

1980/11. The stability of a building allotment at Armidale Street, Norwood, Launceston

*D.J. Sloane*

*Abstract*

An area of land adjacent to Armidale Street, Norwood, is underlain by up to 0.75 m of silt and gravelly silt (ML) topsoil which overlies at least 3.25 m of clay (CH) and sandy clay (CL). The clay has a high plasticity and natural moisture content and has high values for Atterberg Limits. Linear shrinkage is high and two tests indicated residual values of the angle of internal friction as  $11^\circ$  and  $21^\circ$ .

Stability analysis indicates that the area has short term stability but is unstable in the long term, assuming zero cohesion and fully saturated conditions. The area is considered stable in the long term if development is restricted to areas of slope  $11^\circ$  or less and slope drainage is provided to a depth of three metres.

Care in foundation design and drainage will be required in view of the clay properties measured.

INTRODUCTION

At the request of Mr A. Wilkes of Boiton Hill farm, an investigation was conducted to determine the stability of a building allotment adjacent to Armidale Street, Norwood [EQ149099]. A visual site inspection indicated that the allotment was marginally suitable for building development. A geotechnical investigation was required to confirm the stability of the allotment. Three test pits were dug by backhoe in the areas indicated on Figure 1. These holes were logged in detail and selected samples were taken for natural moisture content, Atterberg Limit, linear shrinkage and shear box testing. Two samples were taken for clay mineral identification. Vane shear and hand penetrometer tests were performed in each test pit.

The adjacent area to the north has been subdivided by Dunorm Pty Ltd and Sculthorpe Pty Ltd and has been subject to geotechnical investigations by Geotechnical Engineering Pty Ltd and Smith and Sale Pty Ltd for Campbell-Smith, Phelps, Pedly and Associates.

Geotechnical Engineering concluded that the maximum slopes of  $11^\circ$  will be stable in the long term if drains are constructed to maintain the water table at a depth of at least 1.2 m below ground surface. Smith and Sale concluded that excavations in excess of 1.5 m depth should be effectively retained and adequately drained. They also concluded that if the water table is kept below 1.5 m by constructing drains, then the slope should be stable. Counterfort drains to a depth of four metres were to be constructed to maintain a low water table.

It is considered that part of the adjacent area to the north has the appearance of an old landslip and hence development of the area should be treated with caution. The area is located in Zone IV of the Tamar Valley Landslip Zone Map, a zone described as 'Old landslips and adjacent areas. No building permitted pending further studies'.

TOPOGRAPHY

The area is situated at the top of a valley slope adjacent to the

LOCATION: ARMIDALE ST.  
BOITON HILL FARM

SUBURB: NORWOOD

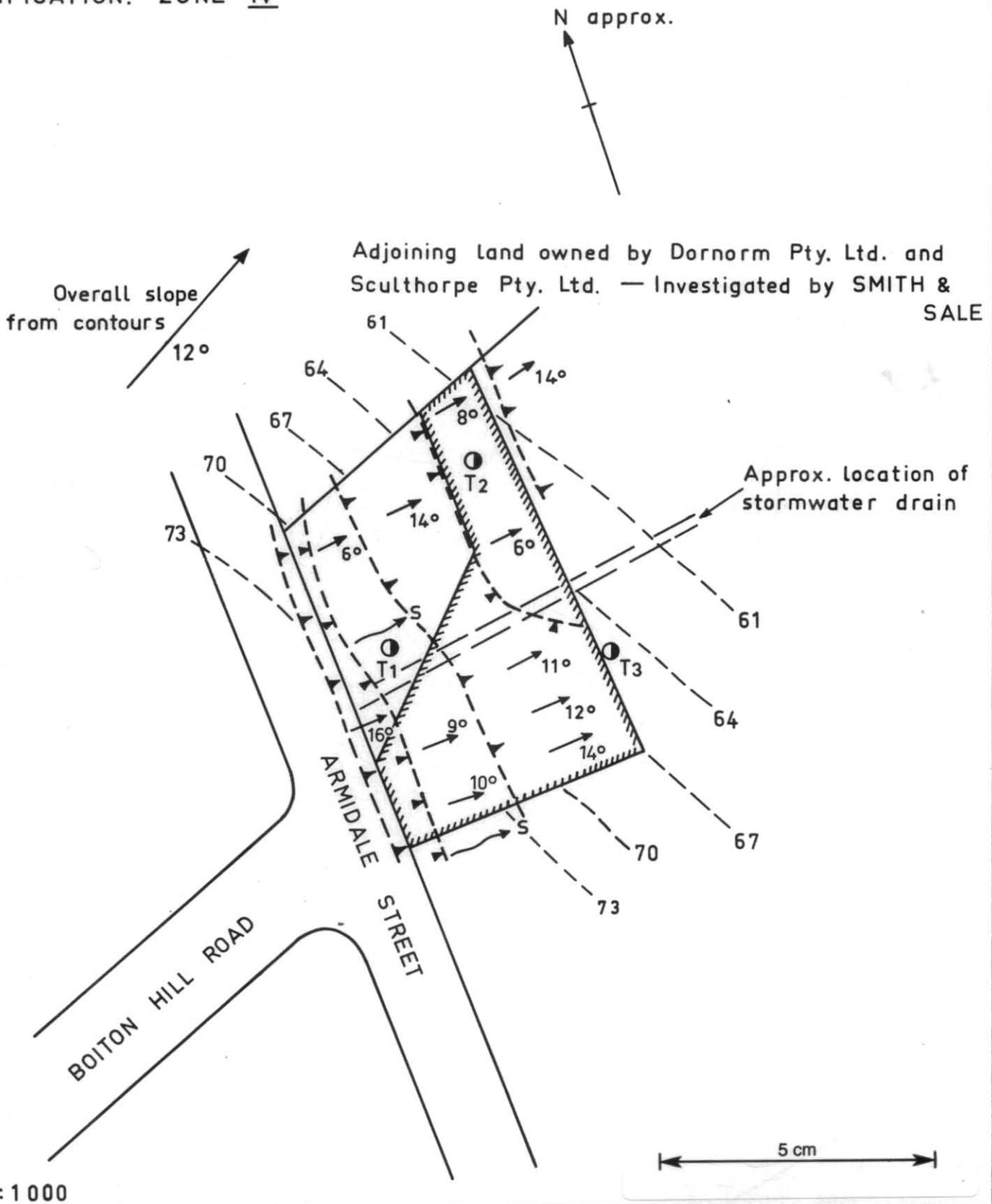
GEOLOGIST: D. J. SLOANE 2/9

OWNER: A. WILKES

TOWN: LAUNCESTON

DATE 11/3/80

TAMAR LANDSLIP ZONE MAP  
CLASSIFICATION: ZONE IV



SCALE 1:1000

LEGEND

- 20° Slope angle and direction
- Change of slope - downslope side indicated
- Change of slope - upslope side indicated
- Area in which building advised
- " " " septic tank "
- Approx. Test Pit Location
- Stormwater seepage

North Esk River floodplain to the east. These slopes have resulted from downcutting of the North Esk River through Tertiary sediments. The area immediately to the west is flat lying or gently undulating. The allotment in question has two benches sloping between 6° and 10° and separated by an 11° to 14° slope facet (fig. 1).

GEOLOGY

The area is underlain by Tertiary sediments. These sediments are considered to have been deposited in a lacustrine environment and consist of clay, sand and quartzite gravel.

TEST PITS

Detailed logs of the three backhoed test pits are presented in Appendix 1. In summary, the northern half of the block is underlain by 0.75 m of gravelly silt topsoil containing well rounded quartzite pebbles. This in turn overlies clay and clayey sand which has yellow-brown and grey mottles. The area adjacent to test pit T3 is underlain by more sandy sediments containing ironstone layers. Here, 0.2 m of silty gravel overlies sandy clay and clayey sand. This test pit also shows a columnar fissure structure, a result of soil dessication, to a depth of one metre. These fissures will allow water to penetrate more readily into the subsurface material and indicate the mechanism by which water may cause saturation and subsequent instability after prolonged dry spells.

X-ray diffraction analysis of two samples of clay indicate that the clays are composed of quartz and the clay mineral kaolinite.

CLAY ANALYSIS-GEOMECHANICAL PROPERTIES

Four samples have been tested for various properties.

*Field moisture content*

Field moisture contents were moderate to high and are as follows. T1(2 m) - 36.7%; T1(3 m) - 32.7%; T2(1 m) - 26.8%; and T2(2 m) - 31.0%. These figures are expressed as a percentage of dry weight.

*Liquid limit*

Liquid limits of two samples tested were in close accordance. Values are 100.8% from pit T1 at a depth of two metres and 112.5% from pit T2 also at a depth of two metres. These values are considered very high.

*Plasticity index*

This value indicates the moisture content range over which the clay remains plastic. Values ranged from 73.2% for pit T1 at a depth of two metres to 84% for pit T2, also at a depth of two metres. The clay can consequently be classified as of high plasticity and compressibility on Casagrandes (1948) plasticity chart classification. The values also indicate high toughness and dry strength of the clay.

*Linear shrinkage*

Linear shrinkage values measured from pits T1 and T2 at a depth of two metres were high and closely corresponding. Measured values were 18% and 19% respectively.

*Vane shear testing*

*In situ* vane shear tests provide an indication of the shearing resistance of the clay and its sensitivity. Peak values were generally greater than 120 kPa, apart from readings at a depth of one metre in pit T1, where peak values averaged 48 kPa. This result was due to clay softening by seepage water originating from stormwater drains along Armidale Street. Residual values were generally in the range 10 to 17 kPa with most between 15 and 17 kPa, indicating a clay sensitivity ranging from about 5 to 10 as measured by vane shear. These sensitivity values appear too high and should be taken only as an indication of clay sensitivity.

*Hand penetrometer tests*

Hand penetrometer test results were generally greater than 500 kPa. Test pit T1 showed lower values of 200 kPa at a depth of one metre where seepages had softened the clay. These readings indicate that for the prevailing moisture conditions, unconfined compressive strengths are generally about 250 kPa and reflect the high dry strength of the clay.

*Drained, slow shear box testing*

Angles of internal friction ( $\phi'_r$ ) were determined on samples from depths of two metres in test pits T1 and T2. Values varied markedly from 21° in test pit T2 to 11° in test pit T1. Corresponding values of cohesion ( $C'$ ) also varied from 11 kPa to 24.5 kPa respectively. These values are residual values determined on remoulded clay samples.

Most clay properties can be considered consistent in test pits T1 and T2. Variations do occur in  $\phi'_r$  and  $C'$  values.

STABILITY ANALYSIS

For the purposes of this stability analysis, the lowest laboratory measured value of the angle of internal friction ( $\phi'_r$ ) will be used. The maximum slope angle of 14° measured by Brunton compass will also be considered in the calculations. The area has been considered as a simple embankment failure problem with a height of five metres and a slope of 14°. The following clay and slope properties have been considered.

cohesion	( $C'$ ) = 11 kPa
embankment height	(H) = 5 m
angle of internal friction	( $\phi'_r$ ) = 11°
slope angle	( $\alpha$ ) = 14°
bulk density (assumed)	( $\gamma$ ) = 17.6 kPa

*Slab failure (Skempton and Delory, 1957)*

Assuming the above clay properties and that the embankment is in a fully saturated condition, calculations indicate a range of safety factors from 1.2 for a slab of three metres thickness to 1.7 for a two metre slab thickness. The embankment is considered stable in the short term. From the geometry of the slope, a slab failure plane at a depth of two metres is most likely. However for long term stability, cohesion should be considered as zero, and consequently the factor of safety reduces to 0.8 dry and 0.4 fully saturated. It appears a little unreasonable to assume  $C' = 0$  as slopes in the area are often greater than 11°. In the case of a two metre slab failure, only 17% of the lowest laboratory measured cohesion is required

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to produce a factor of safety of 1.0 if the slope is drained to a depth of two metres. Considering a two metre slab failure and the zero cohesion condition, a slope angle of  $11^\circ$  will have a safety factor of 1.0 for fully drained conditions. It therefore appears that for long term stability, drainage to a depth of at least two metres and a maximum slope angle of  $11^\circ$  is required.

#### *Cousins (1978) stability charts*

Assuming fully saturated conditions and the clay properties listed above, the stability charts indicate that the safety factor is 1.5 for critical slip circle failure (toe failure or otherwise with a depth factor of 1.5). This factor increases to 1.75 if the slope is drained to a depth of two metres. The cohesion must be reduced to only 30% of its lowest measured value to produce a safety factor of 1.0.

The embankment appears stable from slip circle failure. The safety factor will be increased if drainage is provided.

#### CONCLUSIONS

Stability analysis indicates that the  $14^\circ$  slope is stable for slip circle failure. The safety factor will be increased if the slope is drained. Considering slab failure, the most likely depth at which this could occur is between two and three metres. The slope is stable in the short term but unstable in the long term when considering  $C' = 0$ . If the slope angle is reduced to  $11^\circ$  and the slope is fully drained to a depth of two to three metres, then this condition is considered stable. It is therefore advised that any building be restricted to slopes of  $11^\circ$  or less and slope drainage to a depth of three metres is installed. The area considered suitable for development has been indicated on Figure 1. The small area of  $14^\circ$  in this region has been included due to the nature of sediments encountered in test pit T3. These sandy sediments with ironstone bands are considered more stable than the clayey sediments. It is also suggested that a french drain be installed to a depth of three metres. This drain could be installed along the stormwater drain which is to be constructed by the developer and whose approximate position is shown on Figure 1. It is also recommended that no excavation should be greater than 1.5 m in depth. Any such excavation should be adequately retained with provision for drainage behind such retaining structures. The provision of extra french drains which could link to the main drain as described above will undoubtedly assist in lowering water tables and hence increasing the stability of the area. In view of the measured clay properties, especially linear shrinkage values, it may be prudent to consult a qualified geotechnical engineer who may advise on suitable foundation design.

These decisions have been made with reference to observations of naturally occurring slopes. Analysis has been used as an additional tool to indicate slope stability. Residual clay properties have been used and long term stability conditions have been inspected, with zero cohesion.

#### REFERENCES

- CASAGRANDES, A. 1948. Classification and identification of soils. *Trans ASCE* 113:901-992.
- COUSINS, B.F. 1978. Stability charts for simple earth slopes. *J.geotech. eng.Div.ASCE* 104:268-279.

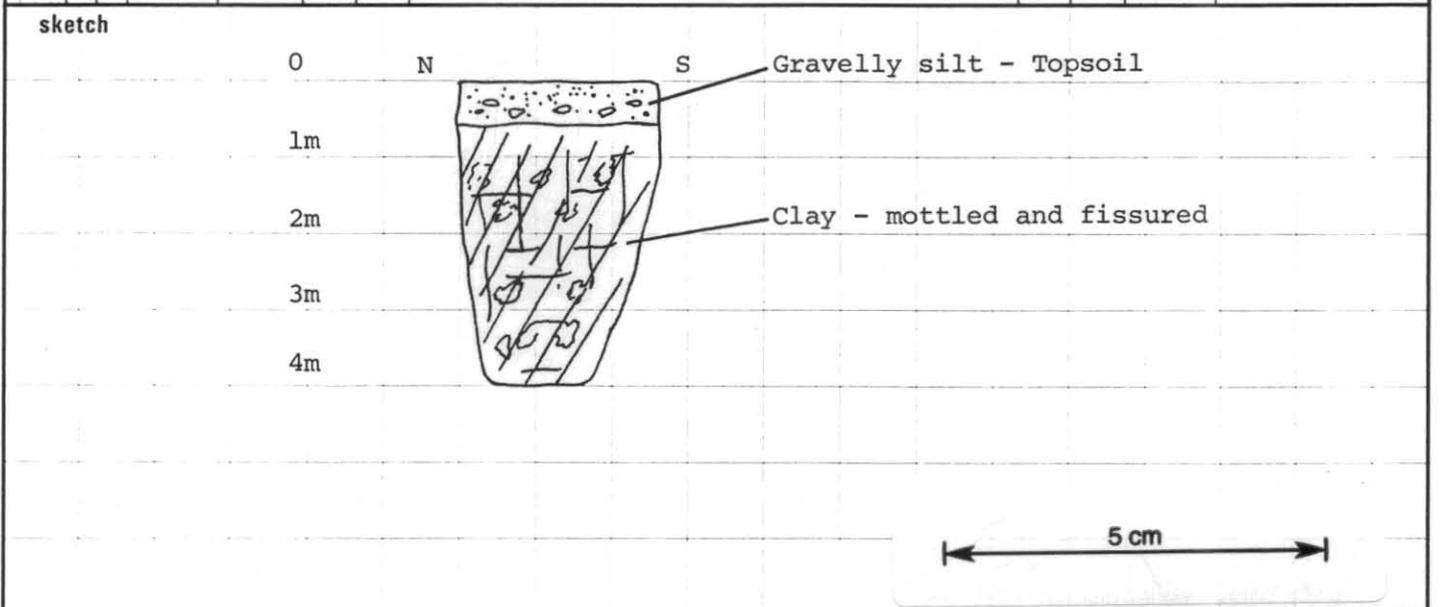
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SKEMPTON, A.W.; DELORY, F.A. 1957. Stability of natural slopes in London  
Clay. *Proc.4th Int.Conf.Soil.Mech.Found.Eng.* 2:378-381.

[5 May 1980]

# ENGINEERING LOG - EXCAVATION

project <b>A. Wilkes</b>	location <b>Armidale St, Norwood, Launceston</b>
co-ordinates <b>EQ149099</b>	exposure type <b>Backhoe pit</b>
R.L. $\approx$ <b>71 m</b>	pit commenced
excavation dimensions <b>2.5 m x 1 m x 4 m</b>	equipment
	operator
	pit completed
	logged by <b>D.J. Sloane</b>
	checked by

penetration	support	notes	metres	graphic log	classification symbol	material	moisture condition	consistency	density index	hand penetrometer kPa	structure, geology
1 2 3		samples, tests	R.L. depth			soil type: plasticity or particle characteristics, colour secondary and minor components				25 50 100 200 400	
		Vane shear tests D kPa seepage D 48p, 9.6r	0		ML	Silt; Slight plasticity. Dull yellowish brown. 15% well rounded quartz pebbles to 5 cm dia. Some granular quartz particles - 2-3 mm dia. Angular to rounded low sphericity. Some iron-stone pebbles.	D	S			Friable and crumbly structure Al soil horizon
			1		CH	Clay; High plasticity. Reddish brown to light grey some orange and bright yellowish brown mottles. Trace fine quartz sand	M	St			Fissured
		D 110p, 12.5r	2		CH	Clay; High plasticity. Grey and yellow-orange mottled clay. Some minor reddish brown Yellow-brown and surrounding grey. Some root fragments along fissures.	D	VSt			Fissured. Some cutans along fissures. Grey maybe gleying? Yellow-brown clay at centre of fissure blocks.
		D >125p, 14.4r	3							>500	
		D >125p, 17.7r	4							>500	



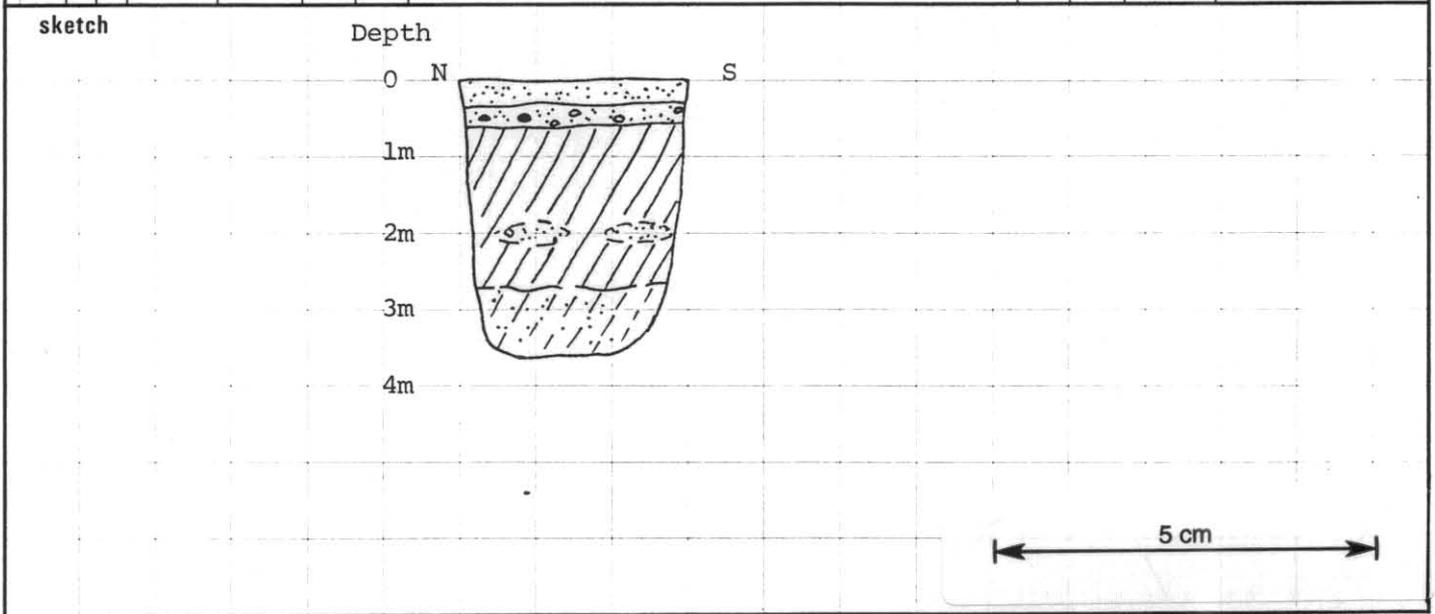
# ENGINEERING LOG - EXCAVATION

excavation no. T2  
sheet 1 of 1

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project <b>A. Wilkes</b>	location <b>Armidale St., Norwood, Launceston</b>
co-ordinates <b>EQ149099</b>	exposure type <b>Backhoe pit</b>
R.L. <b>≈ 63 m</b>	pit commenced
excavation dimensions <b>2.5m x 1m x 3.5m</b>	pit completed
	logged by <b>D.J.Sloane</b>
	checked by
	operator

penetration	support	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	structure, geology
1 2 3			0		ML	Gravelly silt; Greyish yellow-brown. 40% quartz granules mean dia. 2.5mm. Some ironstone granules. Minor bright brown ironstaining.	D	L		'Crumby' open texture-honeycomb. Al soil horizon.
		D >125p 17.7r	1		SP	Gravelly sand; Dull yellow-orange. Coarse quartz sand. Some quartz granules - angular to well rounded. High to low sphericity. 20% well rounded quartz pebbles to 5cm diameter. Occasional yellow-brown mottling.			>500	Open honeycomb type texture.
		D >125p 16.8r	2		CH	Clay; High plasticity. Dull yellowish brown-bright brown mottled clay. Some medium quartz sand. Sandy in patches.	D	H		Some fissuring. Some sandy lenses.
		D >125p 17.7r	3		SC	Clayey sand; Low plasticity. Yellowish brown. Greyish yellow-brown mottles, Medium-fine quartz sand. Some silt.	D	VD	>500	
		D	4						>500	



# ENGINEERING LOG - EXCAVATION

excavation no. T3  
sheet 1 of 1

project	A. Wilkes	location	Armidale St., Norwood, Launceston
co-ordinates	EQ149099	exposure type	Backhoe pit
R.L.	≈ 65 m	equipment	
excavation dimensions	2.5m x 1m x 3.5m	operator	
		pit commenced	
		pit completed	
		logged by	D.J. Sloane
		checked by	

penetration	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	structure, geology
										kPa	
1 2 3			Vane shear tests kPa			GM	Silty gravel; 50% silt, 40% quartz gran- ules angular to well rounded. High to low sphericity. Dull yellowish brown. 10% Quartz pebbles to 8cm dia. Well rounded - moderate to low sphericity.	D	L	25 50 100 200 400	Al soil hori- zon
			D >125	1		CL	Sandy clay; Moderate plasticity. Dull yellow orange - bright brown mottles. Dull yellowish brown clay cutans on fissures. 20% fine sand-quartz and some feldspar?	D	H	>500	Columnar (des- sicated) peda- structure.
			D >125	2			Ironstone				
			>125p D4.8r	3		SC	Clayey sand; low plasticity. Medium- fine sand. Bright yellowish brown, some light grey. Clay cutans along fissures - brown. Contains Ironstone layers	D	VD	>500	Some fissures to 1 m.
				3		CH	Clay; High plasticity. Grey-yellow brown mottles. Some medium sand.	D	H	>500	Pod of clay above Ironstone layer
				3		SC	Clayey sand; As above.	D			
				4							

