



A stability assessment at 9 Orana Place, Riverside.

by D. J. Sloane

Abstract

An allotment of land at 9 Orana Place, Riverside, is classified as Zone IV and III on the Tamar Valley Landslip Zone Map. The land is moderate to steeply sloping, with an overall slope of about 15°. Some topographic features of the area are indicative of previous landslide movements.

The area is underlain by highly plastic (CH) Tertiary clays. Stability analyses of a surveyed profile indicate that the area is potentially unstable in the short term and unstable in the long term. Drainage requirements considered necessary to ensure suitable stability for building development are extensive, expensive, and impracticable.

The area is not considered suitable for building development and septic tank installation.

INTRODUCTION

At the request of Mr W. Edwards an investigation was conducted to determine the stability of an area of land at 9 Orana Place, Riverside. The owner wished to construct a dwelling on the lower, steeply-sloping portion of the allotment.

The allotment is approximately 0.34 hectares in area, with a frontage of 24 m on Orana Place and a depth of about 150 m (fig. 1). The altitude ranges from about 30 m, at road level, to 70 m above sea level at the rear of the lot.

A visual site inspection indicated that the lower, steeply sloping area was probably unsuitable for subdivision and that a geotechnical investigation was required to determine the overall stability of the site.

A seismic spread was fired on the site and an auger hole was drilled to a depth of 7.9 m. Disturbed samples and two undisturbed drive-tube samples were obtained for later laboratory determination of geomechanical properties and clay analysis. A magnetometer traverse was conducted along a profile in an attempt to determine the presence of bedrock.

TOPOGRAPHY AND GEOLOGY

The geological map of the area (Longman, 1966) indicates that the area is underlain by Tertiary clays. The area under investigation lies close to the boundary of a Jurassic dolerite body to the south-west. The overall main Riverside slope represents the escarpment of a major Tamar graben fault, with an approximate north-west—south-east trend.

Surface exposures of high plasticity, brown clay (CH) can be seen in small embankments.

The area under investigation lies on the middle to upper part of the escarpment. The site has an overall slope of approximately 15° but the lower part slopes at an angle of

16°. The overall slope is interrupted by two major benches (fig. 1); these benches have a slope of about 10°. The upper bench is between 10m and 15m in width. The slope segments which separate the benches are between 14° and 16°. It is difficult to determine the topography of the upper part of the allotment because of a dense cover of blackberries; however a cleared adjacent area slopes at 13°.

The small slope benches are not laterally consistent and probably represent old landslide features. The slope has been mapped by Knights (1975) as Zone IV of the Tamar Valley Landslip Zone Map, classified as an 'old landslide and adjacent areas'. Stevenson (1972) also reported on the probable existence of a large 'old landslide' adjacent to Orana Place to the north. An active landslide is evident adjacent to Ecclestone Road, to the south-east of the area under investigation.

RESULTS OF AUGER DRILLING

Site access was difficult and only one auger hole was drilled, to a depth of 7.9 m. The bore log is presented in Appendix 1. In summary, the material encountered in the auger hole was high plasticity (CH) clay, brown to yellow-brown in colour. Some organic plant and stem fragments are present, and the clay contains some ironstone fragments. The fragments indicate the presence of small bands or fissure deposits of ironstone. Most of the samples had a moisture content greater than the plastic limit. The clay deeper than 3.4 m was soft. Some groundwater seepage occurred, with a standing water level of 4.8 m measured on the day after drilling.

The two undisturbed, 70 mm square, drive-tube samples indicated that the clays are fissured and sheared to some extent, with slickensided surfaces evident. Secondary clay cutans occur along many of the fissures, and secondary iron mineral coating was observed in the sample from a depth of 2.5 m. The fissure coatings and shear surfaces indicate that previous disruption of the sediments has occurred, with groundwater movement through the fissures subsequently occurring.

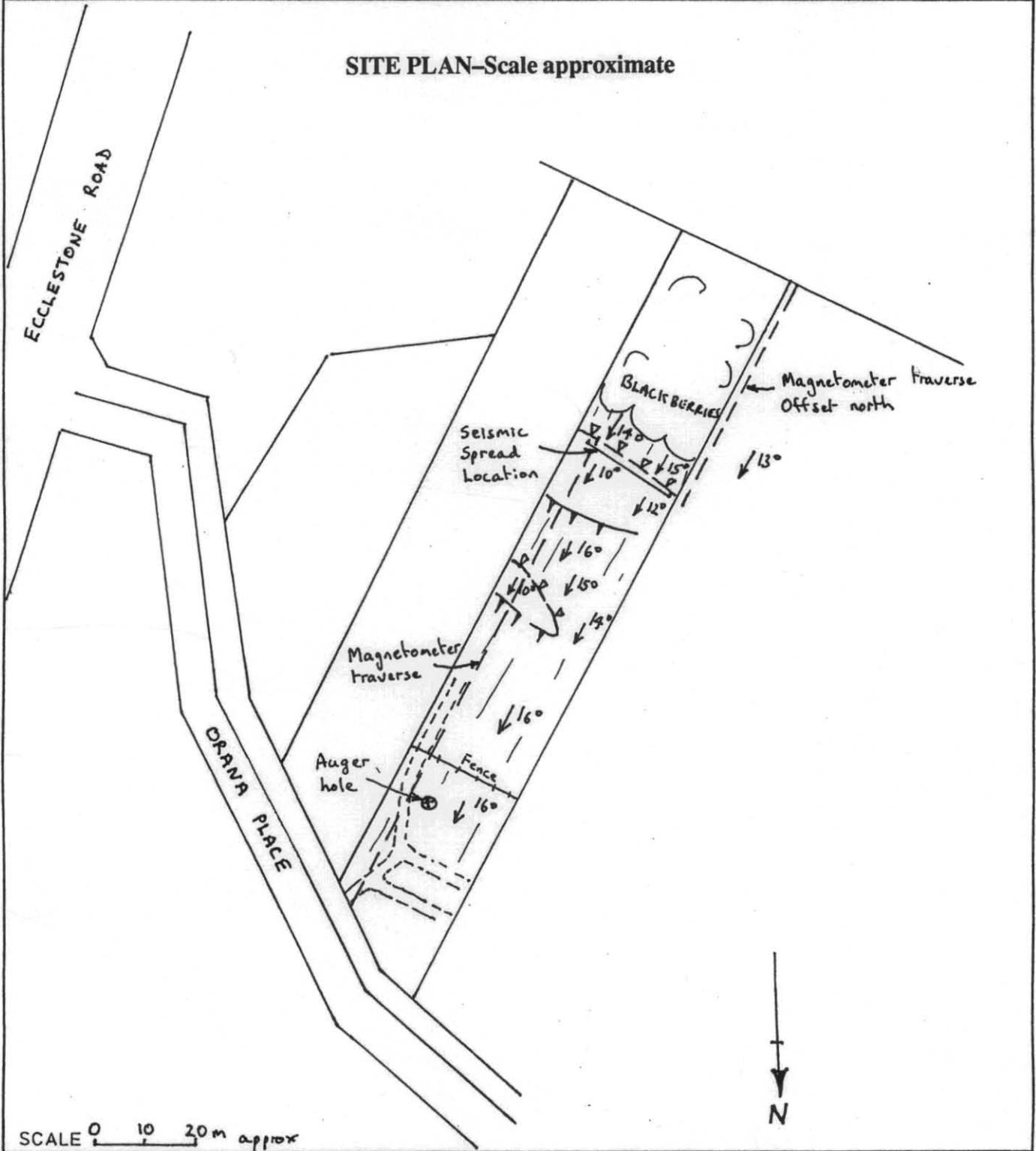
SEISMIC AND MAGNETOMETER SURVEY RESULTS

A seismic spread was fired on the major slope bench; the location is shown in Figure 1. The geophone and shot point spacing was two metres. In summary the results show that bedrock does not occur at shallow depth, and clay or sandy clay extends to depths of at least 10 m from the ground surface.

The first layer velocities of about 250 m/sec indicate a layer thickness of about 0.6 m. This velocity is considered to represent unconsolidated material such as topsoil or dry clay with extensive desiccation cracking.

LOCATION LOT 2, NO. 9 ORANA PLACE	SUBURB RIVERSIDE	GEOLOGIST D.J. SLOANE
OWNER	TOWN LAUNCESTON	DATE 13/1/87

SITE PLAN—Scale approximate



LEGEND

- 20° Slope angle and direction
-
-
- N.A. Area in which building advised
- N.A. " " " septic tank "
- Auger hole location.

Figure 1.

The second layer velocities varied between 330 m/sec and 380m/sec. These velocities are consistent with unconsolidated clay and/or sandy clay which are probably dry and fissured or desiccation cracked. These materials extend to a depth of about 2.5 to 3.0 m.

The third layer seismic velocity is about 660 m/sec to 670 m/sec. This velocity probably represents moist clay or sandy clay which is less fissured than the overlying materials. The overall variations in seismic velocity are attributable to differences in the sediment density, water content, and the degree of fissuring of the clays.

A magnetometer survey was conducted along a central profile of the lot, with readings taken at two metre intervals. The survey showed that dolerite bedrock was not present close to the ground surface. The survey showed subdued results with recorded readings between 61.2×10^3 and 62×10^3 gammas. The results tend to indicate a deep, sloping dolerite interface, with a greater thickness of sediment cover towards the base of the slope.

LABORATORY RESULTS

The results of laboratory testing by R. N. Woolley of the Department of Mines are presented below. Results from an investigation of an adjacent property to the north, at 11 Orana Place (Sloane, 1987), are also presented.

The liquid and plastic limit results for the samples are very similar, and reflect the highly plastic nature of the clays. Linear shrinkage results indicate high shrink-swell characteristics of the materials. The laboratory results can be taken as indicative of the clay properties over the entire site.

The laboratory results from undrained shearbox testing show some variation. The sample of clay from a depth of 2.7 m in Hole 2, drilled on the adjacent property at 11 Orana Place, shows much higher results for the angle of internal friction ($\phi'_r = 22^\circ$, $c'_r = 5$ kpa) than the lower sample from a depth of 3.6 m in hole 3 ($\phi'_r = 15^\circ$, $c'_r = 6$ kPa). This latter sample has

very similar properties to the sample from a depth of 5.4 m at 9 Orana Place ($\phi'_r = 16^\circ$, $c'_r = 3.1$ kPa).

The difference in properties is mirrored by the X-ray diffraction analysis results, which show that the lower samples contain 10% of the clay mineral montmorillonite. Montmorillonite has high shrink-swell characteristics and weak interlayer bonding in its structure. The presence of this clay mineral is often conducive to slope failure.

STABILITY ANALYSIS

Stability analysis has been performed on the slope profile shown on the site plan, and the analysis sheets are appended (Appendix 3). The laboratory test results from undisturbed samples have been used in the analysis and the results have been shown in Table 1. Stability analysis has been performed using SLIPCIRC, a GW-BASIC program for Bishop's (1955) simplified slip circle stability analysis on an IBM compatible micro-computer, written by B. D. Weldon (1987). Planar failure analysis has been performed using PLANAR, a program also written by B. D. Weldon and based on slab failure analysis by Skempton and Delory (1957). The slip circles have been chosen after careful examination of the morphology of the area. The slip circles have been chosen with toes at road level and intersecting the groundsurface at the rear of each of the two slope benches.

Sheared and fissured clays have been observed in drive tube samples, and the morphology of the area indicates features of previous instability, therefore residual strength parameters should be used in analysis. The lower values are also favoured because of the similarity with results obtained from the investigations of an adjacent property to the south.

It is interesting to note that the majority of 13 results from the Orana Place area are within the 15° to 19° range for the angle of internal friction. These values approximate to a mean range for the area, and therefore it is reasonable to use the laboratory determined value of 16° obtained from the site, as it falls within the 'mean' range.

Table 1. RESULTS OF SOIL LABORATORY TESTING OF SOIL SAMPLES

Hole No.	Depth (m)	Liquid Limit	Plastic Limit	Linear Shrinkage	Internal Friction (ϕ'_r)	Cohesion c'_r (kPa)
<i>9 Orana Place</i>						
1	5.4	73	24	17	16	3.1
<i>11 Orana Place</i>						
2	2.7	63	21	16	22	5
3	3.6	78	20	21	15	6

X-RAY DIFFRACTION-CLAY MINERAL ANALYSIS

Hole No.	Depth (m)	Kaolinite (%)	Gibbsite (%)	Goethite (%)	Montmorillonite (%)
<i>9 Orana Place</i>					
1	5.4	70-75	15-20		5-10
<i>11 Orana Place</i>					
2	2.7	75	20	5	
3	3.6	80	10		10

The properties used in the stability analysis are shown on the computation sheets which are appended to this report (Appendix 3). The results are shown as Factors of Safety (FS) in relation to pore pressure ratios (ru). A pore pressure ratio of 0.5 occurs when the assumed slide is totally saturated, a ratio of 0.25 occurs when the slide is half saturated, and a ratio of 0.0 occurs when the assumed slide is fully drained.

In summary, the lowest acceptable factor of safety is considered to be a safety factor (FS) of about 1.4. The stability analysis results for the two assumed slip circles are shown in the Appendix. Using the residual strength parameters $\phi'_r = 16^\circ$ and $c'_r = 3.1$ kPa the factor of safety results indicate that the area is potentially unstable unless fully drained conditions can be assured for each slip circle. The factor of safety does not rise above $FS=1$ unless the pore pressure ratio is $ru=0.0$. This indicates that drainage would be required to a depth of at least 7 m or 11 m for an assumed slip circle at the lower and upper bench respectively.

In each of the above cases, drainage to the required depth is considered difficult to achieve. The construction of drains may also have a deleterious effect on stability due to removal of lateral support.

The alternative method of analysis, which considers the potential for planar failure, indicates that the slope is only marginally stable. The results, using the PLANAR program mentioned previously, are shown in Appendix 4. Slab thicknesses of 3 m and 7 m have been used, together with residual strength values. A suitable factor of safety cannot be achieved even if the area is fully drained. Assuming a pore pressure ratio (ru) of 0.0, the factor of safety for planar failure is 1.22 and 1.09 for thicknesses of 3 m and 7 m respectively.

CONCLUSIONS

Auger drilling and seismic and magnetometer surveys indicate that the site is underlain by high plasticity (CH) clays to depths in excess of 10 m.

The residual strength value, which has been obtained from laboratory testing of a sample taken from the site, is considered to be in the average value range for the Orana Place area. The value is similar to results obtained from an investigation of the adjacent area to the north.

The stability analysis results show that the area is of doubtful stability when using residual strength parameters. Factors of safety greater than 1 can only be obtained by assuming the analysed failures are fully drained, apart from considering a 3 m thick slab failure. Even considering this latter case, the maximum factor of safety that could be obtained from stability analysis was 1.22. The area must be considered to be potentially unstable, given the assumptions used in the analysis.

When considering the stability results it must be remembered that the site has morphological peculiarities which have been mapped by the author and others as representing old landslide features. Other factors to consider are:

- The presence of fissuring and slickensides indicates previous disruption.
- The site is underlain by soft, high plasticity clays with moderate to high shrink-swell characteristics.
- There is some evidence of seepage on the property which, together with secondary clay and iron mineral deposition along fissures, indicates the movement of groundwater within the clays.

It is also generally considered that long slopes are potentially more unstable than short slopes, and for long term stability the cohesion value should be considered as zero. If this cohesion value is used in the stability analysis the resulting factors of safety are even lower than those determined in this report.

Previous reports by Sloane (1979, 1980, 1987) all indicate stability problems in the region.

The property is not serviced by the town sewerage system. An alternative method of sewage treatment and effluent disposal is therefore required. The Municipality of Beaconsfield health inspector considers that the property is unsuitable for the installation of a septic tank and associated French drain effluent disposal system. The stability investigations confirm the unsuitability of the site. Even an 'Envirocycle' system is not advised, as it is obviously unwise to irrigate the area with treated effluent. While most of the irrigation water will evaporate some will undoubtedly infiltrate into the underlying desiccated and fissured clays. This will only result in an increase in moisture content with a corresponding reduction in stability.

As a result of the investigations it can only be concluded that the property is potentially unstable and therefore unsuitable for development. A suitable house site cannot be realistically recommended.

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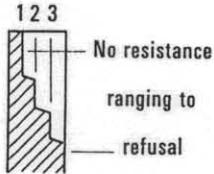
[16 June 1989]

APPENDIX 1
Log of auger hole

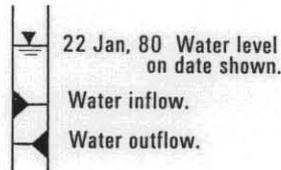
EXPLANATION SHEET FOR ENGINEERING LOGS

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 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

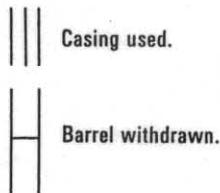
Density index

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

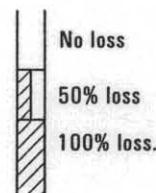
Notes: X on log is test result
— is range of results.

Cored borehole log

Case - lift



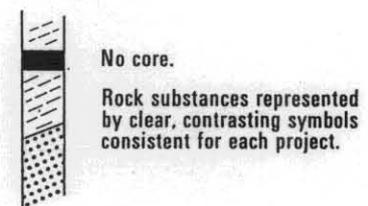
Fluid loss



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

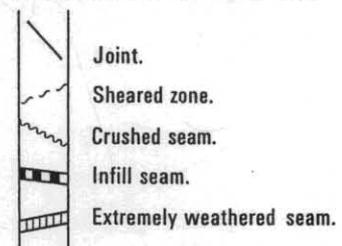
- EL Extremely low. < 0.03
- VL Very low. 0.03 - 0.1
- L Low. 0.1 - 0.3
- M Medium. 0.3 - 1
- H High 1 - 3
- VH Very high. 3 - 10
- EH Extremely high. > 10

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

Note: X on log is test result.

Significant defects

Significant defects shown graphically.



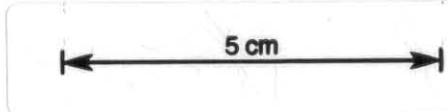
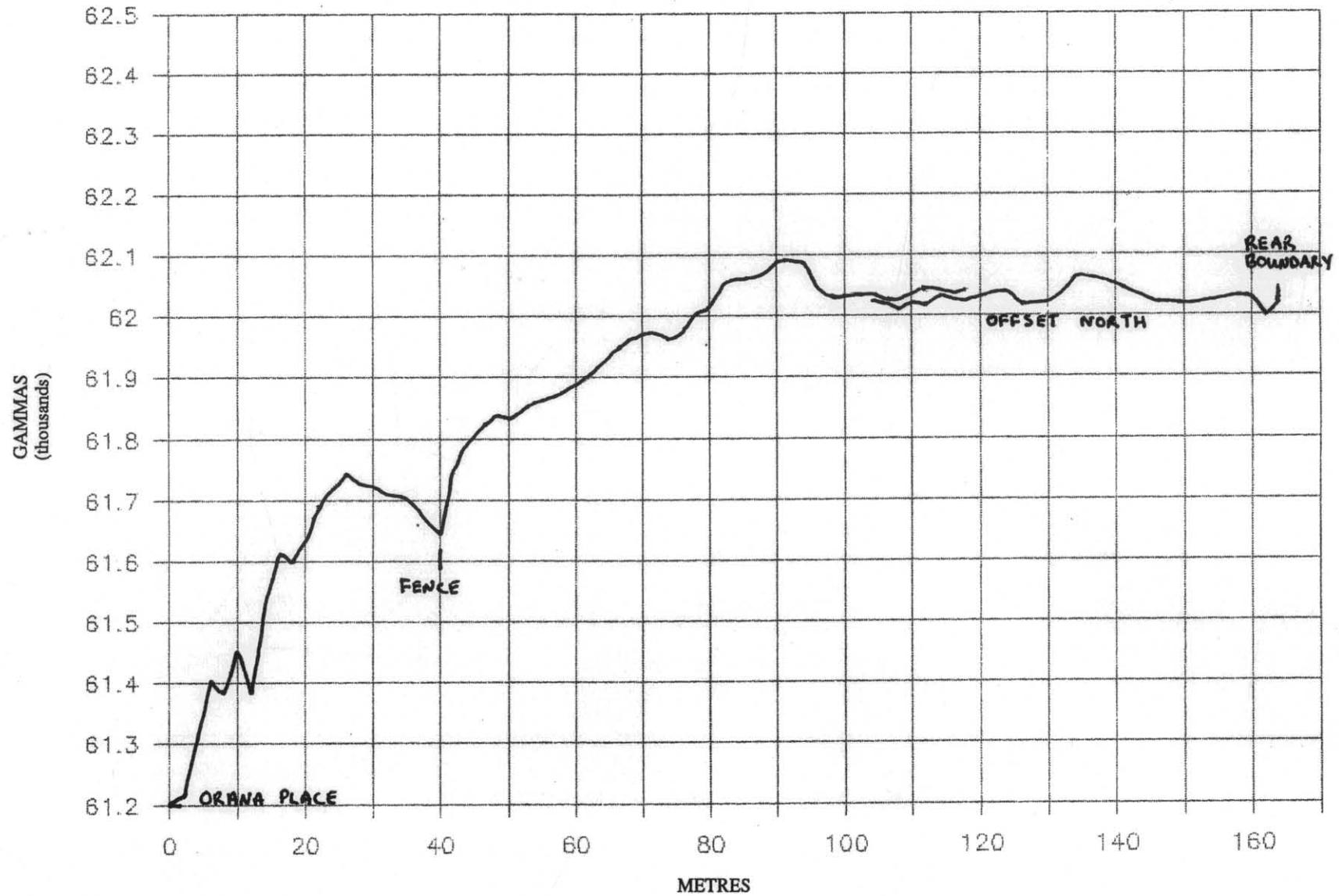
ENGINEERING LOG - BOREHOLE

project W. H. EDWARDS	location LOT 2, 9 ORANA PLACE, RIVERSIDE	
co-ordinates 507554158	drill type TRIEFUS	hole commenced 23/10/87
R.L. ≈ 35m	drill method Auger screw	hole completed 23/10/87
inclination VERTICAL	drill fluid	drilled by B.C.
bearing		logged by D.J.S.
		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
				0		SM	SILTY SAND. Grey-brown.	D	L		TOPSOIL
		D		1		CH	CLAY. Dull yellow-brown. Mod-high plasticity Trace medium sand	M<	PL	VST	TERTIARY SEDIMENTS
		D		2		CH	CLAY. Mottled grey-yellow brown. Trace limonite fragments to 5mm dia. High plasticity.	M>	PL	ST	
		D	u 75	3		CL	SANDY CLAY. Yellow-brown. Low plasticity Approx 40% medium sand.	M		ST	
		D		4		CH	CLAY. Brown. High plasticity. Trace limonite fragments to 3mm Trace medium sand	M>	PL	S	
		D	u 75	5		CH	CLAY. Brown. High plasticity. Trace organic stem + leaf fragments	M>	PL	S	
		D		6							
		D		7		CH	CLAY. Brown. High plasticity. Trace limonite fragments to 3mm. Trace medium sand.	M>	PL	S	
		D	END	8			HOLE TERMINATED AT 7.8m				
				9							

APPENDIX 2
Magnetometer survey profile

Magnetometer survey—Lot 2, Orana Place, Riverside



APPENDIX 3

**Slope stability analysis computation sheets.
Bishops Simplified method using SLIPCIRC program**

APPENDIX 4.

Stability analysis—planar failure. Using PLANAR program.

Angle of internal friction = 16°
 Cohesion = 3.1 kPa
 Density = 18 kN/m^3
 Slope angle = 16°

Ru	FS	FS
<i>Depth</i>	=3 m	=7 m
0.0	1.22	1.09
0.1	1.11	0.98
0.2	1.00	0.88
0.3	0.89	0.77
0.4	0.78	0.66
0.5	0.68	0.55