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UR1986_83

1986/83. Investigation of cracking of S. Pickett's house, Windermere Road, Windermere.

W. R. Moore

Abstract

A very badly cracked house on the eastern shore of the River Tamar at Windermere was investigated by drilling three auger holes. Two further holes were drilled on a movement-monitoring survey line on the road above the house. The house has a long history of movement, some of which has been downslope. The block has a slope of 14° flattening to 6° and is at the foot of an old, complex, large landslide.

The drilling showed that highly plastic and expansive clay underlies the house to six metres depth and this clay is thought to underlie the entire block. Shear box tests indicate that the clay has a low angle of friction (16°) and low cohesion (1.1 kPa). Using these results as a basis, slope stability analyses indicate that the block has a high potential for failure. The investigation did not establish the cause of the movement and further monitoring is required.

INTRODUCTION

Mrs Pickett contacted the Department on 11 June 1986 concerning the cracking of her house at Windermere Road, Windermere. The house is on the downslope side of the road, overlooking the River Tamar. The house has a long history of movement and cracking, with some costly remedial measures having been undertaken. These include the rebuilding of the south wall of a large extension and the later underpinning of the wall. A series of tie rods have been used between many of the floor joists and piles to stop the movement.

The house was inspected on 2 June and a report written (Appendix 1). The conclusions of this report were:

(a) the cause of cracking appears complex and is thought not to be the result of one type of movement;

(b) before any remedial work is undertaken more information is required as to the type of material on which the house is founded and as to the movements of the house.

In line with these conclusions, it was recommended that three to four auger holes be drilled around the house, as well as the setting up of a monitoring survey line on the road, from which the house movements could be measured. This line was to extend laterally beyond any possible failure zone on the road. Two survey station holes were to be drilled at each end of this line, to a depth below any likely moisture fluctuations. A drill rod is then cemented in the base of the hole, the hole cased, filled with sand, and then capped. The top of the drill rod serves as a levelling station which should not fluctuate with changing moisture conditions of the surrounding clay.

This report covers the drilling around the house and on the road, the soil laboratory results, and the stability analysis of the block.

LOCATION AND SLOPE

Pickett's is a split level brick-veneer house situated on a double block on the eastern side of a low spur which forms a small promontory on the northern bank of the River Tamar [EQ015261]. The spur merges with the higher level flood plain on these blocks. The southern boundary of the blocks is the river bank between the higher flood plain and the tidal flats and flood plain of the river.

The house is situated on the northern lot of this double block. The southern lot is mainly in lawn with trees. On the western boundary of the house lot, slopes of 12° occur which flatten to 7° from the south-west corner of the house to the river bank. On the east side of the house lot the driveway slopes down from 14° to 12°, flattening to 6° on the fill near the underhouse garage. The slope then flattens to 6° on the flood plain. This higher flood plain comprises most of the lower southern block which has slopes of 5° flattening to 3° (fig. 1).

SURFACE GEOLOGY

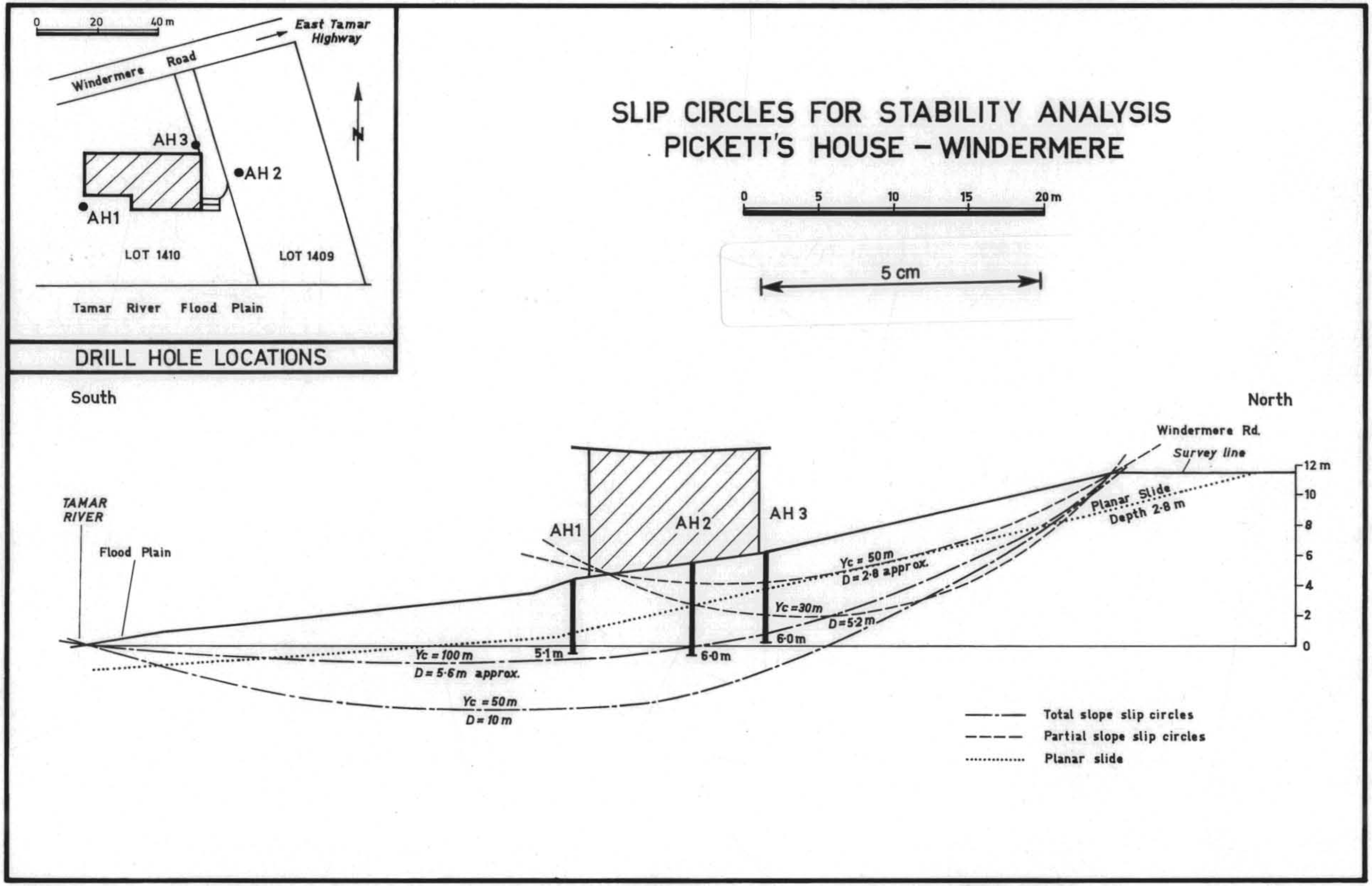
Opposite Pickett's house, on the northern banks of Windermere Road, are good exposures, two to three metres high, of basalt boulders and cobbles underlain by and mixed within clay. Beneath the black clayey soil are white, grey and yellow clay. These clays are very stiff and hard when dry but become soft and even fluidised when moist, with two or three small mud springs present in winter along these road banks.

SUBSURFACE GEOLOGY

Three auger holes were drilled around Pickett's house using the Triefus trailer-mounted drill rig. Hole H1 was on the southern lawn near the south-west corner of the main section of the house. Hole H2 was below the driveway opposite the garage on the side of the east lawn, and Hole H3 was just off the driveway at the north-east corner of the house (fig. 1). Unfortunately it was not possible to get the drilling rig along the west side of the house.

The three auger holes around the house showed the same lithological clay sequence of a surface layer of black and dark brown soil and sub-soil layers, followed by a yellow-brown clay to depths of 5.1 m and 6.0 m. Some minor grey clay bands and ironstone grits were encountered in the drilling. No basalt boulders, seen in outcrop on the road bank above Pickett's house, were encountered; neither were any of the heavy quartzite gravels that were encountered in the drill holes at the western end of the survey line on the road (Appendix 2).

In Hole S1 (on the western end of the survey line off the southern edge of the road 100 m west of Pickett's) the drill could not penetrate beyond 1.8 m because of gravel in the yellow clay. The survey line was shifted 10 m to the east and Hole S2 was drilled. After penetrating the base coarse of the road, clay and clay with gravel was drilled to 3.3 m when the hole was stopped by heavy gravel. From the few pebbles lifted to the surface by the augers, this gravel appears to comprise rounded quartzite pebbles. In Hole S3, approximately 200 m east of Pickett's on the northern side of the road, coarse gravel and clay occurred to a depth of 1.5 m. This was underlain by light brown clay. All the clay in the two holes on Windermere Road appeared lithologically similar to the clay drilled on Pickett's block.



SLIP CIRCLES FOR STABILITY ANALYSIS
PICKETT'S HOUSE - WINDERMERE
0 5 10 15 20 m
5 cm
0 20 40 m
East Tamar Highway
Windermere Road
AH 3
AH 2
AH1
LOT 1410
LOT 1409
Tamar River Flood Plain
DRILL HOLE LOCATIONS
South
North
Windermere Rd.
Survey line
TAMAR RIVER
Flood Plain
AH1
AH 2
AH 3
Planar Slide
Depth 2·8 m
Yc = 50 m
D = 2·8 approx.
Yc = 30 m
D = 5·2 m
6·0 m
5·1 m
6·0 m
Yc = 100 m
D = 5·6 m approx.
Yc = 50 m
D = 10 m
12 m
10
8
6
4
2
0
Total slope slip circles
Partial slope slip circles
Planar slide

Figure 1.

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SOIL LABORATORY RESULTS (Table 1)

All of the clays sampled were highly plastic with a wide range of liquid limits from 78 to 125 (fig. 2). In Hole H2 the plasticity indices range from 87 to 98 whereas in Hole H3 they range from 57 to 96. In Hole H3 the highest value was near the surface at 0.6 m and lowest at 1.5 m. From this depth the plasticity index increases with depth from 62 at 2.4 m to 92 at 6.0 m depth (fig. 3a). The linear shrinkage shows a similar pattern with depth and varies from 20-26%. Hole H2 shows little of this variation and the liquid limits are higher (fig. 3b).

The XRD analyses of the clay samples collected from Hole H3 show the samples to be composed of two clay fractions of the kaolinitic family, comprising 50% to 60%, with the expansive montmorillonites comprising 35% to 50% of the total sample. Quartz fines comprise 5% to 20%, with the highest percentage from the sample collected at 2.4 m depth with 20 - 25% of quartz.

The moisture content profile of Hole H3 shows a very moist surface layer of 38% at 0.6 m depth, which declines considerably to 21% at 1.5 m depth. Then, with increasing depth, the moisture content increases constantly to 41% at 6 m depth (fig. 4). In Hole H2, drilled on the higher flood plain level on the east side of the house, the clays have very high moisture contents of 39% to 57%. Near the surface, at 0.6 m depth, the moisture content is 46%. This declines to 39% at 1.5 m depth and remains at this level with a consistent 39 - 40% between 1.5 m and 4.2 m depth. Below this depth there is a steep rise to 57% at 6.0 m depth which is below river level (fig. 1).

In Hole H1, drilled at the south-west corner of the house (on the shady side of the house), the moisture content profile is intermediate between Holes H2 and H3. It has a high surface moisture content, 42% at 0.9 m depth, which declines to 30% at 1.5 m and increases to 34% at 1.9 m and remains between 35% and 36% to 4.2 m. It then increases rapidly to 40% at 5.1 m, which is also below the water level of the river flood plain.

These holes were drilled on 6-7 August after a period of very heavy rain and cold frosts at Windermere, and these moisture content values are probably representative of winter values.

A clay sample from Hole H3 at 3.3 m depth, with intermediate plastic index values and moisture contents for this hole, was shear box tested. This test resulted in an angle of friction of 16° and effective cohesion of 1.1 kPa for the clay.

SLOPE STABILITY ANALYSES

Bishop's simplified method of slip circle failure for slope analysis was used in the following analyses. The method of analysis has been adapted by Moon (1984) for a Hewlett-Packard 41C calculator and reprogrammed by B. Weldon for a Canon X-07 hand computer. Two slope configurations were used at Pickett's (fig. 1). The first profile was the total slope from Windermere Road to the River Tamar across Pickett's block. The second profile was the steeper section of the block from Windermere Road to the south side of the house. The planar slide analysis of Morgenstern and Sangrey (1978) was also used on the total slope.

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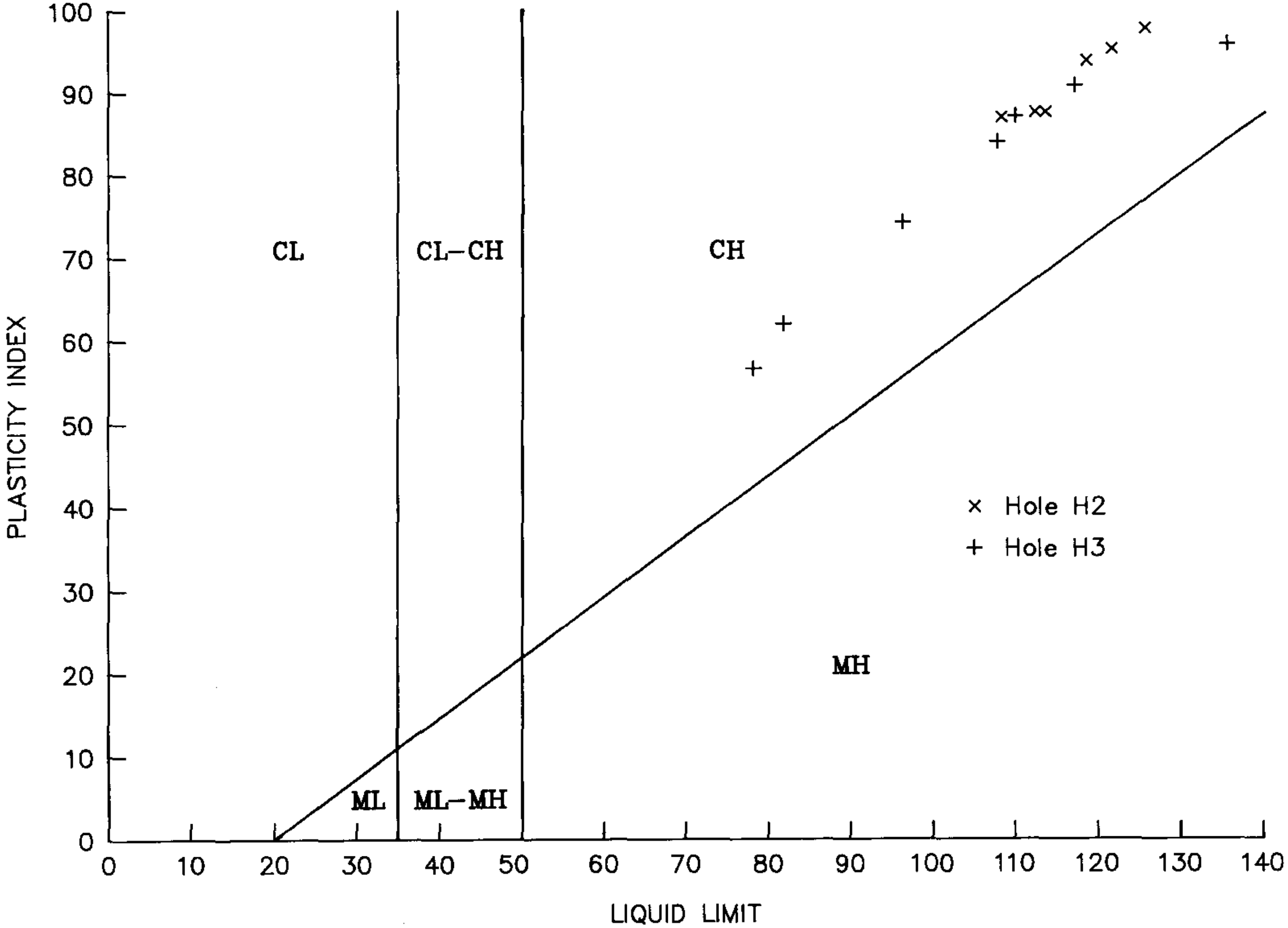
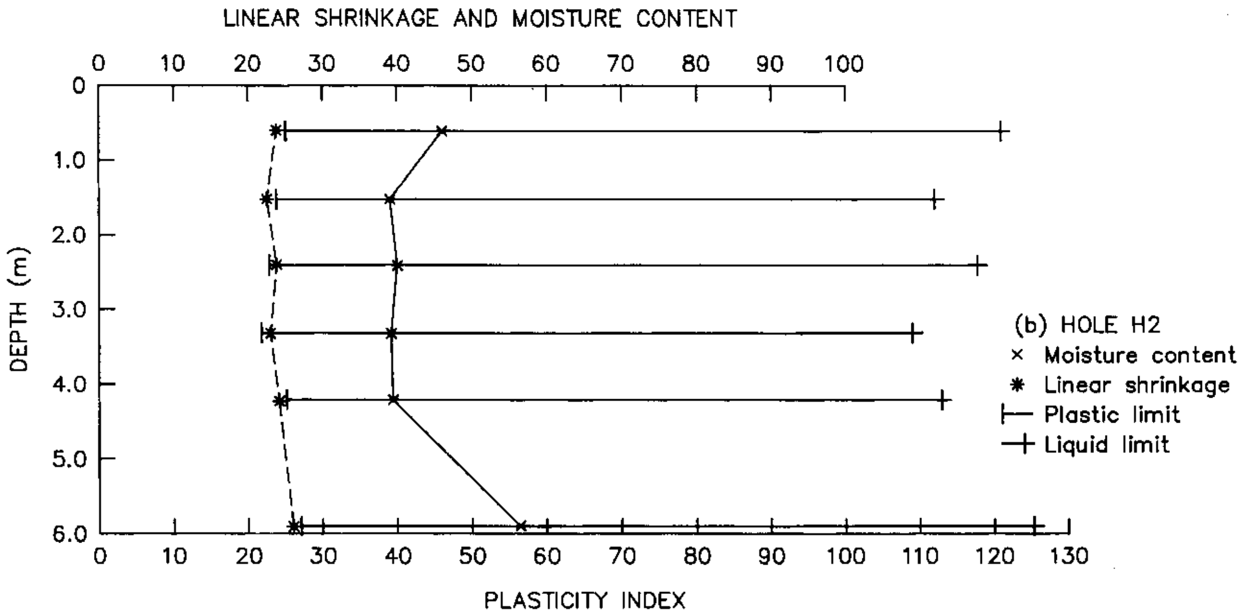


Figure 2. *Soil laboratory classification of clays*

5 cm



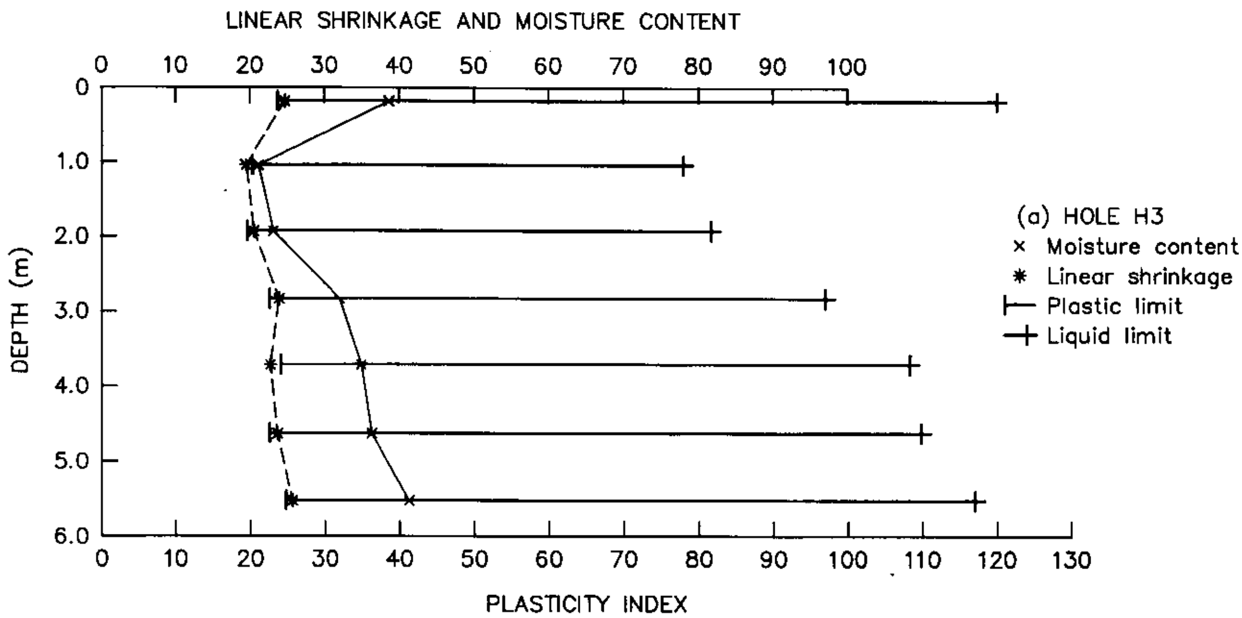


Figure 3. *Soil testing results, Holes H2 and H3*

5 cm

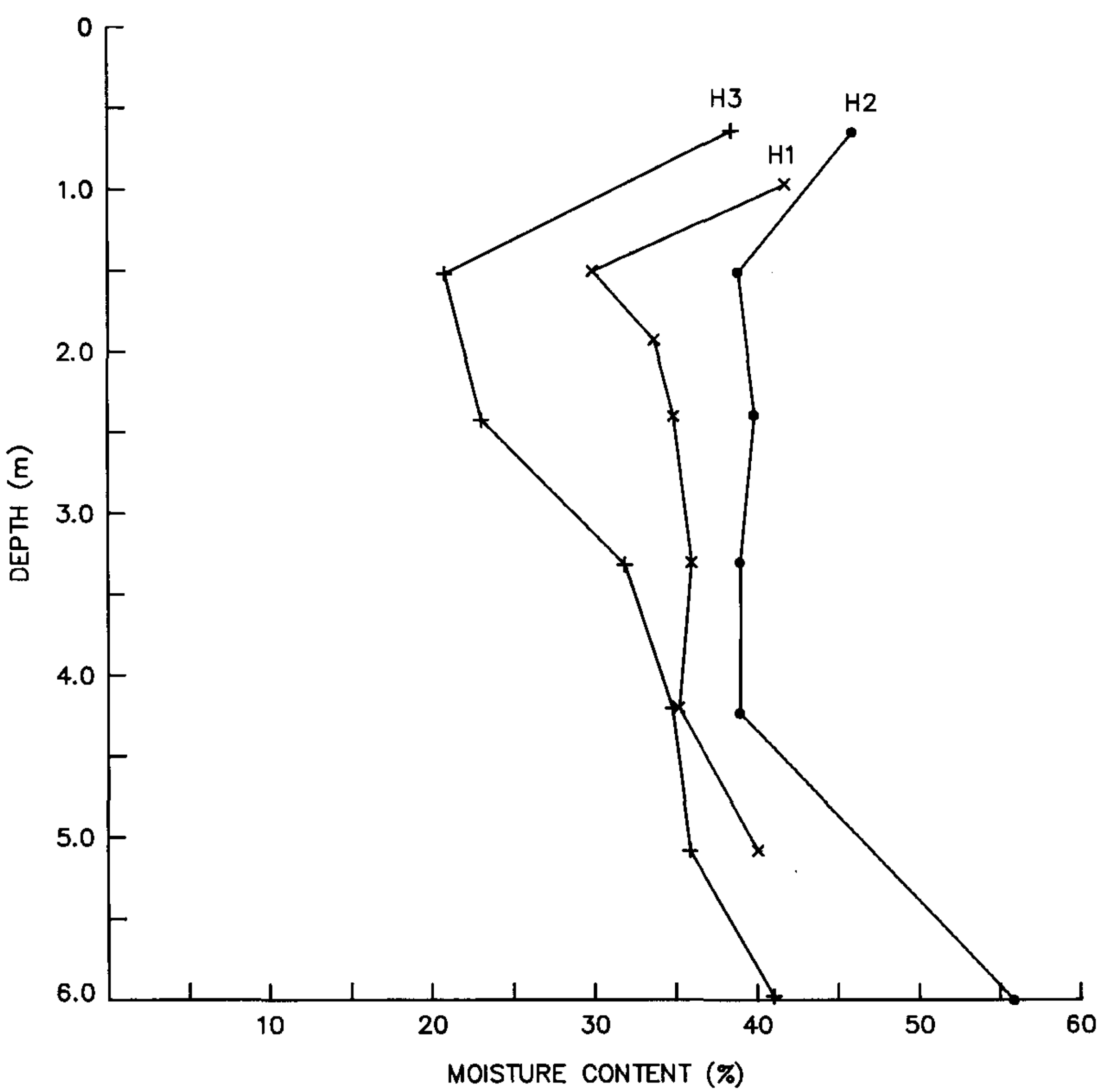


Figure 4. *Moisture content profiles, holes H1 to H3.*

5 cm

In all of these analyses it is assumed that the entire slope is underlain by clay, as found in the holes around Pickett's house and in the survey line holes on Windermere Road. The shear box test results from this clay (an angle of friction of 16° and cohesion of 1.1 kPa) were used as a basis for the back analyses of the slopes.

Total Slope Analysis (Table 2)

For the total slope analysis two potential slip circle failure planes were used: one with a radius (Yc) of 50 m and the other 100 m. The maximum depth to these two potential failure surfaces was 10.0 m and 5.6 m respectively. With no water table above the failure plane, the two analyses gave factors of safety of 2.50 and 2.30 respectively. With the water table rising almost to ground surface, the factors of safety declined to 1.27 and 1.19.

As the shallower potential failure was marginally more unstable and its failure plane is within the known depth of clay, the shallower potential failure plane (Yc = 100) was used when the angle of friction and the cohesion were varied in further analyses. The angle of friction was lowered from 16° to 14° and then to 12°, with the cohesion remaining at the tested value of 1.1 kPa (Table 2b). Then using these same three angles of friction, the factors of safety were recalculated using no cohesion, over the same range of moisture ratios (Table 2c).

From these calculations, with an angle of friction of 14° at a moisture ratio of 0.5, the total slope would be at the point of failure with a factor of safety of 1.05. With the clay angle of friction lowered further to 12°, the point of failure would occur with the moisture ratio at 0.4, with a calculated factor of safety of 1.0 (Table 2b).

When the cohesion was lowered further from the low tested value of 1.1 kPa to that of no cohesion (0.0), the factors of safety only declined marginally for the same slope and water table levels (Table 2c).

From these calculations, given that the clay sample tested is representative of the clay and that such clay underlies the total slope to the depth below the potential failure planes, the slope at Pickett's is stable except under very adverse and exceptional conditions. The water table would have to rise close to the ground surface. Such an event would appear, to the writer, to be a rare occurrence.

A greater danger of a total slope failure would appear if the river bank, forming the toe of this slope, was eroded in an exceptionally high flood. Such an occurrence would move the total slope analysis towards the partial slope analysis case.

Partial Slope Analysis (Table 3)

The steeper section of Pickett's block was modelled in this analysis. Two potential failure circles were used with radii of 30 - 50 m, giving the maximum depth to these surfaces of 5.2 m and 2.8 m (fig. 1).

In contrast to the total slope analysis, using the same shear box results for the clay and same range of moisture ratios, the partial slope analyses indicate that this slope has a high potential for failure. If the water table should ever rise above the projected slip circle failure planes of 2.8 m and 5.2 m depth, the slope will be close to failure or will fail

(Table 3a). When the water table is below the projected failure planes and the slope dry, with a moisture ratio of 0.0, the factors of safety for this partial slope are low at 1.17 and 1.11. When the moisture ratio is increased to 0.1, with a theoretical water table level rising to 0.5 m and 1.0 m above the projected failure planes at their greatest depths for Yc = 50 m and Yc = 30 m, the slope is at the point of failure with factors of safety of 1.0 and 1.05. If the moisture ratio is increased above this level the slope fails, with the deeper slip (Yc = 30 m) being marginally more stable.

The shallower potential failure plane (Yc = 50 m) was used when the angle of friction was increased (Table 3b) and then followed by changing the effective cohesion value (Table 3c). When the angle of friction of the clay was increased from 16° to 18° and then 20°, the factor of safety only increased marginally. The slope is calculated to fail with a moisture ratio at 0.2 and angle of friction of 18°, with a factor of safety of 0.99. With a further increase of the angle of friction to 20°, the factor of safety was calculated at 1.10 with the moisture ratio at 0.2 but then failed when the moisture ratio was increased to 0.3 with a calculated factor of safety of 0.96 (Table 3b).

Only in this model, when both the angle of friction and the effective cohesion are increased to 20° and 3.3 kPa, does the slope achieve any reasonable stability (Table 3c). With these values, only when a theoretical water table is close to the ground surface (i.e. with a moisture ratio of 0.45) is the slope calculated to be at the point of failure with a factor of safety of 1.0. With a moisture ratio of 0.45 (i.e. with a theoretical water table close to the surface) the slope is at the point of failure with a factor of safety of 1.0 with 20° angle of friction and cohesion of 3.3 kPa, compared with a factor of safety of 0.76 with an angle of friction of 20° and cohesion of 1.1 kPa (Table 3c).

Planar Slide Analysis (Table 4)

For this analysis the slope was subdivided into two segments, with an upper section with a slope of 14° and the lower slope of 8°. The depth of failure was taken at 2.8 m as used in the previous analysis, as was the angle of friction of 16°. The cohesion values were varied from the soil laboratory result of 1.1 kPa to no cohesion.

The planar slide analysis calculations confirmed the slip circle analyses results that the upper slope has a high potential for failure, whereas the lower slope is potentially stable. The deterioration of the cohesion of the clay through long term weathering appears to have little effect on the slopes stability because the tested effective cohesion value is so low at 1.1 kPa.

RESULTS OF THE INVESTIGATIONS TO DATE

(1) The cracking of Pickett's house externally and internally indicates that the house is under stress. Some of the resultant cracking from movements of the house indicate a downslope component in this movement.

(2) Pickett's land is at the foot of a very complex landform formed from a series of old landslides.

(3) Reactivation of these old landslides has destroyed a house in a similar location, approximately one kilometre to the west along Windermere Road.

(4) Pickett's house is underlain by five to six metres of yellow clay. This clay is thought to underlie the entire block as it occurs mixed with quartzite gravel in a drill hole on Windermere Road and is exposed along the road bank mixed with basalt boulders.

(5) The clay is highly plastic and expansive, and all samples tested contain a high percentage of the expansive montmorillonite clay. The linear shrinkages range from 20 - 26%.

(6) The clays were very moist when drilled in August and appeared to be close to saturation at a depth of five to six metres.

(7) The clay sample shear box tested gave a low angle of friction of 16° and very low effective cohesion of 1.1 kPa.

(8) Given that the shear box test results are representative of the clay, slope stability analysis calculations indicate that large scale failure from the road to the flood plain of the River Tamar is unlikely.

(9) These slope stability analyses show that given specific conditions, such as fissuring in the clay with a rising water table, the steeper section of the block on which the house is situated has a high potential for slope failure.

(10) To date no damage has been reported from neighbouring houses. Nor was any direct evidence of landslide movement seen on Pickett's house, such as wall buckling or arching etc. No tension cracks were seen on the ground or on the bitumen drive down to the house on the steep section of the slope.

(11) Little is known about the water table levels on Pickett's blocks.

CONCLUSIONS

(1) This investigation has been inconclusive as to the cause of the cracking on Pickett's house or the major direction component of this movement.

(2) It is thought that most of the movement on the house is caused by expansive clay - particularly as Mrs Pickett is no gardener and has indicated that the lawns are not watered in summer.

(3) The downslope movement could be the result of soil creep combined with vertical seasonal fluctuations from the expansive clay. Such a movement would be enhanced if the house foundations are shallow, as is suspected.

(4) There is a possibility that the small amount of downslope movement could be the start of the reactivation of the old landslides that are present above Windermere Road but no definite evidence for any recent landslide movement has been found.

RECOMMENDATIONS

(1) No further remedial work be undertaken until the movements of the house and block have been monitored over this summer as a minimum period.

(2) At the end of the summer and autumn dry period the auger holes be redrilled and moisture contents of the clays compared with those collected in July.

(3) Two piezometers be installed, one above the house near Hole H3 and the other close to Hole H1. Preferably these should have automatic water level recording devices on them.

(4) On the upslope side of the house a series of four deformation measuring tubes be installed as well as one of the Department's movement recording measuring devices on the house.

(5) The council be persuaded to improve and preferably concrete the culvert along the north side of Windermere Road. At present this drain has little fall and collects water rather than drains it. Water seeping into the ground can only be a destabilising factor at this location, particularly if landslide reactivation is the cause of the movement on Pickett's house.

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[3 December 1986]

Table 1. PICKETTS WINDERMERE ROAD, SOIL LABORATORY RESULTS

Hole no.	Sample no.	Depth (m)	Moisture content (%)	Plastic Limit	Liquid Limit	Plasticity Index	Linear Shrinkage (%)	Soil Lab. Classif.	XRD Clay Fraction — Mineral composition (%) Kaolinite	Montmorillonite	Goethite	Total Sample — Quartz Content (%)
H1	S1	0.9	42									
	S2	1.5	30									
	S3	1.9	34									
	S4	2.4	35									
	S5	3.3	36									
	S6	4.2	35									
	S7	5.1	40									
H2	S1	0.6	46	25	121	96	24					
	S2	1.5	39	24	112	88	23					
	S3	2.4	40	23	118	95	24					
	S4	3.3	39	22	109	87	23					
	S5	4.2	39	25	113	88	24					
	S6	6.0	57	27	125	98	26					
H3	S1	0.6	39	24	120	96	25	CH	50-55	45-50		15-20
	S2	1.5	21	21	78	57	20	CH	55-60	40-45		15-20
	S3	2.4	23	20	82	62	21	CH	60-65	35-40		20-25
	S4	3.3	32	23	97	74	24	CH	55-60	40-45		10-15
	S5	4.2	35	24	108	84	23	CH	55-60	40-45		10-15
	S6	5.1	36	23	110	87	24	CH	55-60	40-45		10-15
	S7	6.0	41	25	117	92	26	CH	60-65	35-40		5-10

Sample 4 Bore Hole 3 at 3.3 m depth—

Slow shear box tested gave ϕ angle of friction 16° and C' effective cohesion 1.1 kPa

R.N. Woolley, Soil Laboratory Technician.

Table 2. TOTAL SLOPE, BACK ANALYSIS

Assume: Density = 19 kN/m^3
Number of slices = 7

Soil laboratory results: Angle of Friction (ø) = 16°
Effective cohesion (c') = 1.1 kPa

(a)

Varying slip circle radius (Yc):
Yc = 100 m - Maximum depth of failure surface = 5.6 m
Yc = 50 m - Maximum depth of failure surface = 10.0 m

Factor of Safety		Moisture Ratio (ru)
Yc = 100 m	Yc = 50 m	
1.19	1.27	0.50
1.30	1.38	0.45
1.63	1.76	0.3
1.86	2.01	0.2
2.08	2.26	0.1
2.30	2.50	0.0

(b)

Given Yc = 100 m Cohesion = 1.1 kPa
Varying angles of friction

Factor of Safety		Moisture Ratio (ru)
14°	12°	
1.05	0.91	0.5
1.14	0.96	0.45
1.24	1.00	0.40
1.44	1.24	0.3
1.63	1.41	0.2
1.82	1.57	0.1
2.02	1.74	0.0

Table 2 (continued)

(c)

Given Yc = 100 m No cohesion
Varying angles of friction

Factor of Safety			Moisture Ratio
16°	14°	12°	(ru)
1.07	0.93	0.79	0.5
1.18	1.03	0.88	0.45
1.29	1.24	0.96	0.4
1.51	1.32	1.12	0.3
1.74	1.51	1.29	0.2
1.96	1.70	1.45	0.1
2.18	1.90	1.62	0.0

Table 3. PARTIAL SLOPE, BACK ANALYSIS

Assume: Density = 19 kN/m³
Number of slices = 7

Soil laboratory results: Angle of Friction (ø) = 16°
Effective cohesion (c') = 1.1 kPa

(a)

Varying slip circle radius (Yc):
Yc = 30 m - Maximum depth of failure surface = 5.2 m
Yc = 50 m - Maximum depth of failure surface = 2.8 m

Factor of Safety		Moisture Ratio (ru)
Yc = 30 m	Yc = 50 m	
0.64	0.63	0.45
0.82	0.78	0.3
0.93	0.90	0.2
1.05	1.0	0.1
1.17	1.11	0.0

(b)

Given Yc = 50 m Maximum depth of failure 2.8 m
Varying angles of friction

Factor of Safety		Moisture Ratio (ru)
18°	20°	
0.69	0.76	0.45
0.87	0.96	0.3
0.99	1.10	0.2
1.12	1.24	0.1
1.24	1.32	0.0

(c)

Given Yc = 50 Angle of friction (ø) = 20°
Varying cohesion

Factor of Safety		Moisture Ratio (ru)
c' = 3.5 kPa	c' = 1.1 kPa	
1.0	0.76	0.45
1.21	0.96	0.3
1.34	1.10	0.2
1.48	1.24	0.1
1.56	1.32	0.0

Table 4. BACK ANALYSIS OF TOTAL SLOPE SUBDIVIDED INTO TWO SEGMENTS

Assume: Density = 19 kN/m³
Depth of failure = 2.8 m

Soil laboratory results: Angle of Friction (ø) = 16°
Effective cohesion (c') = 1.1 kPa

Factor of Safety Slope = 14°			Factor of Safety Slope = 8°		
Cohesion 1.1 kpa	No Cohesion	Moisture ratio (ru)	Cohesion 1.1 kpa	No Cohesion	Moisture ratio (ru)
0.69	0.60	0.45	1.25	1.10	0.45
0.87	0.78	0.3	1.57	1.42	0.3
0.99	0.91	0.2	1.77	1.62	0.2
1.12	1.03	0.1	1.98	1.83	0.1
1.24	1.15	0.0	2.19	2.04	0.0

APPENDIX 1

Letter from W. R. Moore to Mrs S. Pickett

CRACKED HOUSE - WINDERMERE, EAST TAMAR

As requested in your letter of 16 June, your cracked house was inspected on 2 July by Mr Moore and this report covers the results of this inspection.

The block is on the lower side of Windermere Road and has a steep section of 14° in the NW corner. The slope flattens to 7° and 5° to merge with the river flats of the River Tamar. The steep section is the toe of a long slope that extends above the road. The house has been cut into it. Above the house, on the road, are exposed basalt boulders underlain by highly plastic clays which were fluidised in two or three very small mud springs after the overnight heavy rain. This type of material is inducive for landslides as well as expansive soil movements.

The house is a split-level, white brick, with concrete brick wall perimeter base and pile foundations. The house was built in two sections with the new front section built in the 1970's. This section of the front wall (south) was rebuilt and the foundations were apparently underpinned because of movement. No cracking was visible on this new section.

The most severe cracking occurs on the east wall of the house where wide gaps are present in the brickwork and the concrete patio has moved away from the house. This cracking extends into a retaining wall on the north side of the downstairs garage. The north wall of the house, closest to the steep slope, shows cracking at each end, with cracking near the middle. The cracking along this wall has the appearance that the house may be arched towards the centre. On the west wall an old consolidation crack runs from the roof of the house to the base of the foundation wall.

None of the cracking on the external walls showed a major downslope component. All the walls of the house were vertical and no buckling was visible.

Underneath the house the thickness of the outside wall foundations and their depth in the ground is not known. The concrete block piers showed tilting at various angles. The rust marks on a couple of vertical steel tie rods on these piles indicated a downslope tilting as did a set of two piles towards the SW corner of the house. The wooden beam which these piles are supporting is also warped.

Internally the house is badly cracked but no pattern was obvious in these cracks. It may become necessary to map the cracking internally and externally, as well as level the house internally, room by room.

The cause of the cracking of this house appears complex, and is thought not to be the result of one type of movement. It does not appear to be caused by translational downslope movement associated with a landslide movement of the steep slope area on your block. There is a possibility that it could be associated with the upswelling of the clay in a toe area of a large slip of which no recognisable features as yet have been distinguished above the road, similar to that which destroyed the house by the church at Windermere. This appears unlikely as there are no signs of failure on the road bank or slope above which has been mapped in considerable detail. The third possibility for causing the cracking is fluctuating seasonal movements associated with the expanding and shrinking of the underlying clay. These movements, combined with some minordown slope movement from soil creep, are thought the most likely cause. Support for this hypothesis is the success of the underpinning in the new section of the house where no cracking is present. As always, with any expansive clay damage, the depth and strength of the original foundations of the house become suspect as well as the depth and properties of the clay.

Unfortunately, the presence of an expansive clay beneath the foundations does not explain the concentration of cracks at the east and shadier side of the house. This may be the result of the design of the house with a lack of support for the downstairs garage, or alternatively it may be a soil consolidation problem. This section of the house may be partially on fill pushed out for levelling of the house and digging of the garage. The driveway outside the garage is clearly on fill but unfortunately has been recently resurfaced with bitumen. Consequently, no cracking pattern is visible.

Clearly before any remedial work is undertaken more information is required as to the type of material on which the house is founded and as to the movements of the house. The subsurface work required is three or four auger holes drilled around the house. The cost for this work is expected to be $150-$200, including the testing of any clay samples obtained.

The monitoring of the movements should include the cracks on the house as well as a survey of the house from the road, over the wet months and next summer. This work could be included in the Department's monitoring programme, as Windermere is one of the critical problem areas of the Tamar Valley.

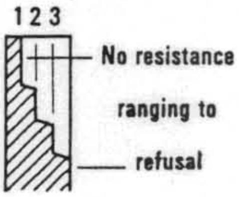
[17 July 1986]

TASMANIA DEPARTMENT OF MINES

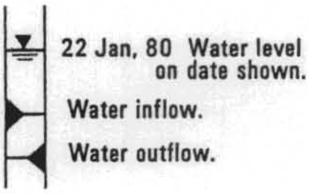
EXPLANATION SHEET FOR ENGINEERING LOGS

Borehole and excavation log

Penetration



Water



Notes - samples and tests

U50	Undisturbed sample 50mm diameter.
D	Disturbed sample.
N	Standard penetrometer blow count for 300mm.
N *	SPT + sample.

Material classification

Based on Unified Soil Classification System.

In Graphic Log materials are represented by clear contrasting symbols consistent for each project.

Moisture content

D	Dry, looks and feel dry.
M	Moist, no free water on hand when remoulding.
W	Wet, free water on hand when remoulding.
LL	Liquid limit.
PL	Plastic limit.
PI	Plasticity Index.

eg. M > PL - Moist, moisture content greater then the plastic limit.

Consistency

		hand penetrometer (kPa)
VS	Very soft.	< 25
S	Soft.	25 - 50
F	Firm.	50 - 100
St	Stiff.	100 - 200
VSt	Very stiff.	200 - 400
H	Hard.	> 400
Fb	Friable.	

Notes: X on log is test result

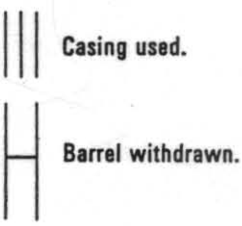
— is range of results.

Density index

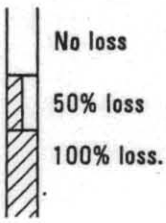
		%
VL	Very loose.	0 - 15
L	Loose.	15 - 35
MD	Medium dense.	35 - 65
D	Dense.	65 - 85
VD	Very Dense	85 - 100

Cored borehole log

Case - lift



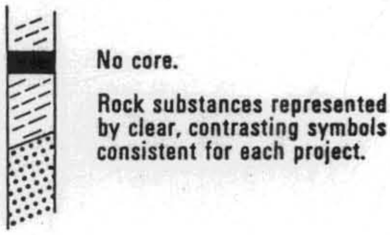
Fluid loss



Lugeons

Lugeon units (μL) are a measure of rock mass permeability. For a 46 to 74mm diameter borehole 1 Lugeon is defined as a rate of loss of 1 litre per metre per minute. 1 Lugeon is roughly equivalent to a permeability of 1×10^{-4} mm/sec.

Graphic log



Weathering

Fr	Fresh.
SW	Slightly weathered.
HW	Highly weathered.
EW	Extremely weathered.

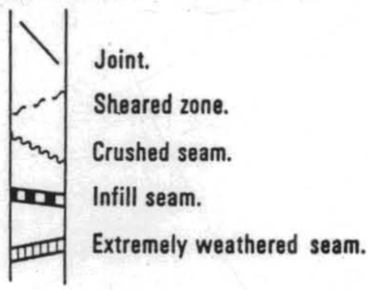
Strength

		point load strength index $I_{s(50)}$ (MPa)
EL	Extremely low.	< 0·03
VL	Very low.	0·03 - 0·1
L	Low.	0·1 - 0·3
M	Medium.	0·3 - 1
H	High	1 - 3
VH	Very high.	3 - 10
EH	Extremely high.	> 10

Note: X on log is test result.

Significant defects

Significant defects shown graphically.



TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – BOREHOLE

borehole no. H1
sheet 1 of 1

20/25

project cracked house investigation S. Pickett, Windermere Road.
location West Lawn, River Tamar side.

co-ordinates	5008-54261	drill type	Triefus	hole commenced	6.8.86
R.L.	2m	drill method	Auger	hole completed	6.8.86
inclination	vertical	drill fluid	none	drilled by	B.E.Cox
bearing	–			logged by	W.R.Moore
				checked by	R.C.Donaldson

penetration 1 2 3	support	water	notes samples, tests	metres depth	classification symbol	material (soil type: plasticity or particle characteristics, colour, secondary and minor components.)	moisture condition	consistency density index	structure, geology
	None	None	S1	0–0.6	CH	Clay. Highly plastic, dark brown. Some organic in top half	M ≈ Pl.	St.	Soil & subsoil
			S2	0.6–2.0 (1.0)	CH	Clay. Highly plastic, grey.	M < Pl	V St	Launceston Beds
			S3, S4, S5, S6	2.0–5.1 (3.0, 4.0, 5.0)	CH	Clay. Highly plastic, brown	M < Pl; M ≤ Pl; M = Pl	V St.; St	Clay; Soft Zone

Hole stopped. Required depth reached (5.1 m.)

5 cm

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – BOREHOLE

borehole no. H2

sheet 1 of 1

project	Cracked house investigation, S. Pickett, Windermere.
location	South Lawn (Launceston side)
co-ordinates	5008-54261
R.L.	3 m
inclination	vertical
bearing	-
drill type	Triefus
drill method	Auger
drill fluid	none
hole commenced	6.8.86
hole completed	6.8.86
drilled by	B.E. Cox
logged by	W.R.Moore
checked by	R.C.Donaldson

penetration 1 2 3	support	water	notes samples, tests	depth (metres)	classification symbol	material (soil type: plasticity or particle characteristics, colour, secondary and minor components)	moisture condition	consistency density index	structure, geology
	None	None	S1		OH	Clay. Organic, black, highly plastic	M = Pl	S	Soil
						Clay. Highly plastic, dark brown			Subsoil
			S2		CH	Clay. Highly plastic, brown.	H ≤ Pl	St	Clay Launceston Beds
				1.0					
			S3				M < Pl	V St	
				2.0					
			S4						
				3.0					
			S5						
				4.0					
			S6					St	
				5.0					
			S7	6.0		Hole stopped 6.0 m. Required depth reached.			

hand penetrometer kPa: 25 50 100 200 400

5 cm

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – BOREHOLE

borehole no. H3

sheet 1 of 1

22/25

project: Cracked house investigation, S. Pickett, Windermere

location: East Lawn, S.E. corner of house

co-ordinates	5008-54261	drill type	Triefus	hole commenced	7.8.86
R.L.	5m	drill method	Auger	hole completed	7.8.86
inclination	Vertical	drill fluid	none	drilled by	B.E. Cox
bearing	-			logged by	W.R. Moore
				checked by	R.C.Donaldson

penetration 1 2 3	support	water	notes samples, tests	metres depth	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	structure, geology
	None	None			OH	Clay. Organic, black. Highly plastic	M	S	Soil
			S1	1.0	CH	Clay. Highly plastic, yellow	M = Pl	S	Yellow Clay
			S2, S3	2.0, 3.0	CH	Clay. Highly plastic, brown with ironstone grit.	M < Pl	V St	Launceston Beds
						Clay. Highly plastic, grey			
			S4, S5, S6, S7	4.0, 5.0, 6.0		Clay. Highly plastic, brown.		V S ↓ H; H	Clay
						Hole stopped at 6 m. Required depth reached.			

hand penetrometer kPa: 25, 50, 100, 200, 400

5 cm

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – BOREHOLE

borehole no. S1

sheet 1 of 1

23/25

project	Survey line 2, west end. Windermere Road.	location	By old shop, S. side of Windermere Road.

co-ordinates	5006-54261	drill type	Triefus	hole commenced	26.6.86
R.L.	15 m	drill method	Auger	hole completed	26.6.86
inclination	Vertical	drill fluid	None	drilled by	B.E. Cox
bearing	-			logged by	W.R. Moore
				checked by	R.C.Donaldson

penetration 1 2 3	support	water	notes samples, tests	metres R.L. / depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
	None	None	S1			GC & OH	Gravel & organic clay. Gravel, coarse Road base coarse. Clay - Black organic				Fill & Soil
			S2	1.0		CH	Clay. Highly plastic, yellow-brown	M = Pl	S		Clay and gravel
			S3	2.0		GC	Clay with gravel. Clay, highly plastic, yellow. Gravel, coarse quartzite pebbles. 10%	M < Pl	V St		

Hole stopped by gravel at 1.8 m.

5 cm

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – BOREHOLE

borehole no. S2

sheet 1 of 1

24/25

project	Survey line No. 2 West End Windermere Road	location	10 m east of Hole 2. Windermere Road

co-ordinates	5006-54261	drill type	Triefus	hole commenced	26.6.86
		drill method	Auger	hole completed	26.6.86
R.L.	15 m			drilled by	B.E. Cox
inclination	vertical	drill fluid	none	logged by	W.R. Moore
bearing	-			checked by	R.C.Donaldson

penetration 1 2 3	support	water	notes samples, tests	metres R.L. / depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
	None	None				GC	Gravel. coarse, poorly sorted. Road base coarse with some clay.				Fill
				1.0		OL	Silt. Organic, fine, low plasticity	M	S		Soil layer
						CH	Clay. High plasticity, brown	M ≡ Pl			Clay
			S1			GC	Clay with gravel. Gravel coarse. Clay, highly plastic.	M < Pl	St		interbedded
			S2	2.0		CH	Clay. Highly plastic, brown	M <	V St		with gravel
			S3			GC	Clay with gravel. Clay, highly plastic, brown. Gravel, coarse.	Pl			
							Drill refused at 3.3 m. Heavy gravel.				

5 cm

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – BOREHOLE

borehole no. S3
sheet 1 of 1

project: Survey line No. 2, East End Windermere Road
location: Northside of Windermere Road

co-ordinates: 5013-54261
R.L.: 15 m
inclination: vertical
bearing: -
drill type: Triefus
drill method: Auger
drill fluid: none
hole commenced: 27.6.86
hole completed: 27.6.86
drilled by: B.E. Cox
logged by: W.R. Moore
checked by: R.C. Donaldson

penetration 1 2 3	support	water	notes samples, tests	metres R.L. / depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
	None	None	S1	1.0		GC	Gravel and clay. Gravel, coarse. Clay, highly plastic, grey-brown.	M = Pl	S		Gravelly clay
			S2					M < Pl	St		
			S3	2.0		CH	Clay. Highly plastic, light brown	D	H		Clay

Hole stopped. Required depth for survey pole.

5 cm