

1982/21. Slope stability investigation of a proposed subdivision near Station Road, Norwood.

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Abstract

The slope stability of a proposed subdivision at Norwood has been investigated. The subdivision is situated on the slope between an elevated terrace and the flood plain of the North Esk River, the slope having an average angle of 18° flattening to 6° at the foot. The slope is underlain by Tertiary aged clay and sandy clay. Five auger holes were drilled and undisturbed samples were taken for shear box testing. Auger samples were subjected to X-ray analysis to determine the mineralogy. The stability analyses show that although there may be some risk of unstable conditions developing, with some precautions this risk could be minimised to an acceptable level for development to proceed.

INTRODUCTION

Mr M. King of Launceston requested advice on the stability of land owned by Mr A.E. Wilkes near the corner of Penquite and Station Roads, Norwood [EQ15250950]. The land has been classed as Class IV on the Tamar Valley Landslip Zone Map, i.e. an area of old landslips or adjacent areas. Advice was given to the Town and Country Planning Commissioner on 13 January 1982 that subsurface investigations should be undertaken to examine soil and groundwater conditions at the site. Drilling was suggested because of the deep seated nature of the probable old slips that occur in the area; it was thought that any old slip surface zones that may occur in the area would be too deep for backhoe holes to reach.

On 23 February Mr King requested that subsurface investigations be undertaken and five holes were drilled (fig. 1) during the week ending 9 April. The results of these holes are given in Appendix 1. As the holes were auger drilled, the logs must be regarded as only indicating the approximate levels of the various materials. These holes were used to select zones for taking undisturbed samples for strength measurements from further holes drilled nearby.

RELIEF AND GEOLOGY

The proposed subdivision is situated on slopes formed between an elevated, relatively flat terrace area and the flood plain of the North Esk River. Average slope angles directly beneath the terrace are up to 18°, with local slopes greater than 20°. The rear boundary of the proposed subdivision extends around the middle of this slope. At the foot of the slope the land surface flattens to about 6° over most of the subdivision, although near the south boundary there is a small area of internal drainage. The slope angles on the front of the lots towards Penquite Road increase to 10-12°.

The material underlying the subdivision is composed of Tertiary clay and sandy clay with minor fine-grained clayey quartz gravel horizons. The sand in some locations is composed mainly of quartz, while in others it has some quartz but is mainly of clayey material (possibly weathered feldspar grains). The terrace top has quartz gravel at some locations.

Samples of material from the auger holes have been X-ray analysed to examine the mineralogy, especially the clay mineral content. Results of

these are given in Table 1. Samples 1 to 10 are disturbed auger samples, while Samples 11-15 are from undisturbed tube samples. These determinations were made mainly on the fine silt and clay size fractions of the samples.

Table 1. RESULTS OF X-RAY ANALYSIS

| Sample No. | Hole | Depth (m) | Montmorillonite | Illite | Kaolinite | Gibbsite | Quartz | % >63µm |
|------------|------|-----------|-----------------|--------|-----------|----------|--------|---------|
| 1 | 1 | 5.5- 6.4 | F | | S | | S | |
| 2 | 1 | 9.1-10.0 | F | | M | | S | |
| 3 | 2 | 6.7 | F | | F | F | F | |
| 4 | 2 | 7.9- 8.2 | F? | | M | | S | 30 |
| 5 | 3 | 2.7- 3.7 | | | M-S | | M-S | |
| 6 | 3 | 7.3- 8.2 | F | | S | | S | 7 |
| 7 | 4 | 5.5- 7.3 | VF? | | F-M | | S | 30 |
| 8 | 4 | 2.7- 4.6 | F | | S | | S | |
| 9 | 5 | 0.9- 1.8 | F | | S | | S | |
| 10 | 5 | 2.7- 5.5 | F? | | S | M | VS | 33 |
| 11 | 1 | 3.7 | F | | VS | | VS | 21 |
| 12 | 1 | 8.2 | F? | | S | | VS | 26 |
| 13 | 2 | 4.1- 4.6 | F? | | S | S | M-S | 18 |
| 14 | 3 | 4.6 | F-M | F-M | S | | S | |
| 15 | 3 | 7.3 | M | M | S | | VS | |

F = faint; M = moderate; S = strong; VS = very strong (peak heights - may suggest relative abundance).

To give an indication of the quantity of material of sand size or greater some samples were sieved with a 63µm screen to separate the silt and clay sizes from the larger fractions. Most of the material greater than 63µm in each sample consists of quartz grains, mainly of fine sand size, together with small quantities of ilmenite and magnetite of similar size and a few larger limonite fragments.

STRENGTH TESTS

Because there is some doubt about the continued stability of the area, samples were selected for strength measurements. These measurements were performed in a shear box and approximate figures of peak and residual values for angle of internal friction (ϕ) and cohesion (c) have been determined in each case.

Hole 1 (8.2 m depth)

$$\begin{aligned}
 c'_p &= 19 \text{ kPa} & \phi'_p &= 24^\circ \\
 c'_r &= 13.6 \text{ kPa} & \phi'_r &= 18.5^\circ
 \end{aligned}$$

Hole 2 (4.1-4.6 m depth)

| | | | |
|--------|------------|-----------|----------|
| c'_p | = 13.5 kPa | ϕ'_p | 23.5° |
| c'_r | = 7-11 kPa | ϕ'_r | 16.5-21° |

STABILITY ANALYSES

Using the above information on factors of strength and a study of the plots used to obtain the above figures, A. Moon of the Department of Mines undertook stability calculations. The residual values were used on the assumption that a slip surface may already exist. Plots of strength data are seldom perfect straight lines and a range of values for cohesion (down to 5 kPa) and a slightly lower angle of internal friction (16°) were used in the analyses. Two methods of analysis for sections CD and EF (fig. 2) were used - infinite slope and Cousins' stability charts. Calculations from the infinite slope method using the worst test results ($c' = 5$ kPa and $\phi' = 16^\circ$) and a high water level (one metre below the surface) show that the land along these sections is only marginally stable. Similar results are obtained using Cousins' stability charts. Stability becomes more certain with higher strength values and lower water levels.

Two methods of analysis were used for section AB - Bishop's simplified method and Cousins' charts. Again, analysis using Cousins' charts shows that for the lowest strength factors and the highest water levels, stability is only marginal, taking a large slip circle into consideration. Bishop's method for a similar slip circle and using similar strength values indicates that the area along this section could be stable.

Analysis of the steep cutting above Penquite Road shows an unstable situation if residual strength values are considered. It is probably inappropriate to use residual values in this case and if peak values are used, the stability situation is much better. Only small shallow slumps are likely in this area (as have occurred in the recent past).

DISCUSSION OF STABILITY

Using the results obtained from strength tests, the stability analyses show that with very high subsurface water levels, unstable conditions involving large sections of the land could occur. There is no record of the level the water table reaches during wet periods, but the highest water levels used in the analysis may not occur in practice or may only occur in extremely rare situations. It should be possible to decrease the chance of the water table rising to levels where the stability is endangered by ensuring good surface drainage and the cutting of french drains two metres or more deep in three equally spaced locations down the slope (from the flattish area towards Penquite Road). If the water table can be kept to a low level, there is a greater likelihood that stability will be maintained.

Another factor that could influence stability is the removal of material from the slopes near the road. This material is helping maintain stability and any removal will increase the risk of instability over a large part of the subdivision.

CONCLUSIONS AND RECOMMENDATIONS

Investigations show that the area could become unstable if water levels rise towards the surface. This assumes that a slip surface is

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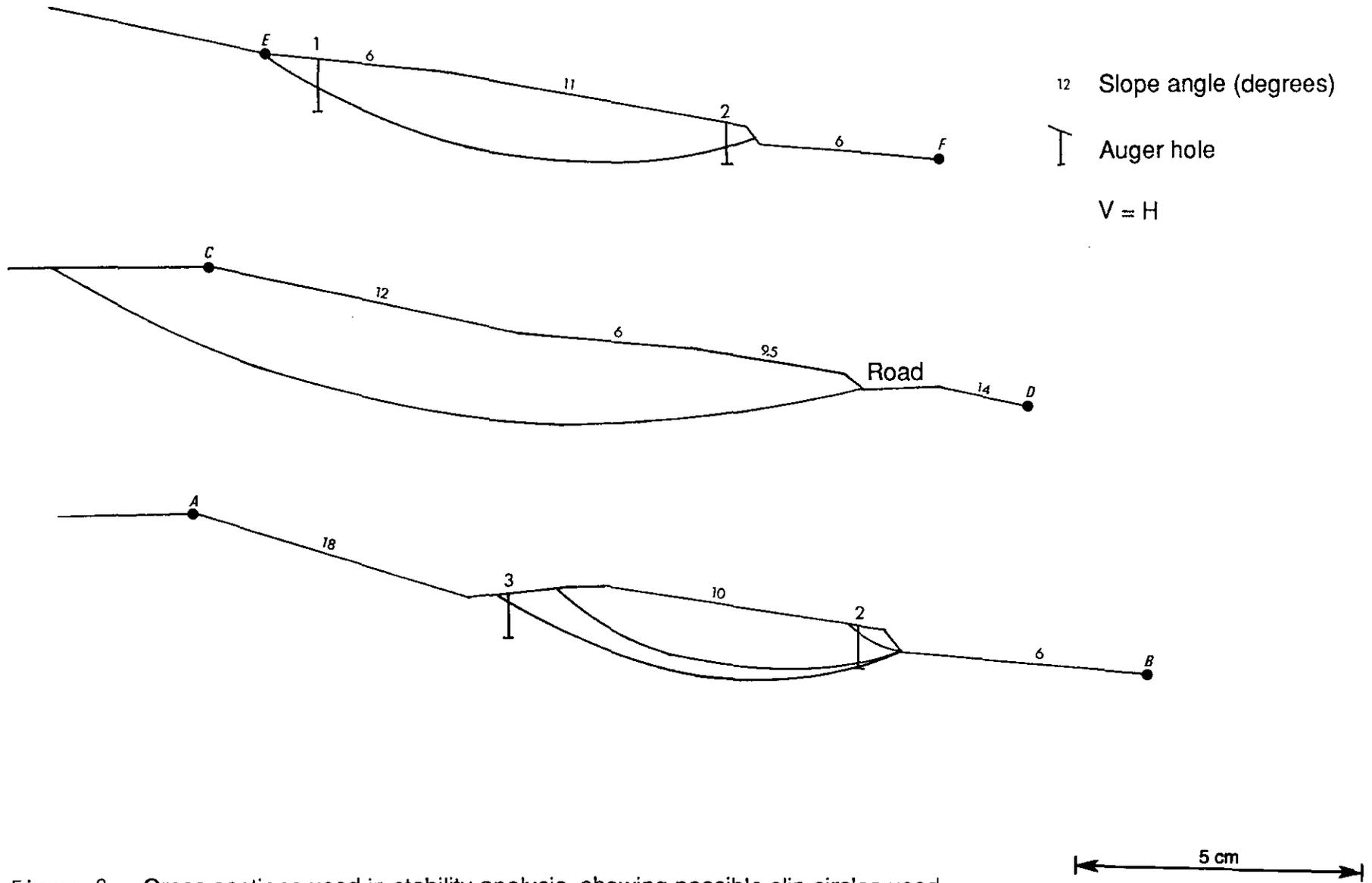


Figure 2. Cross sections used in stability analysis, showing possible slip circles used.

already present (thus the use of residual strength values in the stability analyses) and that the surface passes through material of similar strength to that tested. Use of the higher values of residual strength determined from the strength tests suggests that the area should be stable. If no slip surface (from an old slip) exists, strength values approaching the peak values would be used in stability analyses and these would suggest stable conditions.

It cannot be said that there is no risk of landslip affecting the subdivision, but even taking the lowest possible strength factors indicated from the tests, measures can be taken to minimise the risk. This would involve drainage measures to ensure the water level does not approach the surface. Surface storage of water, such as in swimming pools from which leaks could occur, is not recommended.

Removal of material from the area just above Penquite Road should be avoided, as this will have a destabilising effect. If, as planned, access roads will be cut in this area, specially designed and drained retaining walls, which will provide the support that is removed, should be installed. An access road which parallels Penquite Road with entrances to each lot would avoid excavations and steepening of existing slopes.

If the lots are developed, houses should be sited on the flatter portions away from the steeper slopes. Lot 1 takes in some of the steeper land with only a narrow flat area along the northern boundary. A house on this lot, as outlined at present, would only be recommended near Penquite Road and on the most northerly part. Here a house would be far enough from the steep slope so as not to be affected in the event of a landslip occurring. An alternative would be to move the boundary of the lot 15-20 m to the north; it should then be possible to safely build a house on low sloping land at any point over the whole length of the northern boundary.

The presence of montmorillonite in the clay suggests that the clay may have expansive properties as in some other parts of the Tamar Valley. Foundations of houses should be designed so that the effects of drying and wetting are reduced. This is usually achieved by extending the foundations to depths where these fluctuations are only small.

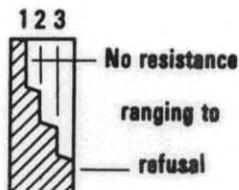
In conclusion, although some risk exists of unstable conditions developing, with the above precautions, it should be possible to reduce this to an acceptable level to allow development to proceed.

[3 June 1982]

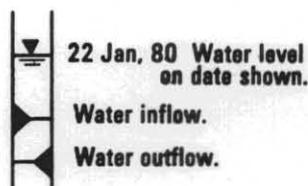
EXPLANATION SHEET FOR ENGINEERING LOGS

Borehole and excavation log

Penetration



Water



Notes - samples and tests

- U50 Undistributed 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 than the plastic limit.

Consistency

- VS Very soft.
- S Soft.
- F Firm.
- St Stiff.
- VSt Very stiff.
- H Hard.
- Fb Friable.

hand penetrometer (kPa)

- < 25
- 25 - 50
- 50 - 100
- 100 - 200
- 200 - 400
- > 400

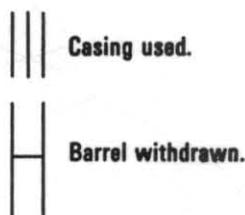
Notes: X on log is test result
— is range of results.

Density index

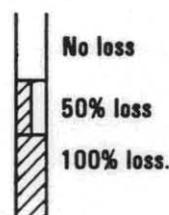
- VL Very loose. 0 - 15
- L Loose. 15 - 35
- MD Medium dense. 35 - 65
- D Dense. 65 - 85
- VD Very Dense 85 - 100

Cored borehole log

Case - lift



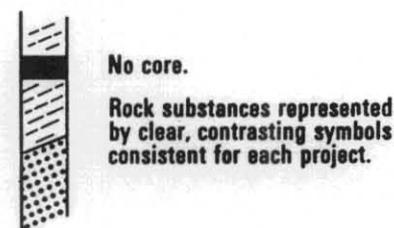
Fluid loss



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

- EL Extremely low.
- VL Very low.
- L Low.
- M Medium.
- H High
- VH Very high.
- EH Extremely high.

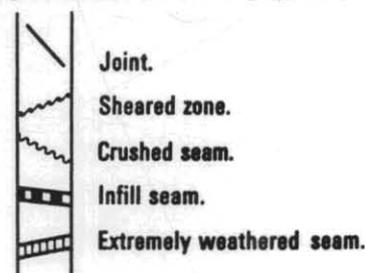
point load strength index $I_{5(50)}$ (MPa)

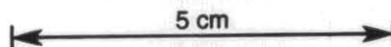
- < 0.03
- 0.03 - 0.1
- 0.1 - 0.3
- 0.3 - 1
- 1 - 3
- 3 - 10
- > 10

Note: X on log is test result.

Significant defects

Significant defects shown graphically.

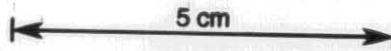




ENGINEERING LOG - BOREHOLE

| | | | | | |
|----------------------------------|------------|---------------------------------|---------------------|----------------|--------|
| project A.E. Wilkes' subdivision | | location Penquite Road, Norwood | | | |
| co-ordinates | EQ15250950 | drill type | Proline auger drill | hole commenced | - |
| R.L. | - | drill method | - | hole completed | - |
| inclination | Vertical | drill fluid | - | drilled by | - |
| bearing | - | | | logged by | W.L.M. |
| | | | | checked by | - |

| 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 penetr- ometer kPa | | | | structure, geology |
|----------------------|------------------|----------------------------|-------------------------|-------------|--------------------------|--|-----------------------|------------------------------|----------------------------------|----|-----|-----|---|
| | | | | | | | | | 25 | 50 | 100 | 200 | |
| | | | | | CL CH | Soil - silty clay, light grey. Underlain by clay, greenish brown | D | F | | | | | Soil |
| | | | 1 | | CL or CH | Sandy silty clay - brown, fragmented | M | S-F Fb | | | | | Unconsolidated Tertiary sediments |
| | | | 2 | | CH - CL | Silty clay - red and grey mottled, fragmented | M | S-F Fb | | | | | Unconsolidated Tertiary sediments |
| | | | 3 | | CH - CL | Sandy silty clay - red and grey, fragmented | M | S-F Fb | | | | | Unconsolidated Tertiary sediments |
| | | | 4 | | CH - CL | Sandy silty clay - light brown, fragmented, some quartz grit fragments in clay, occasional quartz pebbles up to 15 mm across | M | S-F Fb | | | | | Unconsolidated Tertiary sediments |
| | | | 5 | | | | | | | | | | |
| | | | 6 | | CH - CL | Sandy silty clay, red, fragmented, some pebbles - may be contamination from ground above | W | S Fb | | | | | Unconsolidated Tertiary sediments |
| | | | 7 | | CH - CL | Sandy silty clay, brown fragmented occasional pebbles - may be contamination from gravel above. | W | S Fb | | | | | Unconsolidated Tertiary sediments |
| | | | 8 | | | | | | | | | | |
| | | | 9 | | CH - CL | Sandy clay light grey, plastic | M | F | | | | | Unconsolidated Tertiary sediments |
| | | | 10 | | | | | | | | | | |

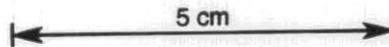


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ENGINEERING LOG - BOREHOLE

| | | | | | | |
|--------------|--------------------------|--|--------------|------------------------|----------------|--------|
| project | A.E. Wilkes' subdivision | | location | Penquite Road, Norwood | | |
| co-ordinates | EQ15250950 | | drill type | Proline auger drill | hole commenced | - |
| R.L. | - | | drill method | - | hole completed | - |
| inclination | Vertical | | drill fluid | - | drilled by | - |
| bearing | - | | | | logged by | W.L.M. |
| | | | | | checked by | - |

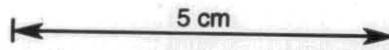
| penetration 1 2 3 | support | water | notes samples, tests | metres R.L. depth | graphic log | classification symbol | material soil type: plasticity or particle characteristics, colour, secondary and minor components. | moisture condition | consistency density index | hand penetr- ometer kPa 25 50 100 200 400 | structure, geology |
|----------------------|---------|-------|----------------------------|-------------------------|-------------|--------------------------|---|-----------------------|------------------------------|---|---|
| | | | | | | | | | | | |
| | | | | | | CH CL | Soil, silty clay, grey-green passing into brown plastic silty clay | D-M | F | | Soil |
| | | | | 1 | | CH CL | Sandy silty clay, brown | M | F Fb | | Unconsolidated Tertiary sediments |
| | | | | 2 | | CH CL | Sandy silty clay, brown | W | S Fb | | Unconsolidated Tertiary sediments |
| | | | | 3 | | | | | | | |
| | | | | 4 | | | | | | | |
| | | | | 5 | | CH CL | Sandy silty clay, lighter brown | M W | S-F Fb | | Unconsolidated Tertiary sediments |
| | | | | 6 | | | | | | | |
| | | | | 7 | | | | | | | |
| | | | | 8 | | CH CL | Sandy silty clay, mottled grey and brown | W | S Fb | | Unconsolidated Tertiary sediments |
| | | | | 9 | | | | | | | |



ENGINEERING LOG - BOREHOLE

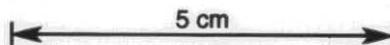
| | | | | | |
|--------------|--------------------------|--|----------------|------------------------|--|
| project | A.E. Wilkes' subdivision | | location | Penquite Road, Norwood | |
| co-ordinates | EQ15250950 | | drill type | Proline auger drill | |
| R.L. | - | | drill method | - | |
| inclination | Vertical | | drill fluid | - | |
| bearing | - | | hole commenced | - | |
| | | | hole completed | - | |
| | | | drilled by | - | |
| | | | logged by | W.L.M. | |
| | | | checked by | - | |

| 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 penetr- ometer kPa 25 50 100 200 400 | structure, geology |
|----------------------|------------------|----------------------------|-------------------------|-------------|--------------------------|---|-----------------------|------------------------------|---|-----------------------------------|
| | | | | | | | | | | |
| | | | | | CL | Soil - silty red-brown clay, passing into sandy silty clay | D | F Fb | | Soil |
| | | | 1 | | CH CL | Sandy clay - red-brown | M | F Fb | | Unconsolidated Tertiary sediments |
| | | | 2 | | CH CL | Sandy clay - grey and red | M | F Fb | | Unconsolidated Tertiary sediments |
| | | | 3 | | | | | | | |
| | | | 4 | | CH CL | Sandy silty clay - red | M | F Fb | | Unconsolidated Tertiary sediments |
| | | | 5 | | | | | | | |
| | | | 6 | | CL CH | Sandy silty clay - brown, some clay - grey | M | F Fb | | Unconsolidated Tertiary sediments |
| | | | 7 | | CH CL | Silty clay - grey and brown | M | F | | Unconsolidated Tertiary sediments |
| | | | 8 | | | | | | | |
| | | | 9 | | CH CL | Clay with coarse sand to grit fragments | M | F | | Unconsolidated Tertiary sediments |



ENGINEERING LOG - BOREHOLE

| penetration | | support water | notes samples, tests | metres | | graphic log | classification symbol | material soil type: plasticity or particle characteristics, colour, secondary and minor components. | moisture condition | consistency density index | hand penetr- ometer kPa | structure, geology |
|----------------------------------|---|---------------------------------|----------------------------|-------------------------|-------|--------------------------------|--|---|-----------------------|------------------------------|----------------------------------|-----------------------------------|
| 1 | 2 | | | R.L. | depth | | | | | | | |
| project A.E. Wilkes' subdivision | | location Penquite Road, Norwood | | co-ordinates EQ15250950 | | drill type Proline auger drill | | hole commenced - | | | | |
| R.L. - | | inclination Vertical | | bearing - | | drill method - | | drilled by - | | logged by W.L.M. | | |
| drill fluid - | | checked by - | | | | | | | | | | |
| | | | | | | ML | Soil, silty, grey passing into sandy silty clay soil, red and grey-brown | D | F | | | Soil |
| | | | | 1 | | CL | Sandy silty clay, red-brown, occasional quartz pebbles | M | F Fb | | | Unconsolidated Tertiary sediments |
| | | | | 2 | | CL | Gravelly clay, quartz fragments | M | F | | | " |
| | | | | 3 | | CL | Sandy silty clay, medium brown to dark brown | M | F Fb | | | Unconsolidated Tertiary sediments |
| | | | | 4 | | | | | | | | |
| | | | | 5 | | CL | Sandy silty clay, light brown, occasional pebbles, becoming a little more sandy towards the end. | M | F Fb | | | Unconsolidated Tertiary sediments |
| | | | | 6 | | | | | | | | |
| | | | | 7 | | | | | | | | |
| | | | | 8 | | | | | | | | |



ENGINEERING LOG - BOREHOLE

| | | | | | |
|--------------|--------------------------|--|----------------|------------------------|--|
| project | A.E. Wilkes' subdivision | | location | Penquite Road, Norwood | |
| co-ordinates | EQ15250950 | | drill type | Proline auger drill | |
| R.L. | - | | drill method | - | |
| inclination | Vertical | | drill fluid | - | |
| bearing | - | | hole commenced | - | |
| | | | hole completed | - | |
| | | | drilled by | - | |
| | | | logged by | W.L.M. | |
| | | | checked by | - | |

| 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 penetr- ometer kPa 25 50 100 200 400 | structure, geology |
|----------------------|------------------|----------------------------|-------------------------|-------------|--------------------------|---|-----------------------|------------------------------|---|-----------------------------------|
| | | | | | | | | | | |
| | | | | | ML | Soil - silty passing into clay - brown, plastic | D | St | | Soil |
| | | | 1 | | CH | Clay - red-brown, plastic | M | St | | Unconsolidated Tertiary sediments |
| | | | 2 | | CL | Sandy clay - mainly quartz sand grains, red-brown, iron oxide seams | M | F | | Unconsolidated Tertiary sediments |
| | | | 3 | | CL | Sandy clay light brown | M | F | | Unconsolidated Tertiary sediments |
| | | | 4 | | | | | | | |
| | | | 5 | | | | | | | |
| | | | 6 | | | | | | | |