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Monitoring an Active Landslide at Howletts Road, Yallourn North

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SUMMARY A method is described for monitoring the velocity of an active landslide at Yallourn North, Victoria which gives advanced warning of imminent catastrophic failure under high rainfall conditions. The system has been a cost efficient method compared to the alternative expensive remedial works.

1 INTRODUCTION

Howletts Road landslide is located on the north-western side of the Latrobe Valley, Victoria and has been active since late 1984 when it resulted in the closure of Howletts Road. Since then, it has moved some 30 metres with velocities ranging from 150mm per day to near stationary depending on rainfall conditions.

When first monitored the mass of the landslide was approximately 150 metres long, 75 metres wide, 9 metres deep and contained 85,000 m^3 of material. The landslide represented a threat to the public safety of the users of a major road (Latrobe River Rd) situated approximately 50 metres downslope of the toe. Expensive methods of controlling the landslide were considered, however, it was decided to let nature take its course and to carry out monitoring of the slope using an alarm system to warn of catastrophic failure. This system represented about 10% of the cheapest estimated remedial work capital.

When the landslide stabilizes, estimated to be in about 5 years, Howletts Road could be reopened by carrying out minor earthworks.

2 GEOLOGY AND SITE CONDITIONS

The geology of the area consists of Mesozoic aged interbedded siltstones and sandstones of varying degrees of weathering overlain by a thin veneer of Tertiary sands and clays. In many cases the dips of the sedimentary rock is similar to the slope angle and contributes to instability. Two major faults are inferred from regional geological mapping to intersect close to the landslide site.

The area in which the landslide has occurred is hilly and has been dissected by steep gullies that drain into the Latrobe River. The slopes in the area are often characterised by fossil landslides and contemporaneous landslides that have generally occurred in these Mesozoic aged sediments. These slides often have occurred on weak clay seams parallel to the bedding of the rock. Many dormant landslides in the area have been reactivated by undercutting of toes of slopes by roadworks and stream erosion combined with heavy rainfall. Raisbeck (1987)

The landslide has a slope angle of approximately 10° and is located on a historically unstable area. Air photographs show scars of old shallow landslides at the site that were in the order of a few metres deep. Adjacent to the left crown is a small recent shallow earthflow which has disturbed an area approximately 25 metres wide by 40 metres long.

The landslide was first noticed in December 1984, but may have occurred in October 1984 after heavy rainfall and a swarm of micro seismic events. At the time of failure of the slide, the site was covered by pasture, a few trees and a farm dam that was excavated in 1982. The dam was constructed in a small gully with a large catchment area above the site. In 1982, the landscape was altered by a bushfire that resulted in the loss of vegetation and several large trees in the vicinity of the present toe of the landslide.

The major feature of landslide was the large scarp at the head and along the right flank of the slide. Initially the height of these scarps were up 2.5 metres, but after 6 months of movement the scarps ranged up to six metres. The slide exhibits two distinctive grabens, which are generally associated with translational slides. They are located parallel to the scarps at the rear of the main slide mass and at the lower half of the right flank. They are approximately 10 and 15 metres wide respectively and had an initial differential vertical displacement of approximately 1 metre. These displacements increased markedly during the first year of observation. The left flank of the slide was marked by a lobate overthrust, approximately 50 m wide. The toe of the landslide was defined by the face of a 10 metre road cut and the side of a small adjacent gully.

Intensity of tension cracking was greater in the top half of the slide. They were generally transverse cracks parallel to contour and ranged in width up to 350mm. A major set of tension cracks 200mm to 350mm wide, parallel to contour extended across the site at dam level. However, the cracks did not exist in the dam excavation lower than 1.5 metres below natural surface where the material is highly plastic. Trenches which were excavated across tension cracks showed a similar pattern and the cracks dipped at approximately 60° downslope. Several cracks occurred perpendicular to contours near the toe of the landslide, as well as those parallel to the contours, indicating an upward thrusting of the slide mass at the toe.

At the crest of the road batter, both traverse and radial cracks up to 600mm wide have occurred as a result of toppling and earthflow effects at the toe of the slide.

A section through the site is shown in Figure 1 and shows the slide is essentially translational (Varnes, 1958) with characteristic grabens at the head of the landslide. The basal slip surface has occurred at a soil/rock interface on a weak seam of clay derived from weathering of the rock. The rock underlying the slide consists of moderately weathered and fractured siltstone and sandstone. The dip of this material varies up to 30° in the area, but it is assumed that the dip of the rock at the landslide is the same as that of the slope.

The material above the slip surface generally consists of silty clay (CH) and sandy clay (CH) extremely weathered sandstone and siltstone, and old slide debris higher up in the profile. The soft weak clay in the slide zone had a high moisture content (49%) and high plasticity (Plasticity Index up to 69%). Direct shear testing of this material gave residual angle of frictions between 10° and 13° with cohesions of zero. Back analyses without groundwater present gave a residual angle of friction of 10°, and with groundwater a residual angle of friction of 13°. Moisture contents in the overlying material are generally much lower (20% to 30%). No groundwater was encountered in the bores on site during drilling or since pneumatic piezometers were installed. The slide surface was well defined by sub-horizontal displacements of up to 50mm observed in bores after the overnight break in drilling operations.

3 SURVEY MONITORING

Initially 11 tape extensometer pins were installed to obtain immediate rates of movement of the landslide on a daily basis. These pins were installed across the main scarp, the right flank scarp and graben, the toe, and several major cracks in slide mass. Results from these pins indicated that the slide movement was at least 60mm per day.

To obtain more accurate information on velocity and direction of various sections of the slide mass, 25 survey pins were installed in key positions on and around the site. The most important pins were located along the main axis of the landslide in a line similar to that of the section in Figure 1. These pins were surveyed on a fortnightly basis. Results of the survey showed that the velocity of the pins increased down the slope from 60mm per day (near main scarp), to 105mm per day (near toe) during January 1985. This shows that the landslide is not driven by groundwater pressures in the main scarp but by ingress of water into the whole slide mass.

The results of plotting horizontal vectors of movement showed that the direction of movement changes down the slope to a more easterly direction. Individual pin direction has remained almost constant but the total change in direction to the east from the head of landslide to its toe is about 30°. This has led to the development of a wedge shaped graben on the right flank which has moved independently of the main slide mass.

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METHODS OF STABILISATION CONSIDERED

Works carried out after the landslide occurred consisted of installing contour drains above the landslide, the infilling of the farm dam, and the covering of tension cracks. These works were aimed at preventing the ingress of water into the slide mass.

In addition to this work, the following options have been considered.

Regular Removal Of Toe Material

This relied on the continued movement of the landslide without catastrophic failure, followed by regular removal and battering of the toe. This would enable Howletts Road to be kept open. It is estimated that the volume of the landslide is 85,000m^3 and approximately half of this material would have to be removed before stable conditions are reached. This condition could have taken up to four years based on the early rate of movement. There is also a risk that in allowing the slide mass to move 70 metres before stable conditions are reached, break-up of the slide mass, loss of strength and mud-flow characteristic may occur. During the period of

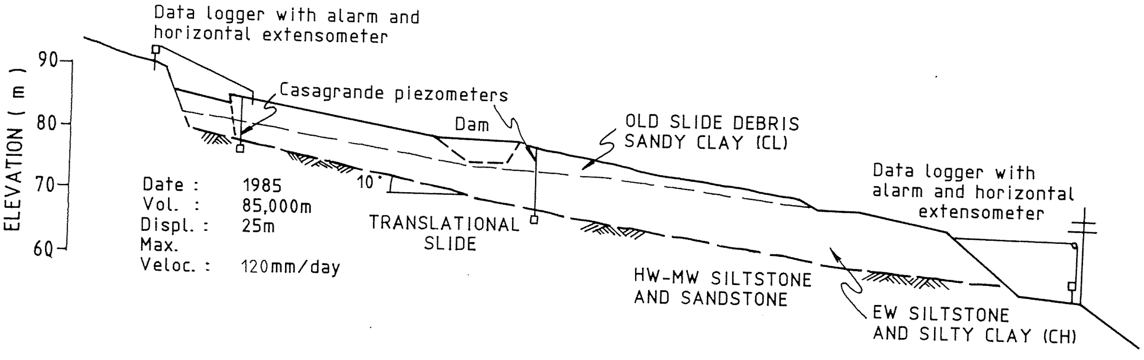

Figure 1 Cross Section of Howletts Road Landslide

slide movement there would be a greater risk to public safety from catastrophic failure because of the lack of reaction time. This method of stabilisation would be expensive but these costs would be incurred over a long period of time.

Removal of Landslide Mass

Stabilisation of the landslide is needed to reopen Howletts Road. To do this it is expected that a long-term Factor of Safety of 1.50 would have to be achieved. This would have required the removal and disposal of approximately 45,000m^3 of material, proper drainage and the vegetation of the remaining slide mass to ensure long-term stability. This was an expensive option and is estimated it would have cost between $150,000 and $200,000 depending on the availability of a disposal area for the discarded material.

Piled Retaining Wall

This option would have involved the construction of a 1 metre diameter bored pile at the toe of the landslide anchored back into the underlying rock. It was estimated it would have cost up to $200,000 if feasible to construct. The construction feasibility of this option was questionable because the velocity of the slide may have been too fast to allow work at the toe to be carried out safely.

Embankment and Monitoring

This option was adopted and allowed for the protection of Latrobe River Road (50m down slope of the landslide toe) and involved the construction of a 3m high embankment, adjacent to Latrobe River Road. Because of the poor foundation condition at this site an embankment of only 3 metres high could be constructed. However, the embankment is capable of containing approximately 65% of the slide volume anticipated under worst catastrophic failure. Stable conditions are expected to be reached within 5 years after which Howletts Road would be reopened. This embankment, together with an alarm monitoring system, was considered adequate for public safety at a relatively low initial cost of approximately $20,000. It also included minor earthworks and drainage improvement.

5 MONITORING SYSTEMS

Because of the relatively high velocity of the landslide there were problems in placing instruments through the slide zone.

A total station laser scanning EDM connected to a motorized rotary table was considered. It would be set up in a protective housing on the ridge east of the slide and would scan all the pins on the slope at regular intervals. Each pin would have a reflector mounted on it. Separate data logging and alarm systems would be connected to this system. This system however was not available off the shelf and a prototype would have cost $100,000 and would take 6-12 months to complete.

It was decided to use two of the horizontal extensometers to provide an alarm system for toe and crest movements (Figure 1). A shaft encoder was placed on the pulley of the Stevens recorder and this connected to a Jabiru data logger programmed to measure at every 30 minutes and recorded at 3 hourly intervals. A specified velocity change was used to trigger the alarm at the SEC fire station at Yallourn via a land line. Results of approximately 1 months recording is stored in the data logger and removed by a portable field computer and transferred to a PC in the office for plotting.

Although this system has provided an excellent method of recording data, there has also been some problems. There were many instances of false alarms caused by vandals, animals and electrical faults. Each false alarm required inspection of the site.

6 MONITORING RESULTS

Logging at 3 hourly intervals allowed correlation of movement and rainfall to be examined on both a micro and macro scale. Figure 2 shows a plot of 6 hourly rainfall intensities versus movement. This plot shows that landslide velocity has increased from 45mm per day to 120mm per day after 18mm of rainfall in a 12 hour period and from 50mm per day to 120mm per day after 20mm of rainfall in a 12 hour period. These plots show that response time of landslide movement to heavy rainfall is less than 12 hours.

In assessing the potential for catastrophic failure of the landslide (i.e. rapid movement of slide across Latrobe River Road) rainfall is a major consideration. Based on the frequency of previous landslide movement in the Yallourn area, it is assumed that a 1 in 5 year storm of 75mm in 24 hours would cause catastrophic failure. However, storms of 3 days duration with a total precipitation of 75mm may also initiate sufficient movement to cause a catastrophic event. Rainfall statistics for the area show that 2 storms of 1 in 5 year intensity occurred in 1984, reducing the likelihood of similar events in the following 5 years.

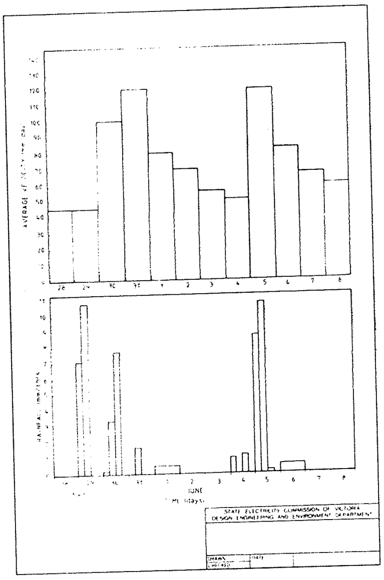

Figure 2 Effect of Rainfall on Landslide Movement

Figure 3 Plot of average movement versus time

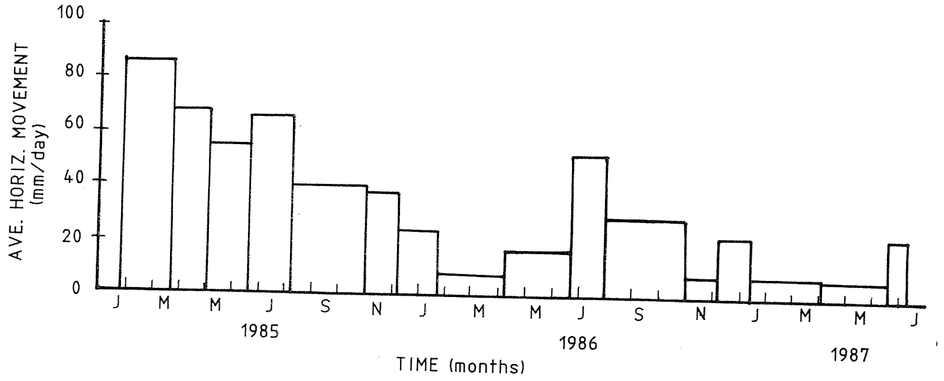

Figure 3 Plot of average movement versus time

Based on the above it was considered that the alarm should trigger at a landslide velocity of 300mm per day. Since the system has been in use the maximum rainfall intensity has been 36mm in a 24 hour duration followed by a rainfall intensity of 39mm in a 24 hour duration 4 days later in December 1986. This produced a landslide velocity of 60mm per day from a relatively slow summer base velocity.

This indicates that the landslide in December 1986 required heavier rainfall intensities to reach similar velocities to those of May 1985. Figure 3 is a plot of average velocity versus time and indicates that the landslide has gradually slowed down and is near to reaching equilibrium. This can be shown by comparing average winter velocities in winter 1985 of 66mm per day with average winter velocities of 25mm per day in 1987.

7 CONCLUSIONS

Although catastrophic failure has not taken place over the life of the system so far, the performance of the surveillance system has provided a cost effective alternative to major remedial works. The system will give adequate warning of catastrophic failure during periods of high rainfall.

8 ACKNOWLEDGEMENT

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9 REFERENCES

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