UR1990_26   '/13

Tasmania Department Of Resources and Energy

Division of Mines and Mineral Resources — Report 1990/26

Shallow subsurface investigations of a proposed subdivision at Newstead

by B. D. Weldon

Abstract

Shallow subsurface investigations of a proposed subdivision development at Newstead encountered a clay with low effective residual cohesion and angle of internal friction. Stability analysis indicates that factors of safety in excess of 1.5 will not be achieved without the installation of deep drainage provisions. Sand encountered on the property is a potential aquifer which could soften clays and contribute to slope instability. Development of part of the property is not recommended without further investigation.

INTRODUCTION

At the request of Engineering Design and Supervision an examination was made of a subdivision proposal in the Launceston suburb of Newstead. The property was initially inspected to determine the rock type and to assess if any further investigations were necessary. The initial inspection indicated variations in soil composition, identified some steep slope segments, and detected an area of seepage. Test pits were considered necessary to determine the sub-surface conditions.

GEOLOGY

The area has been mapped by Longman (1964) as Tertiary age sediments. These consist of clay, sandy clay and sand, sometimes with lignite. The sand consists of grains of extremely weathered rock which can be re-moulded to clay. Some fine-grained quartz is also present. The property is made up of several slope segments. A steep slope of 19–20° occurs beyond the western boundary of the property. From about 10 m beyond this boundary the steep slope flattens to about 11° before steepening again to about 13°. The eastern one-third (approximately) of the property is gently sloping at about 6°. The overall slope appears to contain a moderately-sloping bench which could be the heel or head-scarp area of an ancient landslide.

Several back-hoe test pits were excavated at the approximate locations indicated on Figure 1. The engineering logs are presented in Appendix 1. Slickensided high plasticity clay was encountered in test pit 1. The slickensides indicate prior mass movement of the clay. In test pit 5 a sand was encountered interlayered with clay. Sand was not encountered in any other test pit.

LABORATORY TESTING

Two large block samples of slickensided clay were submitted to the Division of Mines and Mineral Resources laboratory for cyclical shear box testing. This test provides strength parameters which are necessary for stability analysis of the slope. The results of the tests are summarised in Table 1. These results indicate relatively low strength parameters for the material.

X-Ray diffraction analysis of the samples showed a variation in the quantity of the clay mineral montmorillonite. This clay exhibits volume instability (i.e. it will swell when allowed to wet up and will shrink when allowed to dry out). The quantity of this clay present may

Table 1. *Results of laboratory tests*

Test pit	Depth (m)	Effective residual angle of internal friction (degrees)	Effective residual cohesion (kPa)	X-Ray diffraction		
				KAOL (%)	MONT (%)	GOETH (%)
1	1.5	17	4	80	5	15
1	3.0	13	3	75	20	5

KAOL = kaolinite
MONT = montmorillonite
GOETH = goethite

TASMANIA DEPARTMENT OF MINES
SITE PLAN

OWNER: for EDS   STREET/ROAD: GEOLOGIST: BGW
SUBURB: NEWSTEAD   TOWN/CITY: DATE: Sept 90

☐ ZONE III	
⊠ ZONE IV	

SCALE: 5 cm

▼▼▼	Convex break of slope (profile form:)	NA — Suitable area for building
△△△	Concave break in slope (profile form:)	NA — Suitable area for septic outfall
✦✦✦	Ridge crest	↗ 16° — Slope angle and direction
✕✕✕	Gully	

C ⌐ D line of cross-section
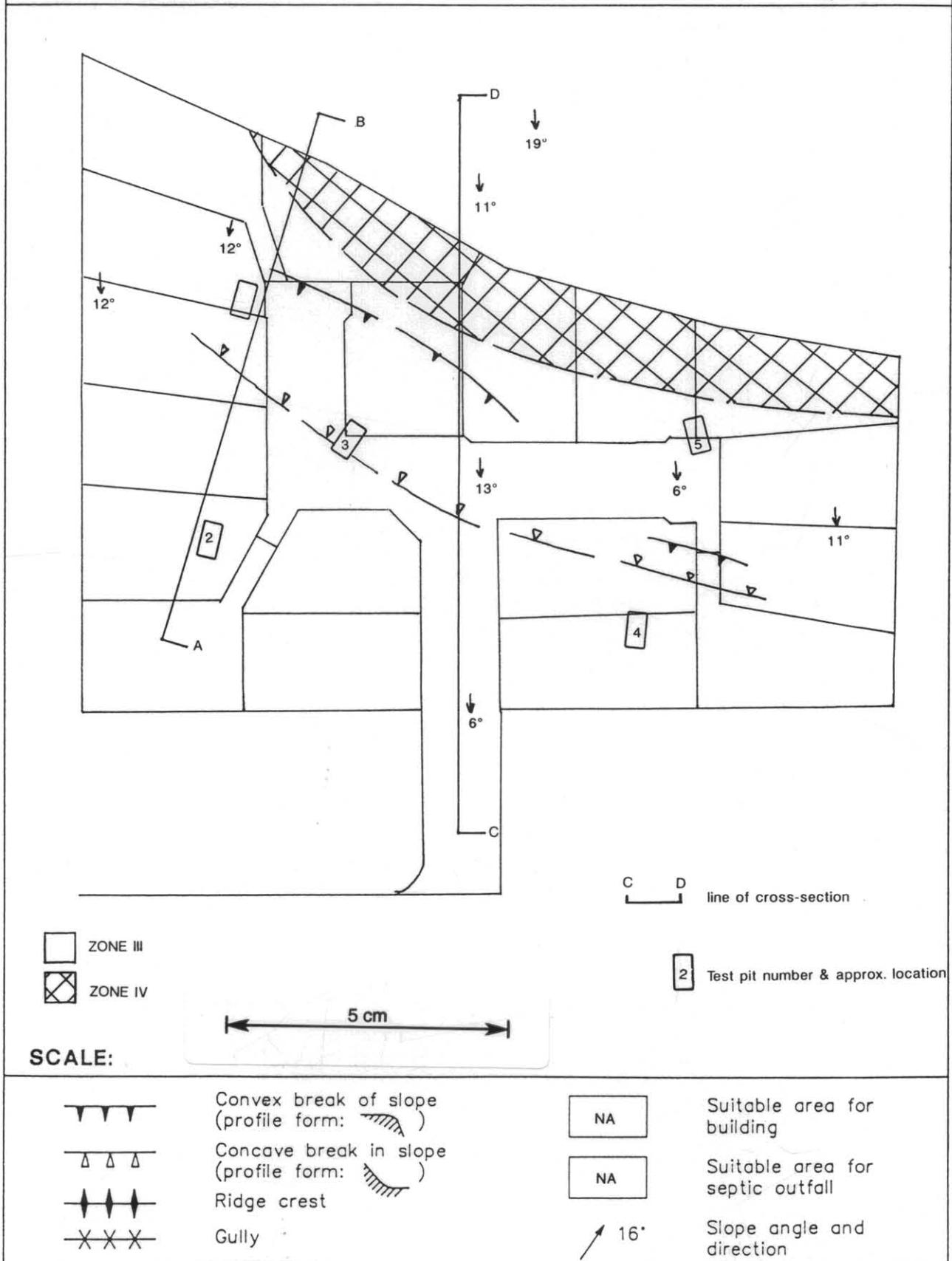
2 Test pit number & approx. location

Figure 1. *Proposed subdivision at Newstead showing approximate location of test pits, Tamar Valley advisory landslip zones, and cross-section lines used in stability analysis.*

also account for the variation in the effective residual angle of internal friction between the two samples.

STABILITY ANALYSIS

Slope stability analysis is performed using the Factor of Safety concept. A commonly used definition is:

$$Factor\ of\ Safety = \frac{Sum\ of\ restoring\ forces\ on\ the\ slope}{Sum\ of\ driving\ forces\ on\ the\ slope}$$

The restoring forces include the strength parameters (cohesion and friction) and the mass of that part of the soil resisting movement. The driving forces include pore pressure, load on the soil and the mass of that part of the soil provoking movement. It can be seen from the above equation that the driving and restoring forces are equal when the Factor of Safety (FS) equals one. The FS becomes less than one when the driving forces predominate and failure occurs.

Stability analysis is usually simplistic and does not take into account the variability of natural materials. For this reason, where the FS is less than 1.3 the slope is considered to be at high risk from landslide movement and building should not be allowed. For FS between 1.3 and 1.5, the slope has medium risk of landslide movement and extreme caution is required in allowing building to proceed. Where the FS is greater than 1.5, the slope is generally considered safe to build upon.

Stability analysis has been performed using SLIPCIRC (Weldon, 1987), a GW-BASIC program for Bishop's (1955) simplified slip circle stability analysis. The analysis has been performed on the slope profiles shown in Figure 2. The locations of the profile lines are shown on Figure 1. An infinite number of potential circular failure arcs are possible on these slopes. The end points of the failure arcs shown on Figure 2 were carefully choosen after due consideration of the geology and geomorphology of the area. The failure arcs shown on Figure 2 are the critical failure arc for that slope between the choosen end points (i.e. the arc which produces the lowest FS when all parameters other than the radius of the circular failure arc are held constant).

Figure 3 shows the results of the stability analysis using the strength parameters as determined for this site by the shear box test for the sample at 3 m depth in test pit 1. It has been assumed that the soil strength parameters obtained from the shear box testing are applicable to the materials at greater depths. The results are shown on Figure 3 as Factor of Safety in relation to pore pressure ratio. A pore pressure ratio of 0.5 occurs when the assumed slide is totally saturated, a ratio of 0.25 occurs when the assumed slide is half saturated, and a ratio of 0.0 occurs when the assumed slide is fully drained.

The most conservative stability analysis is for an effective residual cohesion of zero. This type of analysis is used to determine the long term stability of a slope. The assumption is that small movements of parts of the potential landslide mass over long periods of time tend to reduce the internal effective residual cohesion to zero. Under these circumstances, for the critical failure arcs shown in Figure 2, FS is always less than 1.5 at any pore

pressure ratio for the laboratory determined strength parameters. FS is equal to 1.3 when the pore pressure ratio is about 0.05 (section A–B) and 0.01 (section C–D). This is equivalent to a slope which is drained to a depth of 6.9 m (section A–B) and 6.3 m (section C–D) at the point where the assumed sliding mass is thickest. In summary, drainage of the slope must be assured to a depth of 6.9 m below natural ground level if an FS of 1.3 or better is to be obtained for long term stability.

The laboratory tests indicate that some effective residual cohesion is available in the short term to resist slope movement. In mobilising this effective residual cohesion, a FS equal to 1.5 occurs at a pore pressure ratio of about 0.04 (section A–B) and 0.02 (section C–D). These pore pressure ratios are equivalent to a slope which is drained to a depth of 7.1 m (section A–B) and 6.1 m (section C–D). If a less conservative approach is adopted where a FS as low as 1.3 is considered acceptable, the pore pressure ratio must not exceed 0.18 (section A–B) and 0.17 (section C–D). This is equivalent to a slope which is drained to a depth of 4.9 m below natural ground level (section A–B) and to 4.3 m (section C–D).

DISCUSSION

The morphology of the area suggests that ancient landslide activity has occurred, and part of the proposed subdivision has been zoned on the Tamar Valley advisory landslip zone map as zone IV (i.e. old landslides and adjacent areas). The balance of the proposed subdivision is mapped as zone III (i.e. potential landslide areas). A cautious approach is therefore warranted in assessing the impact of subdividing the area. For this reason, a factor of safety greater than 1.5 should be achieved over the land to be subdivided. The stability analysis indicates that this is only achieved by providing drainage to depths in excess of six metres.

In test pit 5 a sand layer was encountered from 1.4 m below surface level to the end of the excavation at 2.5 m. The sand is a potential aquifer which could feed water into the subsurface beneath the proposed subdivision. It is noted that the Lawrence Vale landslide area is on the opposite slope of the ridgeline to the proposed subdivision. The Lawrence Vale landslide is considered to be a complex of slip lobes motivated by a moist, fully softened sandy clay which occurs downslope of a fine sand pressure aquifer. The sand encountered in test pit 5 was moist, not wet and it is not considered to be the fine sand pressure aquifer associated with the Lawrence Vale landslide. It does however indicate that the geological setting of the proposed subdivision is similar to the Lawrence Vale area. The Tertiary sediments were deposited under deltaic conditions in which the locus of deposition changes rapidly. Both lenses and sheets of sand can be expected in the area. A possible connection to the Lawrence Vale fine sand pressure aquifer should not be discounted.

Council services and individual house connections on sloping sites with doubtful stability require separate comment. Drainage is of the highest importance in minimising the risk of landslide movements. Under no circumstances should the proposed subdivision proceed without connection to the town sewerage scheme. The risk of landslide movement can be reduced by ensuring that all drainage lines are set at a high angle to the contours

(preferrably at right angles, but in no case less than 30°). Backfilling of services or connections must ensure free drainage of any surface or subsurface water which enters. Service connections must therefore have a minimum fall of 3%.

The most important drainage requirements are associated with individual houses. No service line, stormwater or waste water disposal should be placed on the upslope side of a house. Placement is preferred at either side and at the highest possible angle to the contours.

CONCLUSIONS

Shear box laboratory testing of a clay sample from 3 m depth in test pit 1 produced a relatively low value of effective residual cohesion of 3 kPa and an effective residual angle of internal friction of 13°.

Stability analysis using these strength parameters, which are assumed to apply to the materials at greater depth, and a carefully selected circular failure arc indicates that drainage of the slope to depths in excess of 6 m must be installed and effectively maintained to obtain acceptable factors of safety.

Drainage to the required depth is considered difficult to achieve, and the construction of drains may have a deleterious effect on stability because of the removal of lateral support.

The geological setting shows similarities to that at Lawrence Vale, where a landslide destroyed 30 homes between 1956 and 1970.

RECOMMENDATIONS

Slopes in excess of 13° which are underlain by clay have a high risk of landslide movement. Such areas are delineated on Figure 4. Building should not be permitted in these areas. It is also advised that council service trenches should not traverse these areas.

Further investigation of the subsurface conditions beneath the steeper parts of the slope is warranted. The basic assumption that the soil strength parameters obtained from the shear box testing can be applied to the materials at greater depth may not be valid. In the absence of these investigations, development of the property should be restricted to the area delineated on Figure 4. Additional investigations may determine that parts of the area, considered here to be unsuitable for development (refer Figure 4), are not at risk from landslide movement and therefore could be developed.

A revision of the subdivision layout will be necessary.

The clay soil which occurs over the majority of the subdivision proposal contains the clay mineral montmorillonite which exhibits volume instability. House sites should therefore be classified according to Australian Standard 2870-1986 (Residential slabs and footings) which provides details for the appropriate footing design for the determined site classification.

REFERENCES

AS 2879–1986. *Australian Standard 2879–1986. Residential slabs and footings*. Standards Association of Australia.

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

LONGMAN, M. J. 1964. *One Mile Geological Map Series. K/55-7-39. Launceston*. Department of Mines, Tasmania.

WELDON, B. D. 1987. SLIPCIRC — a GW-BASIC program for Bishop's simplified slip circle stability analysis on an IBM-compatible microcomputer. *Unpubl. Rep. Dep. Mines Tasm.* 1987/51.

[11 October 1990]

CIRCULAR STABILITY ANALYSIS: AMY RD

Section A-B showing critical circle
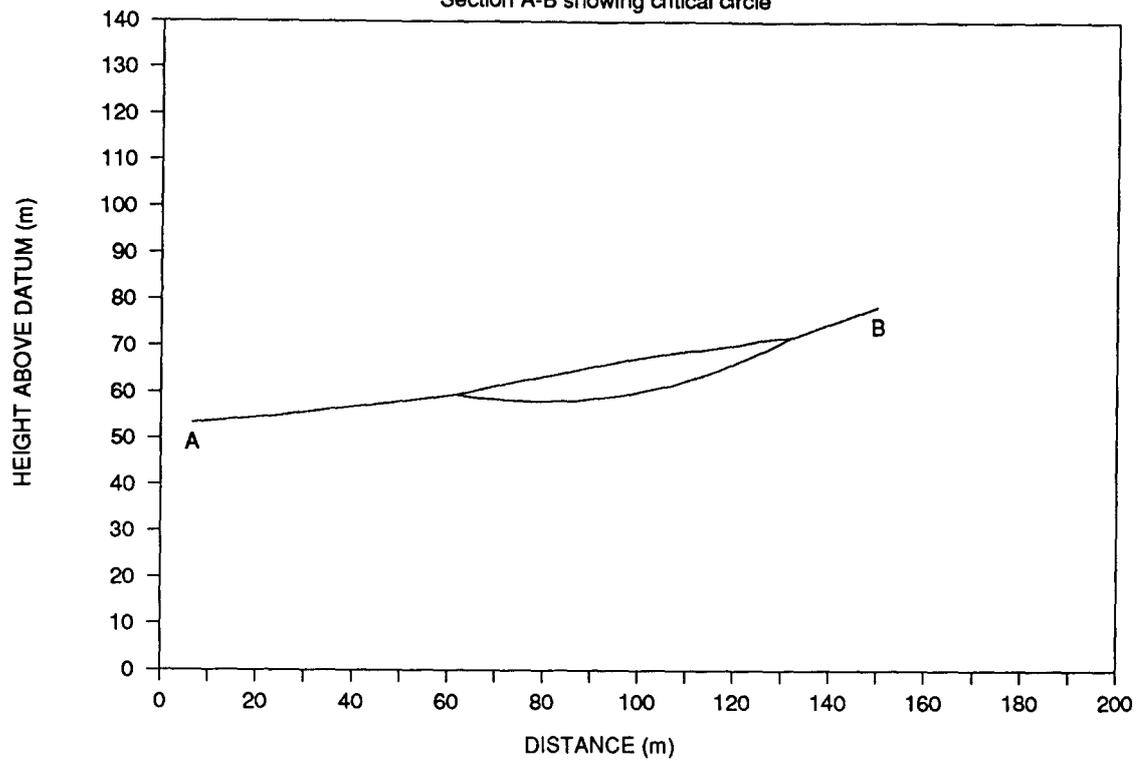
CIRCULAR STABILITY ANALYSIS: AMY RD

Section C-D showing critical circle
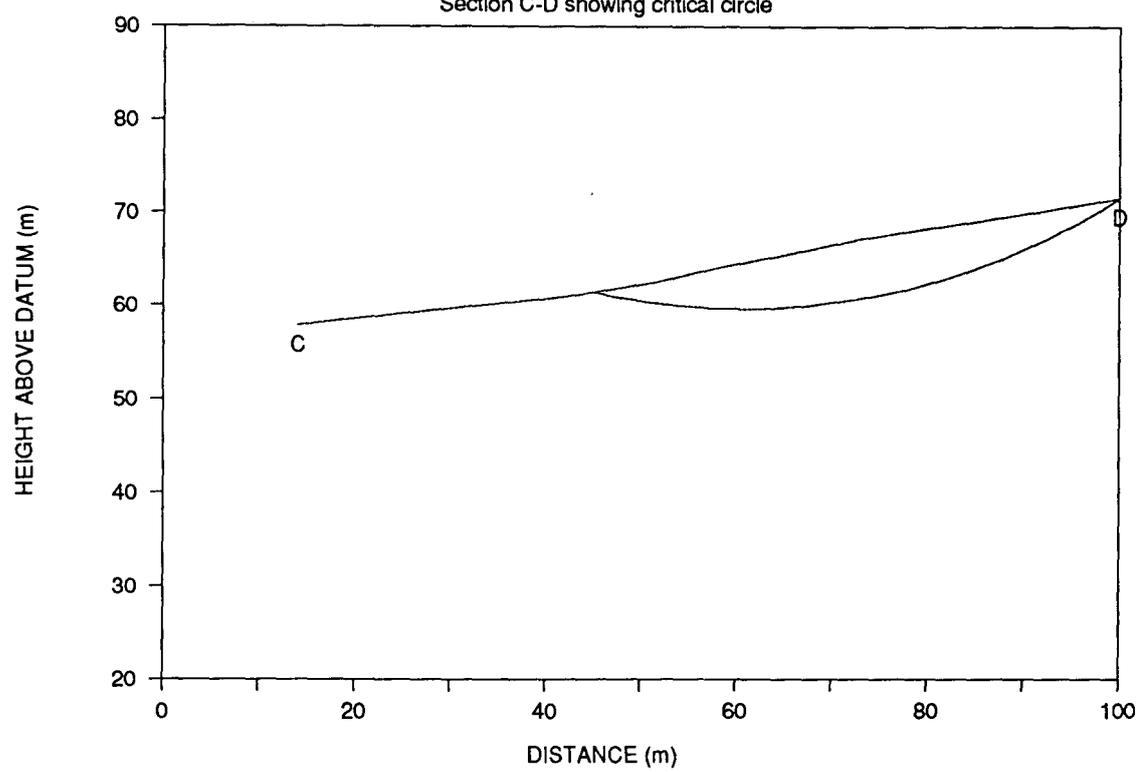
Figure 2. *Cross sections used for circular stability analysis, showing the critical failure arc between selected end points.*

|← 5 cm →|
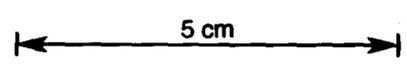
CIRCULAR STABILITY ANALYSIS: AMY RD

Section A-B ø'= 13 degrees
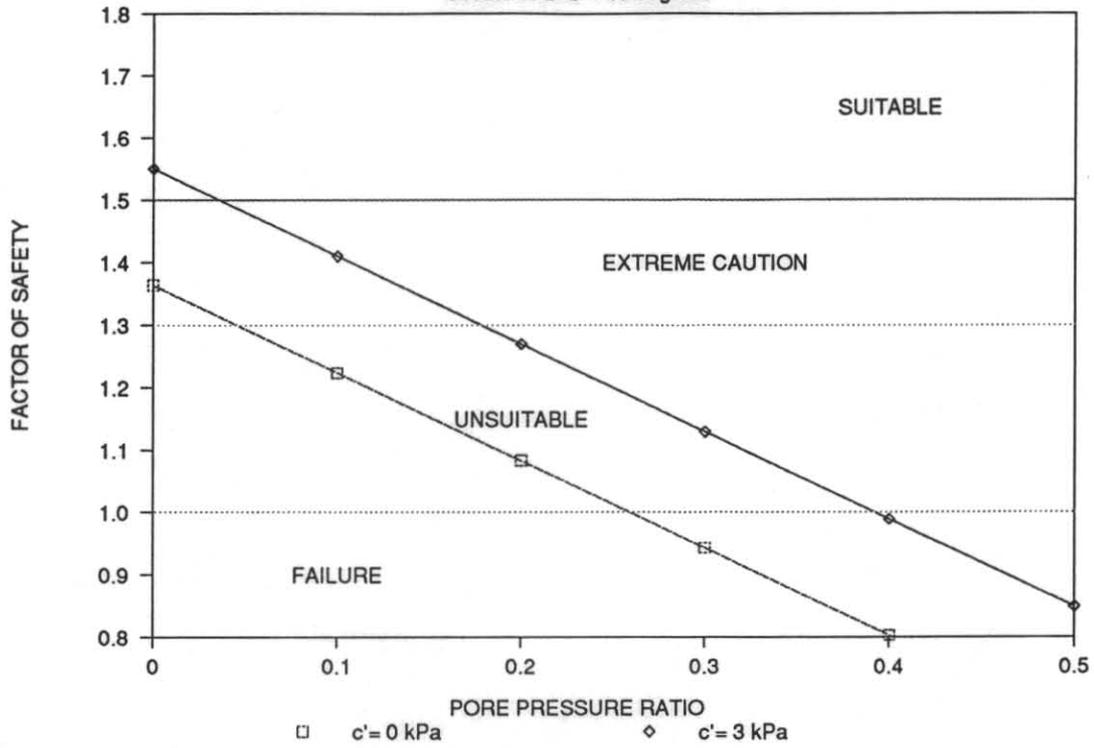
CIRCULAR STABILITY ANALYSIS: AMY RD

Section C-D ø'= 13 degrees
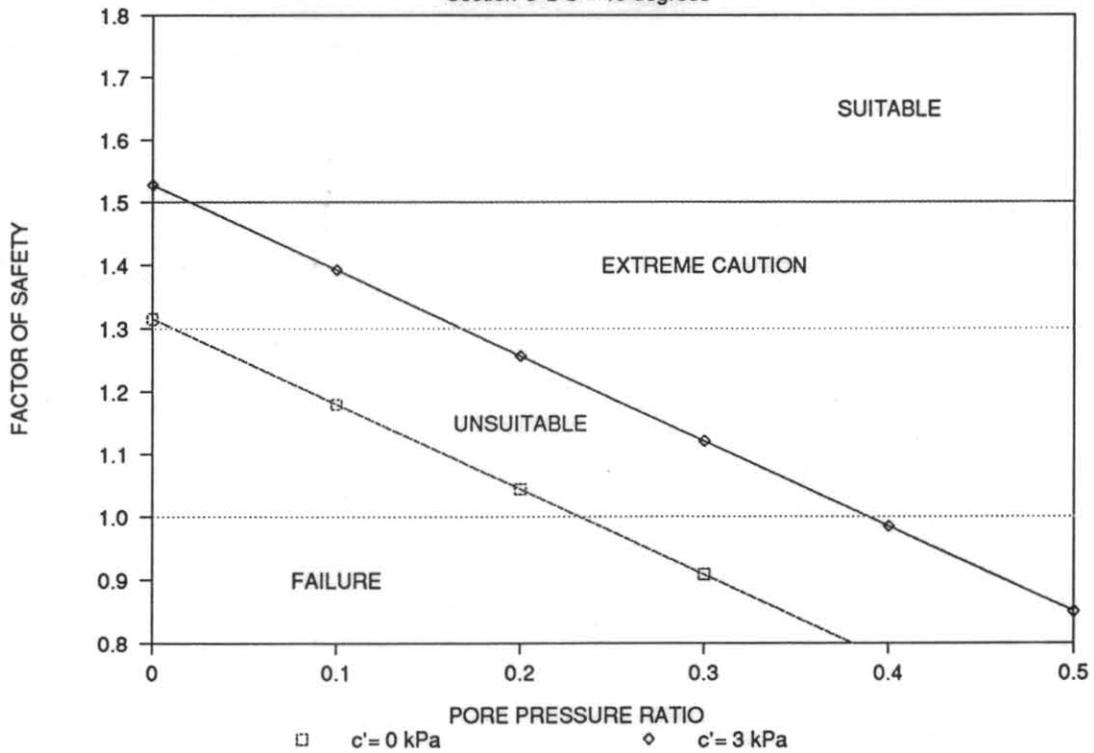
Figure 3. *Results of circular stability analysis for cross-sections A–B and C–D plotted as Factor of Safety in relation to Pore Pressure Ratio for effective residual angle of friction of 13 °.*

5 cm

TASMANIA DEPARTMENT OF MINES
SITE PLAN

OWNER: for EDS   STREET/ROAD:................   GEOLOGIST: BOW

SUBURB: NEWSTEAD   TOWN/CITY:................   DATE: Sept 90

REPORT 1990/26

SCALE: 5 cm

⬦ NOT SUITABLE FOR SUBDIVISION WITHOUT FURTHER INVESTIGATION

▦ Slope approx. equal to or > 13°

TᴠTᴠT Convex break of slope (profile form:)

ᐃᐃᐃ Concave break in slope (profile form:)

♦♦♦ Ridge crest

XXX Gully
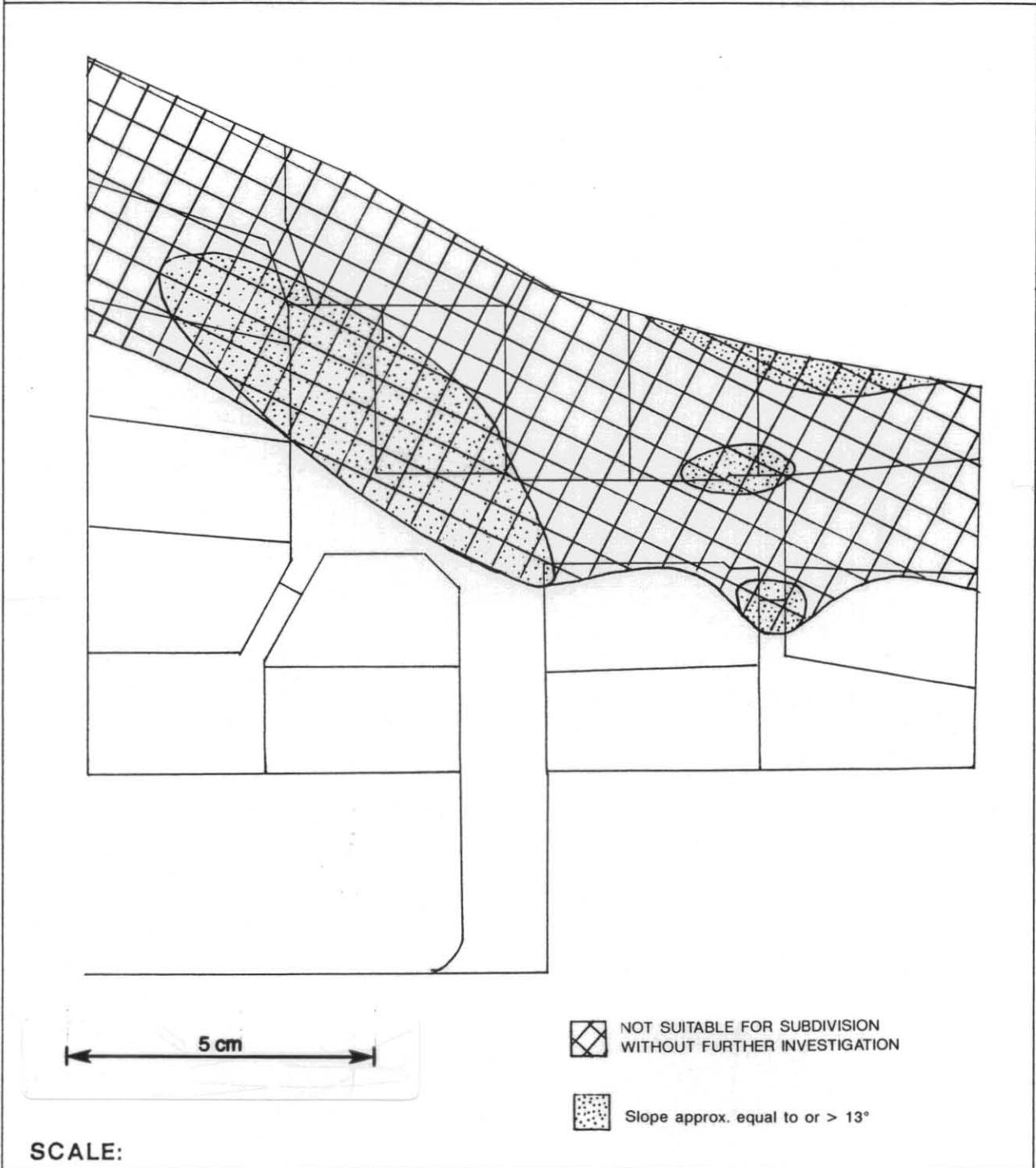
☐ Suitable area for building

NA Suitable area for septic outfall

↗ 16° Slope angle and direction

Figure 4. *Proposed subdivision at Newstead showing areas where the slope is approximately equal to or greater than 13°. The area not suitable for subdivision without further subsurface investigation is hatched.*

APPENDIX 1

Engineering logs of test pits, proposed subdivision, Newstead.

TASMANIA DEPARTMENT OF MINES

REPORT 1990/26

PAGE 9

excavation no. *1*

sheet *1* of *1*

9/13

ENGINEERING LOG – EXCAVATION

project	EDS : AMY RD LAUNCESTON	location		
co-ordinates		exposure type *test pit*		pit commenced *2-4-90*
		equipment *CAT E70*		pit completed *2-4-90*
R.L.				logged by *B. WELDON*
excavation dimensions *0.4 × 5 m*		operator *A. GRIFFITHS*		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 penetrometer kPa 25 50 100 200 400	structure, geology
N/L				0.10			SILTY CLAY TOPSOIL grey, rootlets	D	Fb		
						SM-CL	SANDY SILTY CLAY, grey-brown roots + rootlets, low plasticity moisture content less than plastic limit.	D	H	x	
				0.65							
				1		CH	CLAY: mottled, dominantly brown, sub-ordinate reds + grey mottles. Some fine gravel with some grey clay lenses. Some carbonaceous (organic) material. Medium to high plasticity, moisture content near plastic limit.	M	VSt	x x x x	
				2					St- VSt	x x	
							as above but grey mottle becoming more dominant. Also wood fibres + more organic tissue. Moisture content greater than plastic limit	M	VSt		
				3							

END OF EXCAVATION AT 3.0m

sketch

5 cm

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – EXCAVATION

REPORT 1990/26

PAGE 10

excavation no. 2
sheet 1 of 1

10/13

project	EDS : AMY RD	LAUNCESTON location		
co-ordinates		exposure type *test pit*	pit commenced	2-4-90
		equipment CAT E70	pit completed	2-4-90
R.L.			logged by	B. WELDON
excavation dimensions 0.4 × 4.5 m		operator A. GRIFFITHS	checked by	

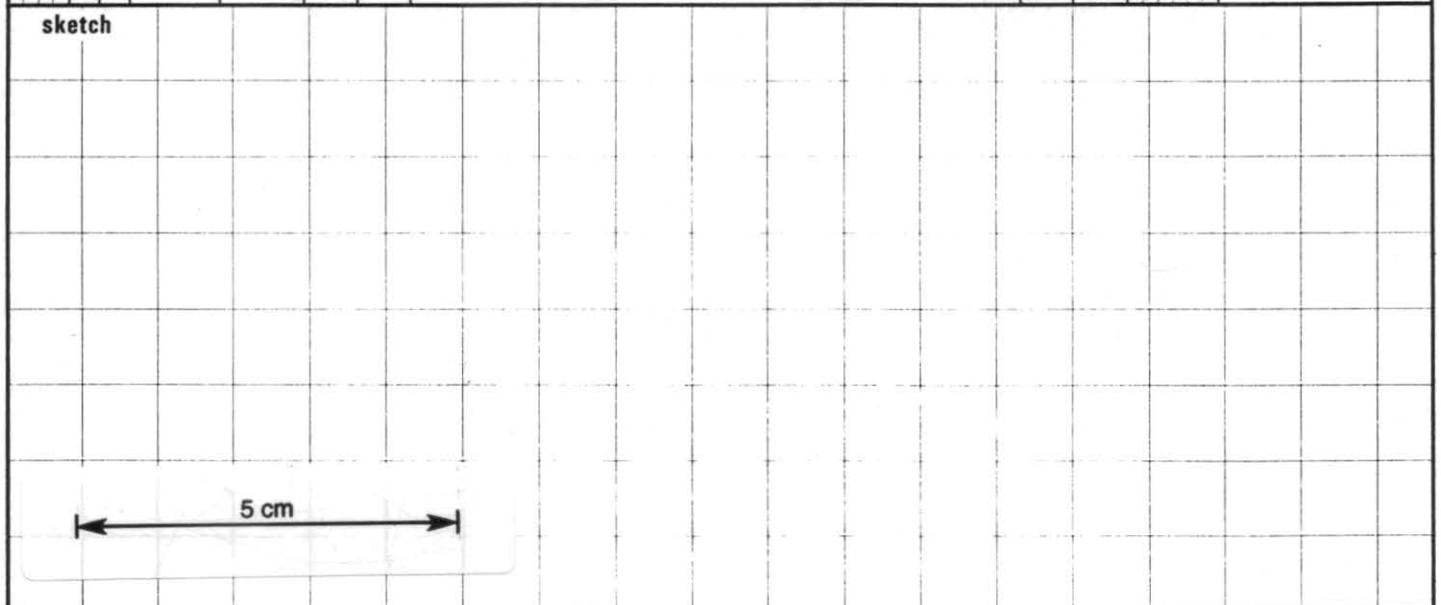| penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
				0.10			CLAYEY SILT: TOPSOIL grey-brown	D	Fb		
						CL	SILTY SANDY CLAY: grey, medium plasticity, moisture content less than plastic limit	D	Fb	x	
				0.45							
						CH	CLAY: brown mottled, subordinate red + grey mottles, one haematitic nodule. Moisture content approx. equal to plastic limit, medium to high plasticity	M	VSt	x x x	
NIL				1.10							
							CLAY: mottled grey-brown with grey clay becoming more dominant with depth. Moisture content greater than plastic limit, high plasticity	M	St-VSt	x x x x	
				2 2.20							
							END OF EXCAVATION				

sketch

5 cm

TASMANIA DEPARTMENT OF MINES

REPORT 1990/26
PAGE 11

excavation no. 3
sheet 1 of 1

11/13

ENGINEERING LOG – EXCAVATION

project	EDS: AMY RD LAUNCESTON	location		
co-ordinates		exposure type	test pit	pit commenced 2-4-90
		equipment	CAT E70	pit completed 2-4-90
R.L.				logged by A. WELDON
excavation dimensions 0.4 × 5.5 m		operator	A. GRIFFITHS	checked by

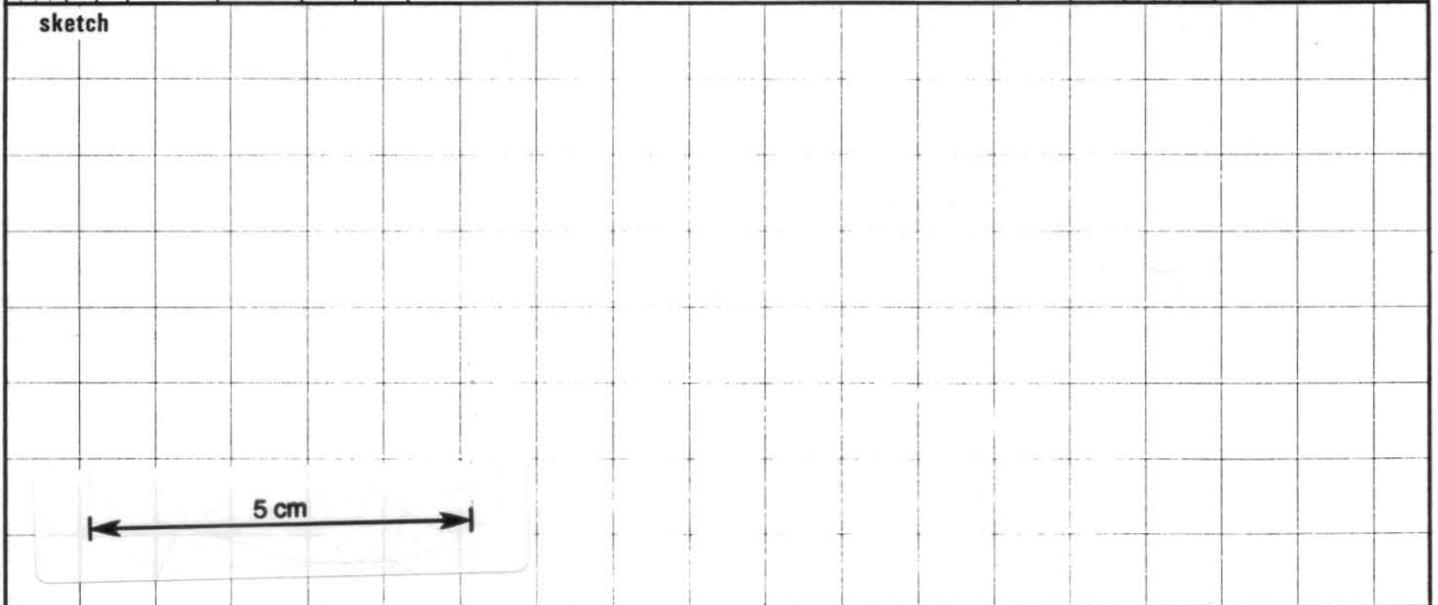| penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
				0.05		CL	SILTY CLAY: TOPSOIL	D	FS		
				0.30		CL	SILTY SANDY CLAY: grey, moisture content less than plastic limit, low plasticity	D	FS		
				1.20		CH	CLAY: brown with sub-ordinate grey-red mottles, some haematitic material and organic material. Moisture content near plastic limit, medium-high plasticity	M	VSt, H		
				2.50		CH	CLAY: brown with sub-ordinate red-brown and grey mottles. Moisture content near to or above plastic limit, high plasticity. Patches of grey clay appear to be preferentially oriented in sub vertical and sub horizontal directions often in association with organic matter.	M	VSt		orientation of grey clay may be associated with past landslide movement.
							END OF EXCAVATION				

sketch

|← 5 cm →|

ENGINEERING LOG – EXCAVATION

12/13

project	EDS: AMY RD LAUNCESTON	location

co-ordinates		exposure type	test pit	pit commenced	2-4-90
		equipment	CAT E70	pit completed	2-4-90
R.L.				logged by	B WELDON
excavation dimensions	0.4 x 5m	operator	A. GRIFFITHS	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 penetrometer kPa 25 50 100 200 400	structure, geology
	NIL			0.15			SILTY CLAY: brown-grey, rootlets	D	Fb		
						CL	SANDY SILTY CLAY - grey, fine sand, low plasticity, moisture content below plastic limit.	D	Fb		
				0.70							
				1		CH	CLAY: brown with SANDY SILTY CLAY patches, mottled red-brown (haematitic material), moisture content near plastic limit, medium plasticity	M	VSt -H		
				1.50							
				2 / 2.20		CH	CLAY: brown mottled red-brown with subordinate grey mottles. High plasticity, moisture content near plastic limit [grey mottles above plastic limit].	M	VSt		
				2.30 / 2.50		CH	CLAY: grey, moisture content above plastic limit, high plasticity	M	St- VSt		
							END OF EXCAVATION				

sketch

|←——— 5 cm ———→|

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – EXCAVATION

REPORT 1990/26
PAGE 13

excavation no.
5
sheet 1 of 1

13/13

project	EDS: AMY RD LAUNCESTON	location	
co-ordinates	exposure type **test pit**	pit commenced **2-4-90**
	equipment **CAT E70**	pit completed **2-4-90**
R.L.		logged by **B. VERDON**
excavation dimensions **0.4 × 5.5 m**	operator **A. GRIFFITHS**	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 penetrometer kPa 25 50 100 200 400	structure, geology
				0.10			SILTY CLAY: brown TOPSOIL roots	D	Fb		
				0.30		CL	SILTY SANDY CLAY: grey-brown roots + rootlets, low plasticity	D	Fb		
				1 / 1.50		CH	CLAY: mottled, dominantly brown, sub-ordinate red + grey mottles. Some fine gravel with grey clay lenses. Medium to high plasticity, moisture content near plastic limit	M	vst	x x x	
		▶ slight trickle		2 / 2.50		SC	SAND: yellow-brown, medium size subrounded sand grains (quartz) with clay fines. Low plasticity. Iron cemented (weak) and banded in places.	M	MD		
		▶ few drops					END OF EXCAVATION				

sketch

|← 5 cm →|