UR1976_64

Investigation of a large landslip near Bradys Lookout, West Tamar.

C.J. Knights

Abstract

This landslip, which is a reactivation of part of a larger older slip, has an active surface area of 180 000 m^2 and is nearly 13 m deep. The slip is in Tertiary sediments, consisting mainly of stiff clay with occasional mineral bands, which are overlain by deeply weathered talus derived from Tertiary dolerite.

The Tertiary clays are less plastic than those normally found in the Tamar area. Back analysis of the landslip indicates residual cohesion (c_r') = 0 and residual friction angle (ϕ_r') = 13°. Peak strengths from triaxial tests were c_p' = 16 kPa and ϕ_p' = 18°. Pore pressure in the aquifer at the base of the slip is 9.5 m, and reaches its peak 10 weeks after maximum rainfall. Vibrations generated by traffic are of high amplitude and attenuate slowly, with dominant frequencies of 14-17 Hz.

1976/64. Investigation of a large landslip near Bradys Lookout, West Tamar.

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During the winter of 1975, a large landslip south of Bradys Lookout [DQ993242] was reactivated, affecting 270 m of the West Tamar Highway. The active area of approximately 180 000 m^2, is part of a dormant older structure. Historic movement of the slip is reported to have destroyed a house.

This report includes the results of diamond and auger drilling, monitoring of piezometric pressures, soil testing and vibration measurements.

TOPOGRAPHY

Three superimposed generations of landslips have been recognised at this locality. The present activity is shown by hummocky ground, and is outlined by surface cracks. It is partially enclosed by a steep scarp, 20 m high which marks the heel of an older dormant slip. The relationship of these features is shown on Figure 1. Immediately south of the present activity a raised hummocky area, covered by boulders, indicates the toe of a large ancient landslip.

GEOLOGY

The hill is underlain by Tertiary sediments considered to be lacustrine in origin. These sediments consist mainly of overconsolidated stiff plastic silty clays with sand and ironstone horizons. Above the steep heel scar is a thin layer of Tertiary fine-grained, basanitic dolerite, which thickens northwards and crops out as cliffs at Bradys Lookout. Deeply weathered talus overlies the Tertiary sediments on the slopes.

DRILLING RESULTS

Diamond and auger holes were drilled in three positions at the side of the road. Hole 2 (diamond) and Hole 4 (auger) were drilled 40 m apart (fig. 1) and gave a similar stratigraphic succession (table 1).

These results show that 5-8 m of wet disturbed material overlie 4-7 m of stiff silty clay beneath the highway. A hard calcareous band occurs at about 11.5 m below the surface, under which is water with a piezometric head of 9.5 m. Stiff clay occurs below 13 m.

These results indicate that the base of the original slip is at the aquifer between 11.8 m and 12.8 m. Monitoring of the recent slip has shown that it is active below 8 m.

GEOTECHNICAL PROPERTIES

Geotechnical properties of the landslip material obtained by the Public Works Department are summarised in Table 2. Atterberg limits were also obtained from samples taken from two shallow holes in weathered talus (table 3).

Plasticity indices and liquid limits of the clay tested in Holes 2a and 3 are lower than those normally found in Tamar sediments. Plasticity indices of the samples from the weathered talus are in the normal range (fig. 2).

STABILITY ANALYSES

Below 11.8 m, the clay is soft and wet, having a high moisture content

Figure 1. *Aerial photograph West Tamar slip.*

5 cm

and a low wet density; it is considered to be part of a failure zone, and it is reasonable to consider that effective cohesion (c') is zero at this depth.

The base of the slip is taken to be at the base of the aquifer, 13 m beneath the highway, and projected in a semi-circular arc to the head scarp (fig. 3).

Using the method of analysis of Bishop (1955), the factor of safety = 1 when $c_r' = 0$ and $\phi_r' = 13°$. The peak strengths obtained by triaxial test at this depth are $c' = 16$ kPa and $\phi' = 18°$.

PIEZOMETRIC PRESSURES

Pore pressures have been measured by checking the water levels in an open, slotted stand pipe which has its base in the aquifer. Hole 4 (fig. 4) has continued to be monitored. Recorded variations in water level have a maximum range of 1.33 m, with the highest pressure for 1975-1976 of 9.5 m occurring between late October and early January.

It is significant that the peak piezometric pressures occur 10 weeks after the peak in the nine-weekly average rainfall.

DEPTH OF SLIP

The depth of the slip has been checked by leaving an object tied on a string hanging into the stand pipe. To date, the pipe closure has been slight, and was noted on 7 September 1976 at a depth of 9 m.

It is expected that movement of the full depth of slip is controlled by the long-term fluctuations in pore pressure. However, shallow disturbed layers could move independently in response to heavy rain.

TRAFFIC VIBRATIONS

During October 1974, measurements were made of traffic vibrations on the downslope side of the highway on the northern edge of the slip. These measurements were taken at 1.7, 6 and 17.5 m from the kerb. Most of the recorded vibrations were generated by a 3 tonne truck driving at known speeds and were recorded in the vertical, horizontal longitudinal and horizontal transverse modes; the horizontal transverse vibrations are insignificant. Detailed results are given in Appendix 1.

Attentuation

In the landslip area attenuation is noticeably slow. It can be assessed by the formula $log_e \frac{A_2}{A_1} = -\alpha x$

where A_1 and A_2 are vibration amplitudes

x = distance between measurements (metres)
α = attenuation factor

Values of α have been obtained from the average A_2/A_1. Between 1.7 and 6 m, α vertical = 0.105 and α horizontal = 0.286 and between 6 and 17.5 m, α vertical = 0.096 and α horizontal = 0.067.

These values are similar to those obtained at Inveresk (Knights, 1976) and suggest a considerable depth of wet material.

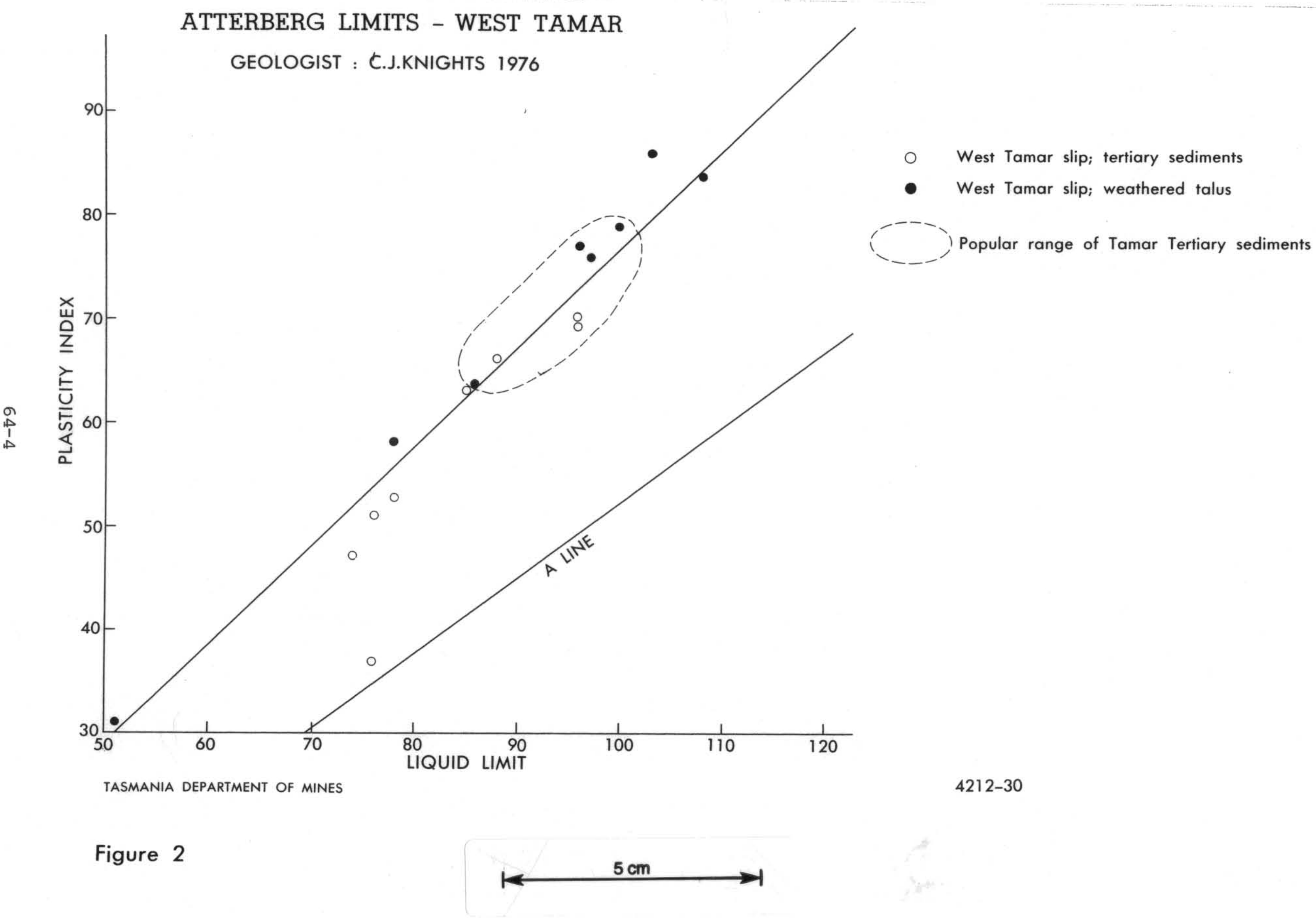

ATTERBERG LIMITS - WEST TAMAR
GEOLOGIST : C.J.KNIGHTS 1976
PLASTICITY INDEX
LIQUID LIMIT
A LINE
West Tamar slip; tertiary sediments
West Tamar slip; weathered talus
Popular range of Tamar Tertiary sediments
TASMANIA DEPARTMENT OF MINES
4212-30
5 cm

Figure 2

5/15

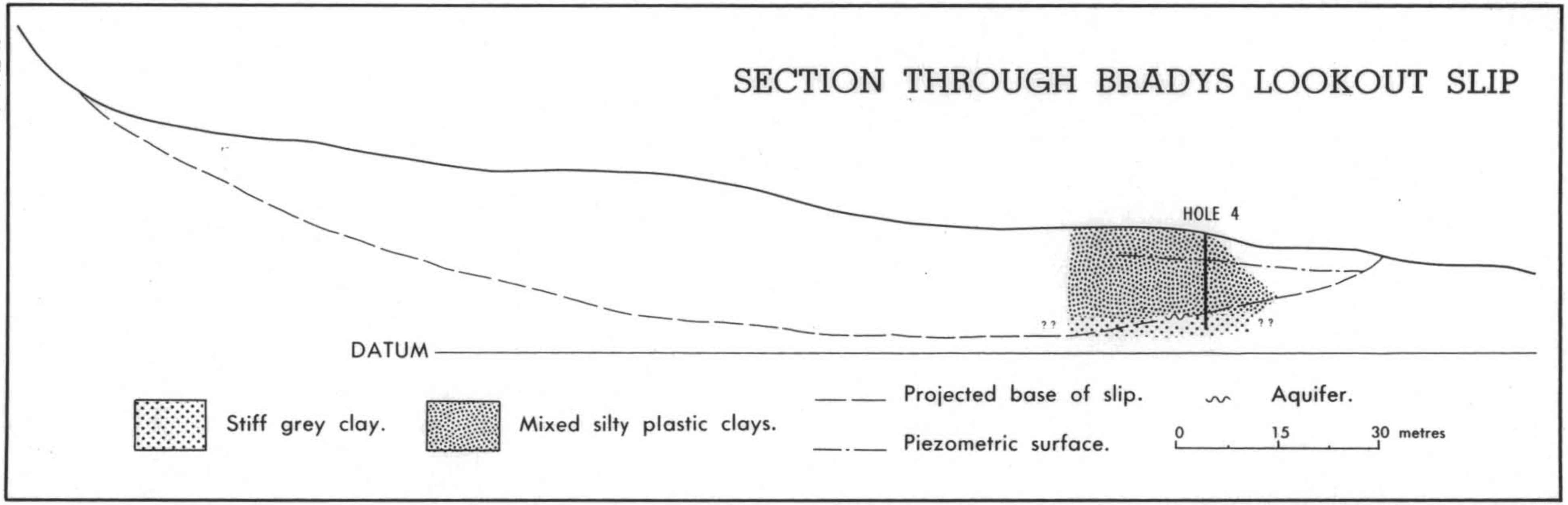

SECTION THROUGH BRADYS LOOKOUT SLIP
HOLE 4
??
??
DATUM
Stiff grey clay.
Mixed silty plastic clays.
Projected base of slip.
Piezometric surface.
Aquifer.
0
15
30 metres

Figure 3.

5 cm

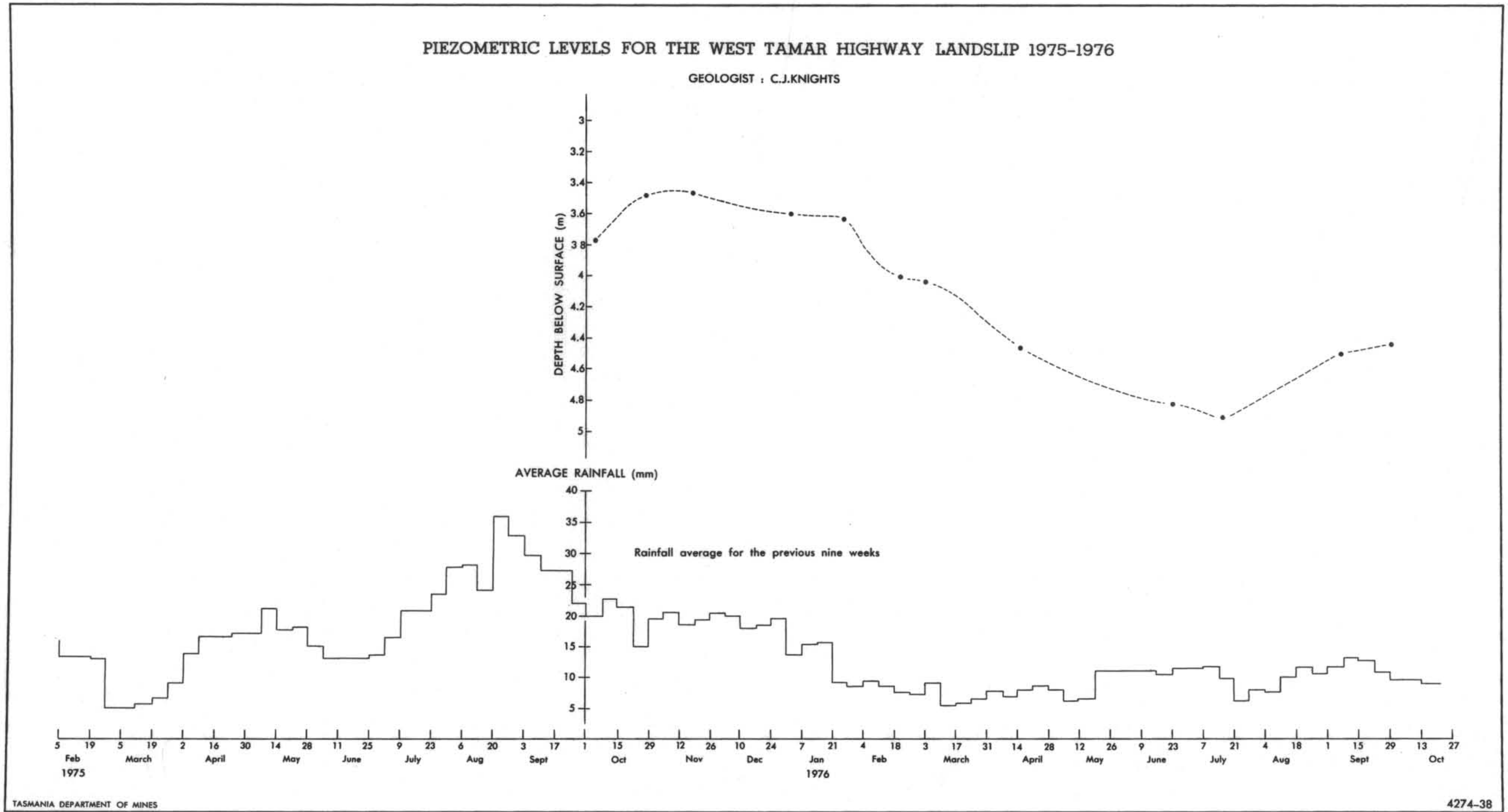


Figure 4

64-6

5 cm

7/15

Table 1. DRILLING RESULTS

Hole 2	Depth below surface (m)	Hole 4
Dark brown clay and gravel.	0	Fill.
	1	Soft greenish fawn clay with occasional fragment of ironstone.
Very soft pale fawn clay.	2	
	3	Soft wet greenish fawn clay with fragments of ironstone
Soft, wet, pale fawn clay with ironstone fragments	4	Water entry. Tougher orange and green clay.
Fragments of pink mudstone, 20% core recovery.	5	Hard band
	6	Tough orange and fawn clay with ironstone fragments.
Medium soft fawn coloured silty clay with grey veins. 20% core recovery.	7	
Stiff, fawn , silty clay with grey clay veins. 75% core recovery.	8	
	9	Medium-stiff augering, with little sample recovery. Orange and grey clay.
	10	
Stiff fawn silty clay with calcareous dendritic veining. 20% core recovery.	11	Hard band Pressure water
Very soft fawn and grey plastic clay.	12	Very soft drilling
	13	Tough dark grey clay, alternating hard and soft drilling at about one metre intervals.
Hard grey mudstone.	14	
Hard grey mudstone	15	

Table 2. GEOTECHNICAL PROPERTIES, WEST TAMAR HIGHWAY SLIP

Hole 2a (stratigraphy as for holes 2 and 4).

Depth (m)	Moisture content (%)	Wet density (kg/m^3)	LL	PI	LS	Triaxial c' (kPa)	Triaxial ϕ' (°)
3.2	37	-	76	37	17	-	-
6.2	37	1875	78	53	20	-	-
9	32	1875	76	51	19	27	34
12	42	1745	96	70	21	16	18

Hole 3 (stratigraphy as for holes 2 and 4).

Depth (m)	Moisture content (%)	Wet density (kg/m^3)	LL	PI	LS	Triaxial c' (kPa)	Triaxial ϕ' (°)
2.2	39	1800	96	69	22	-	-
4	37	1840	74	47	17	-	-
7.2	39	1820	88	66	20	30	27
11.6	37	1840	-	-	-	51	23
12	-	-	85	63	20	-	-

Table 3. ATTERBERG LIMITS OF SAMPLES, WEST TAMAR SLIP

Bore Hole No.	Depth (m)	LL	PI	LS
5	0-0.9	108	89	25
	0.9-1.8	97	76	26
	1.8-2.7	103	86	27
	2.7-3.6	78	58	22
	3.6-7.2	51	31	13
6	0-0.9	100	79	21
	0.9-1.8	96	77	22

Amplitude

The vertical vibrations are greater than the horizontal vibrations near the source, but the horizontal vibrations attenuate less rapidly, so that at 17.5 m they have similar amplitudes.

The largest particle velocities measured were from a gravel truck which generated 2.25 mm/s (vertical) at 1.7 m from the road, and 1.35 mm/s (vertical) at 6 m from the road.

Effect of vehicle speed on amplitude

These effects are shown in Figures 5 and 6. For vertical vibrations there is a sharp increase in generated vibrations at speeds greater than 48 km/h (30 mph). For horizontal vibrations there is a more variable increase of vibration with vehicle speed.

Frequency

Frequencies are mostly between 13 and 17 Hz.

CONCLUSIONS

The landslip on the West Tamar Highway is a reactivated part of an older, larger structure. The slip is in Tertiary sediments, which consist mainly of clay with occasional mineral bands. These sediments are overlain by deeply weathered talus. It is probable that the base of the slip is at 12.8 m, beneath the road, but the slope or inclination of the failure cannot be established without drilling away from the road.

Pore pressure in an aquifer at 12.8 m is 9.5 m, and reaches it peak 10 weeks after maximum rainfall. It is suggested that full slip movement should coincide with high pore pressure in this aquifer, but that shallow movement will take place in the disturbed upper layer in short term response to a period of rain. This suggestion could be tested by surface and sub-surface monitoring of movements.

The Tertiary clays involved in this landslip are less plastic than those normally found in the Tamar area. Back analysis of the slip indicates $\phi_r' = 13°$ and $c_r' = 0$. Triaxial testing of a sample from the failure zone gives $\phi_p' = 18°$ and $c_p' = 16$ kPa.

Vibrations generated by traffic are of high amplitude, and attenuate slowly when compared with vibrations in 'solid' Tertiary sediments. The dominant frequencies are 14 Hz and 17 Hz.

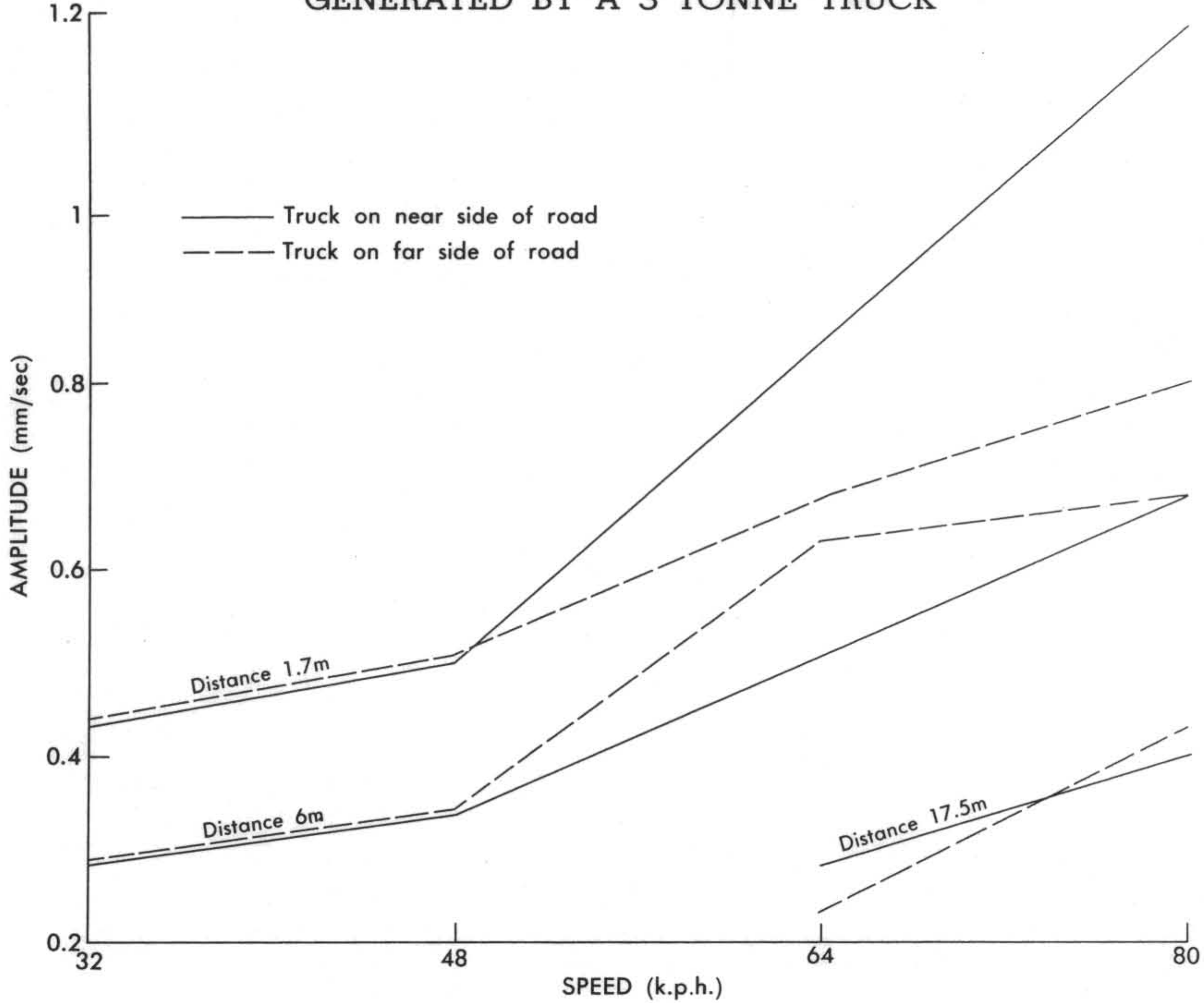
LANDSLIP CONTROL

The following methods should lessen the disturbance caused by the slip. It is unlikely that such a large, old and deep-seated structure could economically be fully stabilised.

Surface drainage. Surface drainage of depressions and pond areas of the landslip would increase the strength of the upper layers of the slip, and lessen surface disruption.

Subsurface drainage of the lower aquifer. This would be an expensive procedure, probably best tackled by a number of pumped, vertical, bore holes. As the pore pressures are so high a significant reduction in head could be made using suction pumps.

EFFECT OF VEHICLE SPEED ON VERTICAL VIBRATION AMPLITUDE GENERATED BY A 3 TONNE TRUCK



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4243-M

Figure 5

5 cm

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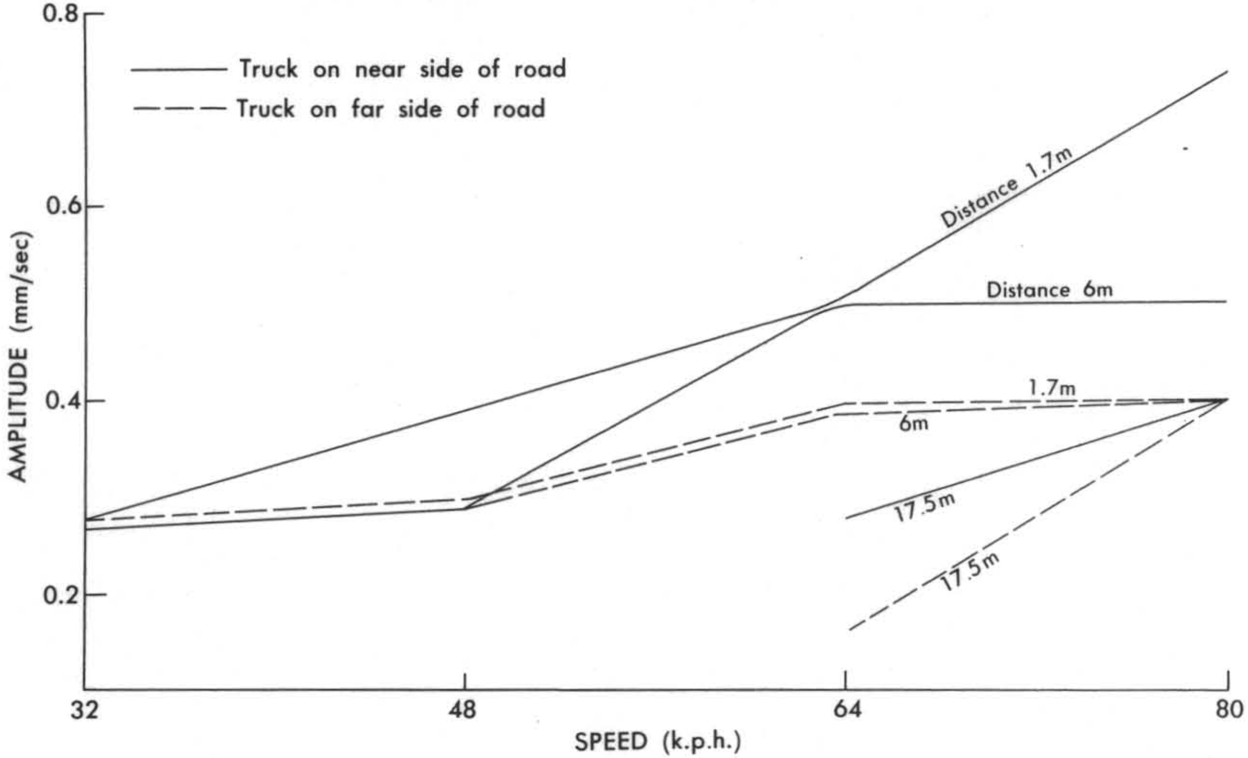
EFFECT OF VEHICLE SPEED ON HORIZONTAL VIBRATION AMPLITUDE GENERATED BY A 3 TONNE TRUCK



TASMANIA DEPARTMENT OF MINES

4243–M

Figure 6

64-11

5 cm

12/15

Shallow subsurface drainage. This would be feasible using horizontal drains. Before such drainage was attempted some assessment of material permeability should be made by pump testing shallow vertical holes.

REFERENCES

BISHOP, A.W. 1955. The use of the slip circle in the stability analysis of slopes. *Géotechnique* 5:1-7.

KNIGHTS, C.J. 1976. Subsurface conditions at Inveresk, Launceston. *Unpubl. Rep.Dep.Mines Tasm.* 1976/27.

[3 November 1976]

APPENDIX 1

Measurement of traffic vibrations

Particle velocity measured in mm/s.

V = vertical mode, HL = horizontal longitudinal mode, N = near side of road, F = far side of road.

Horizontal mode measured but insignificant.

Vehicle description	*Speed kph*	*Speed mph*	*Lane*	*Distance 1.7 m V (mm/s)*	*Distance 1.7 m HL (mm/s)*	*Distance 6 m V (mm/s)*	*Distance 6 m HL (mm/s)*	*Distance 17.5 m V (mm/s)*	*Distance 17.5 m HL (mm/s)*
3 tonne truck	32	20	N	0.425		0.28			
			F	0.4		0.28			
	48	30	N	0.5		0.34			
			F	0.5		0.34			
	64	40	N	0.85		0.625			
			F	0.68		0.5			
	80	50	N	1.18		0.68			
			F	0.8		0.675			
	32	20	N		0.28		0.28		
			F		0.28		0.28		
	48	30	N		0.4		0.3		
			F		0.3		0.3		
	64	40	N		0.5		0.5		
			F		0.4		0.4		
	80	50	N		0.74		0.5		
			F		0.4		0.4		
	64	40	N					0.28	0.28
			F					0.225	0.161
	80	50	N					0.4	0.4
			F					0.425	0.4
Big gravel truck				2.25		1.35			
Heavy truck					1.1		0.95		
Medium truck					0.72		0.47		
Empty gravel truck								0.45	0.4
Light truck								0.5	0.4
Medium truck								0.35	0.4
Medium truck								0.38	0.32
Medium truck								0.3	0.38

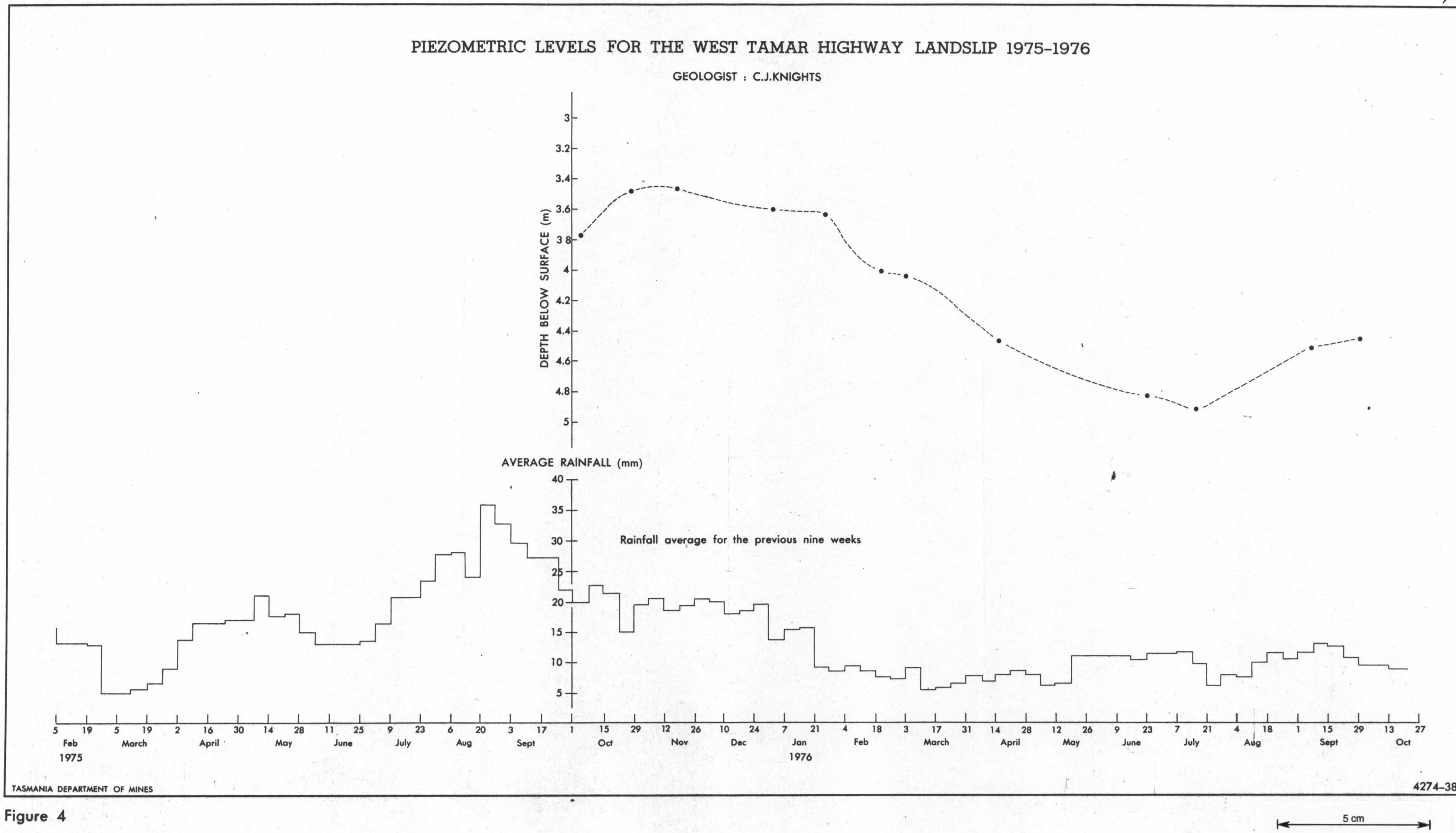

PIEZOMETRIC LEVELS FOR THE WEST TAMAR HIGHWAY LANDSLIP 1975-1976
GEOLOGIST : C.J.KNIGHTS
DEPTH BELOW SURFACE (m)
AVERAGE RAINFALL (mm)
Rainfall average for the previous nine weeks
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
1975
1976
TASMANIA DEPARTMENT OF MINES
4274-38
5 cm

Figure 4