumed that the risk of death was 0.02 (about 1 person in 50 in this situation would die).

On that basis, we estimate the risk to life associated with the canoe landing area to be between about 1:1,000 and 1:10,000. This suggests that the risk to life in the canoe area is not acceptable.

We recommend closure of the canoe landing area. We doubt that it is possible to demonstrate sufficient stability to allow it to be reopened. However, it may be possible to predict the point at which rupture would occur (land sliding will commence) if monitoring data indicates accelerating movements. Saito’s method has been used in other situations to predicting the extent of movement at which rupture will start.

If it is desirable to predict the point of rupture, we recommend that monitoring should be undertaken by measurements between pegs set to straddle the cracks. That would imply the use of pegs approximately 1.5 m apart and disposed so that the measurement is approximately perpendicular to the crack. We recommend measuring between nails set into the head of the pegs as this will improve the accuracy of measurement. The spacing of measuring points should be set not less than 10 m apart along the entire width of the crack.

We recommend that the present canoe landing area should be fenced off and that only personnel involved in measuring should be permitted to access the area. If the measurements indicate ongoing acceleration of the movement it would be prudent to measure only after a risk assessment based on the latest available evidence, including observations of the site before entering the fenced area. We recommend that the fence should be set out not less than 10 m further from the river than the existing cracks.

If the river level were to rise to the point at which the crack became inundated, we expect that failure would occur soon after.

There are nearby areas of bank which do not show signs of incipient landsliding. We suggest that it may be possible to relocate the canoe landing area to such an area.

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ACKNOWLEDGEMENTS

Golder Associates would like to acknowledge the assistance provided by Cynthia Hutchison, the representative of the traditional owners of the land and Barry Furniss of DEH. Our work was made much easier by their contributions. Our time on site was extremely pleasant and for that reason, we thank them sincerely.

CLOSURE

Thank you for the opportunity to contribute to this project. Please call Lyndon Sanders on 8213 2100 or 0414 575 071f you have any questions.

GOLDER ASSOCIATES PTY LTD

Lyndon Sanders
Principal Geotechnical Engineer

LJS/PJB/cf:nd

Attachments Limitations (LEG04, RL1)

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