DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

REPORT ON

GEOTECHNICAL INVESTIGATION
PLANNING PROPOSAL FOR REZONING
PROPOSED SUBDIVISION AND RESIDENTIAL DEVELOPMENT

NO.39 – 55 (LOT 8 DP1191647) ORATAVA AVE
AND PART OF NO.570 (LOT 3 DP1096405) PENNANT HILLS RD
WEST PENNANT HILLS NSW

Submitted to:

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EXECUTIVE SUMMARY

- This report presents the results of a geotechnical investigation carried out at No.39 – 55 Oratava Ave (Lot 8) and part of No.570 Pennant Hills Rd (Lot 3) in West Pennant Hills for purposes associated with a Planning Proposal for the proposed subdivision of the land for residential development.

- The report gives consideration to the environmental sensitivity of the land, namely landslide risk, in relation to its development and the way in which the land may be economically developed. The report in essence addresses s117 Direction 2.1, which supports the planning proposal to amend the development controls applying to the site.

- The existing E4 zoning controls, while in part addressing the landslide risk, do not necessarily contemplate the high cost of stablisation works. As a consequence, the particular development controls have been an impediment to development of the site. Development controls that permit a higher lot yield but still recognising the landslide risk would make development more feasible.

- Preliminary costing for the geotechnical stabilisation of part of the site has been assessed as part of the Planning Proposal. This relates to the additional yield from the rezoned site to offset the cost of managing the geotechnical constraints.

- The investigation provides data for a geotechnical assessment of the slope stability and landslide risk issues for the site, in anticipation of the submission to The Hills Shire Council associated with the proposed residential development following the rezoning of the site.

    - The landslide history of part of the site has been investigated and a reliable geotechnical model developed for analysis.
    - Geotechnical monitoring and analysis have confirmed that stabilisation of the landslide-affected area of the site is feasible and practical by means of subsurface drainage improvements.
    - A preliminary design has been developed for the subsurface drainage improvements utilising trench drains and chimney drains, sufficient to verify feasibility and costs at a preliminary level.
    - Further geotechnical analyses will be undertaken, and engineering design subsequently completed for construction, after Council's approval of the current re-zoning planning proposal and associated subdivision application.
    - Following stabilisation of the site, the proposed subdivision and residential development can be undertaken with engineering controls that are considered suitable and appropriate.
    - Subdivision and development of the remainder of the site requires normal engineering design and construction.
    - Geotechnical involvement is a necessary requirement through the design and construction phases of the development, to ensure the recommendations in this report are appropriately incorporated in the development.

- The slope stability/risk outcome is to be confirmed at completion of the development by a suitably experienced and qualified geotechnical practitioner in landslide risk assessment, with the expectation that the development will meet Council's acceptable risk criteria.

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1. INTRODUCTION

1.1 General

This report presents the results of a geotechnical investigation carried out at No.39 – 55 Oratava Ave (Lot 8) and part of No.570 Pennant Hills Rd (Lot 3) in West Pennant Hills for purposes associated with a Planning Proposal for the proposed subdivision of the land for residential development.

The report gives consideration to the environmental sensitivity of the land, namely landslide risk, in relation to its development and the way in which the land may be economically developed. The report in essence addresses s117 Direction 2.1, which supports the planning proposal to amend the development controls applying to the site.

The investigation was requested by Michael Saadie on behalf of Kai Ling (Australia) Pty Ltd.

The investigation is intended to provide data for a geotechnical assessment of the slope stability issues for the site, in anticipation of a submission to The Hills Shire Council associated with the proposed residential development following the rezoning of the site.

The investigation was carried out in accordance with a scope of work by Davies Geotechnical Pty Ltd, initially dated 7 March 2015 and amended on 9 March 2015. Approval to proceed with the work was received 9 March 2015. The current investigation has involved the following:

- Review of earlier geotechnical investigations of the site undertaken by Davies Geotechnical, and of associated data from other sources
- Borehole drilling and installation of groundwater monitoring and slope monitoring facilities
- Site monitoring, data collection and analysis/review of the data
- Development and confirmation of a geotechnical model of the site/slope area relevant to assessment of the slope stability issues
- Analysis of the slope stability model and groundwater model to determine threshold conditions for limiting equilibrium of the slope, and improvements to the slope conditions that might be achieved through groundwater lowering
- Assessment of a preliminary scheme for site drainage improvements that could be incorporated into the design of the proposed subdivision and residential developments.

The following report presents the factual and interpreted results of the investigation and analyses, and provides interpretation regarding the ground conditions and geotechnical model of the slope at the site, and development of a preliminary slope instability risk appraisal.

Although not a primary focus of the investigation and report, alternatives to the proposed site drainage improvements, and an alternative development of the site are briefly discussed.

1.2 Site History/Previous Investigations

Davies Geotechnical has undertaken previous investigations on this site as part of subdivision appraisals in the period from May 1997 to January 2008.

More recent geotechnical investigations and review for the adjoining land at the east, No.572 Pennant Hills Rd (Lot 9 DP1191647) were undertaken in February 2014 and October 2014 for a Seniors Living development on that land.

Reference is made in the following report to relevant data from the investigations and geotechnical assessment undertaken in the period noted above.

We understand a previous geotechnical investigation of part of the site has been carried out by Coffey & Partners Pty Ltd in 1988, however the details and results of that investigation are not available to us.

Further discussion on the history of site development is provided below in Section 3.

1.3 Proposed Subdivision

Subject to the adoption of the Planning Proposal the proposed subdivision is for residential development on 31 allotments varying from 500m^2 to 688m^2 area, including internal access roads. The current subdivision plan is provided in Attachment 1.

2. SITE DESCRIPTION

2.1 General

Figure 1 provides a Locality Plan of the site.

The combined property (Lot 8 and Lot 3) comprises an area of approximately 2.1 hectares. Access to the property is from Oratava Ave (Plates 1 & 2).

The site is located to the north of Oratava Ave at a right-angle bend, below Thompsons Corner at the intersection of Pennant Hills Rd and Castle Hill Rd (refer to the locality plan in Figure 1).

The site also includes part of Lot 3 DP1096405, No.570 Pennant Hills Rd, which has a frontage onto Pennant Hills Rd.

The property subject to the Planning Proposal and proposed subdivision is shown on the Craig & Rhodes survey plan ref. 1675G-T02 [00] dated 21 May 2015, which has been used as a geotechnical base site plan in Figure 2.

Plate 1 – View north at SW corner of the site.

Plate 2 – View to NE at SW corner of the site.

2.2 Site Topography

The overall site encompasses a number of topographic elements that have differing geotechnical significance, each briefly described below. The geotechnical zones referred to are described in more detail in Section 5.4 below:-

a) An upper ridge and side-slope area within the rear portion of Lot 3, extending westwards and southwards onto Lot 8 (zones G2 and G3).

b) An east-west ridge spur extends down across the approximate centre of Lot 8 (zone G2), with side-slopes grading down to the north and south.

c) In the northern area of Lot 8 (zone G1), the slope is gently undulating, grading to the northwest.

d) In the southern area of Lot 8 below the ridge spur, the land slopes down to the south-west at a moderate gradient (zone G2) with locally steeper slope gradients (zone G3).

e) The southern portion of Lot 8 (zone G4) occupies a gently to moderately sloping benched slope which falls west and south to Oratava Ave, continuing beyond the road and steepening to a drainage line that forms the local valley.

   Fill has been placed on the original natural slope in the eastern half of this portion of the site.

f) The southern area of Lot 8 is flanked by a steeply sloping ridge side slope at the eastern side (zone G5), wrapping partly around the north-eastern side. The slope down from the eastern boundary (adjoining No.572 Pennant Hills Rd) is steeply graded with a height of about 15m and slope angles of 25° - 48°.

The overall site has been cleared of all original timber. Occasional trees, including several tall pines, other introduced species and several youthful gums are growing on the land as regrowth from past clearing. The steeper ridge side slope areas (Zone G5 and part of Zone G3) are overgrown with weed species (mainly lantana and privet), and some camphor laurel trees.

The remainder of the land is open and grassed. Plates 1 & 2 are indicative of the current condition of the land. Figure 3 shows the site to have been completely cleared of vegetation in the early 1940's.

2.3 Site Drainage/Groundwater

Wet surface conditions prevail intermittently on the southern portion of the site at the toe of the steep slope and edge of the fill. A shallow surface drain (now overgrown) has been dug along the toe of the fill to drain surface water to Oratava Ave.

A 6m wide easement for water supply (Sydney Water) cuts across the western side of the property and continues south along Oratava Ave.

At the time of our initial investigations of the site (1997) the wet conditions in this vicinity were thought (possibly) to be the result of groundwater accumulating along the Sydney Water pipeline trench. However, recent observations of surface water flows (April-May 2015) across this area of the site, following extremely heavy rainfalls of the period 20 and 21 April 2015, confirmed that strong spring seepages were generating water flows onto the slope at the base of the ridge side-slope rising above BH2. The seepages and resulting surface flows have subsided gradually as drier weather conditions have prevailed.

2.4 Geology

Published geological mapping (reference 1) and soil landscape mapping (reference 2) indicates the site is within sedimentary bedrock of the Wianamatta Group Ashfield Shale and the Glenorie erosional soil landscape. Materials found during the investigation were consistent with the published data.

The West Pennant Hills colluvial soil landscape occurs below the ridge areas at this location.

The site lies within an area mapped by the Soil Conservation Service of NSW (SCS) for urban capability (reference 1). Areas of extreme hazard ($E\text{-}3_m$ and $E\text{-}1,3_m$ having potential for mass movement) cut across the eastern portion of the site. These areas represent the steep sideslope and the downhill gently to moderately sloping hillside area.

3. HISTORY OF DEVELOPMENT

An old timber dwelling once stood on the grassed slope at the south-western corner of the property. The dwelling was standing at the time of our 1997 investigation and is shown on an earlier Craig & Rhodes survey plan of the site. The dwelling is evident in the 1943 aerial photograph of the site available from Six Maps (Figure 3).

Previous development has been undertaken for industrial purposes at the eastern extremity of the site, operated from the adjoining Lot 9. The remains of an elevated concrete structure used for ready mixed concrete batching previously existed. The remains of the development were standing partly on Lot 8 in 1997. Use of the site for these purposes is reported to have ceased in the 1960's. That structure and associated development have since been removed.

Filling from the earlier development extends across the eastern boundary from Lot 9 onto Lot 8 and forms a steep batter across the eastern boundary.

Excavations appear to have been made into the base of the steep hillside rising up at the eastern end of the site, exposing shale bedrock in places. The site may originally have been a shale quarry.

An access driveway off Oratava Ave runs along the western boundary of the property, turning to the east and running up the crest of the spur-ridge. This currently provides access to a developed property (Lot 21 DP852577) on the elevated ridge/plateau further east.

A second concrete access driveway off Oratava Ave runs up the southern boundary of the site.

The slope at the south-western corner of Lot 3, immediately adjacent to the common boundary with Lot 8, has been re-contoured by construction of a drain and earth mound, and an access track aligned up the slope.

It was reported in 1997 that sullage from the residence on 570 Pennant Hills Rd was being discharged into the slope uphill of the subject site.

A Sydney Water pipeline crosses Lot 8 within a 6m wide easement.

Other land adjoining the subject site is developed with residences ranging from greater than 50 years or so in age to relatively recent (last 5 - 10 years or so). No.570 Pennant Hills Rd is an old property developed with a sandstone cottage at the Pennant Hills Rd frontage.

4. METHOD OF INVESTIGATION

4.1 1997 Test Pits

The initial investigation at this site was undertaken on 3 May 1997, and comprised excavation of sixteen (16) test pits, utilising a tracked Sumitomo SH60 excavator. Substantial clearing of access tracks was necessary in an overgrown portion of the southern area of the site.

Geotechnical inspection and mapping of site features were carried out on the same date. A preliminary inspection of the site had been carried out on 2 January 1997.

A summary of the test pits is provided in Table 1 below. The test locations are shown on the site plan provided in Figure 2. The test pit logs and explanatory sheets are presented in Appendix A. Surface levels at the test sites as shown on the logs were estimated by interpolation of the site contours on the 1:500 scale survey plan dated 25 October 1996, provided by Craig & Rhodes at the time.

TABLE 1 – Summary of Test Pits

Test Pit	Geotech Zone	Surface RL AHD (approx)	Depth (m)	
			Unit 3 Shale	Bottom of Pit
TP1	G3	153.5	--	2.0
TP2	G4	151.0	--	3.5
TP3	G4	154.5	0.6	>3.0
TP4	G4/G5	157.7	0.4	2.2
TP5	G4	151.5	--	3.0
TP6	G4	147.5	--	3.0
TP7	G1	151.0	0.5	1.3
TP8	G1	159.0	1.5	2.0
TP9	G1	161.0	1.4	2.0
TP10	G2	155.0	1.6	2.4
TP11	G3	158.5	0.7	1.7
TP12	G2	151.5	2.2	3.0
TP13	G4	147.0	--	2.9
TP14	G4	148.5	--	2.5
TP15	G4	153.5	3.0	3.3
TP16	--	170.2	2.1	2.6

Note - Surface RL's approx. only, determined from 1996 survey.
- Refer Table 3 for soil/rock units

The test pit locations were set out by our engineer relative to the existing site boundaries and other features. The subsurface conditions encountered were recorded during the progress of the test excavations. Selected soil samples were retained from the test pits. The pits were backfilled on completion. No laboratory soil testing was undertaken.

4.2 2001 & 2015 Borehole Drilling

The initial drilling programme was undertaken on 18 April 2001 and comprised six (6no.) boreholes (BH1 – BH6) using a truck-mounted drilling rig supplied and operated by APS Drilling Pty Ltd.

The current investigation was undertaken on 12 – 14 March 2015. Five (5no.) boreholes (BH7 to BH11) were drilled using a truck-mounted drilling rig supplied and operated by Total Drilling Pty Ltd.

The borehole locations were selected to complement the 2001 boreholes. The borehole locations are shown on the plan in Figure 2. Summary borehole data are provided in Table 2.

TABLE 2 – Summary of Boreholes

Borehole	Geotech Zone	Collar RL AHD (note)	End Depth (m)	Monitoring Installation
BH1	G4	153.40 (153.49)	6.0	Standpipe piezometer
BH1A	G4	(153.49)	4.85	--
BH2	G4	151.48 (151.48)	9.0	Standpipe piezometer
BH3	G4	149.77 (149.82)	9.05	Standpipe piezometer
BH4	G4	149.58 (149.55)	7.50	Standpipe piezometer
BH5	G4	146.98 (147.02)	6.0	Standpipe piezometer
BH6	G4	144.32 (144.30)	6.0	Standpipe piezometer
BH7	G4	148.55	11.78	Inclinometer
BH8	G4	151.07	11.73	Inclinometer
BH9	G4	153.63	11.43	Inclinometer
BH10	G4	148.87	10.98	Standpipe piezometer
BH11	G4	144.39	10.65	Standpipe piezometer

Note – Collar RL's determined from April 2015 survey. RL's in brackets are from June 2001 survey.

BH7 and BH8 were located close to the original boreholes BH4 and BH2 respectively, to provide a correlation of the interpretation of subsurface conditions on the earlier geotechnical slope sections. BH's 9 – 11 were located in other parts of the slope where information had not previously been obtained.

BH1 to BH6 were drilled with solid flight augers to their termination depths. BH1A was similarly drilled, but with Standard Penetration Tests (SPT's) at regular depth intervals.

Boreholes BH7, BH8 and BH9 were initially drilled for a short depth using 100mm solid augers with a tungsten carbide (TC) bit, and were then HQ cored in the clay overburden, continuing into the bedrock for the full depths of each borehole. BH10 and BH11 were commenced using augers to a selected depth and were then were continued using HQ coring to termination depths.

PVC standpipe piezometers were installed in BH1 to BH6, BH10 and BH11, on the day of drilling each borehole. Inclinometer casings were installed and fully grouted in BH7, BH8 and BH9.

The borehole locations were surveyed for position and collar level at a later date.

The drilling and sampling were monitored full-time by an experienced geotechnical engineer and an engineering geologist, who recorded and logged the subsurface conditions encountered in the boreholes during the progress of the fieldwork.

The interpreted subsurface conditions in the boreholes are described on the Borehole Logs presented in Appendix B, together with explanatory notes describing the method of soil and rock classification.

Plate 3 – (12/3/15) Drilling rig at BH8

Plate 4 – (13/3/15) Drilling rig at BH9

Plate 5 – (14/3/15) Drilling rig at BH11

The soil descriptions and strength estimates provided on the logs are based on visual/tactile description in the field. Where precise information on the soil or rock conditions or classifications is required for design or construction purposes, further soil sampling and laboratory testing may be necessary.

4.3 Laboratory Testing

No laboratory testing was undertaken for the current investigation.

4.4 Monitoring

Groundwater monitoring was commenced in April 2001 after installation of the piezometers in the boreholes. The monitoring was continued intermittently until December 2002. The monitoring data collected in this period and subsequently are provided in Appendix C.

Monitoring was recommenced in March 2015 as part of the current phase of investigation. The 2001 borehole installations were checked and found to be in good condition.

Electronic data loggers were installed in three of the borehole piezometers on 22 April 2015 at the end of a short period of extremely heavy rainfalls. The loggers were downloaded on 29 April (1 week interval) and again on 19 May 2015 (4 weeks interval). The results are provided in Appendix C.

Inclinometer monitoring was commenced on 19 March 2015 with baseline readings, and then with further monitoring on three subsequent occasions, with the latest readings taken on 12 May 2015. The monitoring data collected in this period are provided in Appendix D.

Discussion of the monitoring data is provided in Section 5.

4.5 Slope Mapping

Geotechnical inspection was carried out during the fieldwork and on occasions at a later time to provide a visual assessment of the slope areas about the property, particularly at the eastern side adjacent to Lot 9.

Three slope sections have been prepared, using the available survey data (Craig & Rhodes). These sections are presented as Figures 4 – 6.

It is noted that the slope sections presented, as based on earlier survey data, need to be confirmed with the benefit of updated site survey data.

4.6 Geotechnical Model & Analysis

A geotechnical model of the slope conditions in the southern area of the site has been developed from the investigation data gathered from the test pits, boreholes and monitoring, and from available data from investigations by others on adjoining and nearby land.

Section 5.5 below provides further commentary on the development of the geotechnical model of the site.

The purpose of the geotechnical model is to facilitate appropriate analysis of the slope stability and groundwater conditions, to determine:-

- the extent to which slope improvements are required for future residential subdivision and development, and
- appropriate geotechnical design targets for the slope improvements.

Modelling and analyses have been undertaken and results are presented herein, using the established geotechnical analysis computer programs Slope/W and Seep/W (Geo-Slope International Ltd). The modelling and analyses are discussed in Section 5.5, and data from the analyses are presented in Appendicies E and F.

5. RESULTS OF INVESTIGATION

5.1 Sub-Surface Stratigraphy

A summary description of the subsurface conditions observed in the test pit excavations and boreholes drilled on this site (1997, 2001 and 2015) is provided in Tables 1 & 2 above, and Tables 3 & 4 below. The conditions at each test location are recorded on the logs presented in Appendix A and Appendix B.

TABLE 3 – Summary of Soil and Rock Units

UNIT	DESCRIPTION		COMMENT
UNIT 1	FILL	Silty CLAY (CL & CI) low to medium plasticity, grey/red/brown, with fine to coarse gravel and shale fragments and components of ash, concrete, brick and asphalt fragments, pieces of metal, glass, wire.	Variable insitu condition ranging up to moderately well compacted
UNIT 2	NATURAL SOIL Residual and disturbed material Minor shale layers and components (generally very low strength and extensively weathered)	Silty CLAY (CL/CI/CH), low to high plasticity, grey with some orange/red mottle, trace ironstone gravel, clayey shale layers. Generally no clear transition between components.	Firm to Stiff becoming Stiff
UNIT 3	TRANSITIONAL BEDROCK Generally Class V and Class IV Shale, layers of shaley clay, some Class III Shale	Recognisable Shale	Extremely low to low strength, variably weathered
UNIT 4	BEDROCK Class I –II Shale	Shale / Laminite	Slightly weathered to fresh

The soil and rock unit definitions adopted for this report (Table 3) are broad and generally descriptive of the character of the materials. They were determined principally for use in the Slope/W and Seep/W analyses, and accordingly are for the purposes of reference in this report only.

The units are differentiated mainly on the basis of their role in controlling the slope behaviour at this site and assist in the description of the geotechnical model discussed below.

Table 4 provides a summary of the depths at which the different units could be distinguished from the borehole drilling and logging. In some locations the information tabulated is incomplete. This is not regarded as critical in the process of developing the geotechnical model or the analyses undertaken.

TABLE 4 – Summary of Soil/Rock Units in Boreholes

Borehole	Collar RL AHD	Depth (m)				
		Unit 1	Unit 2	Unit 3	Unit 4	EOH
BH1	153.40	0 – 1.05	1.05 – 3.0	3.0 – 4.8	>4.8	6.0
BH1A	153.49	0 – 1.8	1.8 – 3.0	>3.0	Not recognised	4.85
BH2	151.48	0 – 0.9	0.9 – 3.7	3.7 – 7.3	>7.3	9.0
BH3	149.77	0 – 1.6	1.6 – 7.6	Not recognised	>7.6	9.05
BH4	149.58	Not present	0 – 5.2	5.2 – 7.5	>7.5	7.50
BH5	146.98	Not present	0 – 5.4	Not recognised	>5.4	6.0
BH6	144.32	Not present	0 – 5.0	>5.0	Not recognised	6.0
BH7	148.55	Not present	0 – 5.9	5.9 – 7.0	>7.0	11.78
BH8	151.07	0 – 1.7	1.7 – 6.7	6.7 – 8.5	>8.5	11.73
BH9	153.63	0 – 1.3	1.3 – 5.8	5.8 – 8.3	>8.3	11.43
BH10	148.87	0 – 0.3	0.3 – 6.8	6.8 – 9.7	>9.7	10.98
BH11	144.39	Not present	0 – 5.5	5.5 – 8.4	>8.4	10.65

5.2 Groundwater & Inclinometer Monitoring

The monitoring data collected in the period of the investigation are provided in Appendix C and Appendix D.

5.2.1 Groundwater Monitoring

Groundwater level (GWL) variations have been recorded over time, in the periods April 2001 to December 2002, and March to May 2015. Discrete variations related to rainfall events are noted from the data loggers installed in late April 2015. Graphs of GWL over time are provided in Appendix C, and selected data are noted below to illustrate the nature of the variations.

In drier weather conditions, the GWL's in BH5 and BH6 have been consistently high (near to ground surface), with the remainder of the boreholes between 1m and 4m below surface. The monitoring in December 2002 was at a time of hot and dry local weather in Sydney, with severe bushfires to the west and northwest of the site locality. The GWL's recorded at this time are the lowest from the limited records for this site. Although there was no GW monitoring over the 12 years or so between 2002 and 2015, it is likely that the data from that time represent the minimum GWL's anticipated for the site.

At times of wetter weather conditions over the monitoring periods, the other boreholes record rises in GWL's, some near to the ground surface. Surface water flows have been observed on occasions near BH2 and BH5 and over the lower slope area uphill from Oratava Ave at the southwestern area of the site. Spring activity was observed at the base of the ridge side-slope near BH2, which indicates artesian groundwater pressure from time to time.

The recent rainfall event of 21 – 23 April 2015, possibly a 10-year ARI (316.5mm recorded at the Castle Hill BOM Station and 293.5mm at Baulkham Hills BOM Station), produced a significant peak-level response from the groundwater monitoring. Unfortunately, the data loggers were not installed prior to that event, and did not capture the rise from prior levels to a peak. However, the loggers have demonstrated the immediate response at the middle and a taper-off at the end of the 3-day period.

5.2.2 Inclinometer Monitoring

The inclinometer monitoring of installations in BH7, BH8 and BH9 indicate minor slope movements have occurred in response to the recent extreme rainfall event of 21 – 23 April 2015.

BH7 and BH8 recorded movement amounting to 2.1mm down to 5m and 6m depth respectively. BH9 recorded lesser movements (1.2mm) to a depth of 4.5m. The movements have reduced since the rainfalls have ceased.

The slope movements reflect characteristic “stick-slip” type ground movements at a depth consistent with the interpreted base of the landslide model adopted for the Slope/W analysis.

5.3 Slope Conditions

5.3.1 South-Eastern Boundary Area (G5), Lot 8

The steep slope at the south-eastern end of the property (zone G5, bordering with Lot 9) has been measured at various times by detailed survey, hand surveying methods, (tape and clinometer) and in test pits. The slope gradients in this area vary from 10^{o} – 48 ^{o}. In one local zone the slope has a formed a concave slip scarp approximately 25m to 30m in length, up to 5m – 6m in overall height and with slope angles measured up to 48^{o}. The scarp is less than 0.4m height. The failure is inferred to have been in the superficial fill veneer only and does not have the characteristics of being deeper-seated. The timing of this failure is unknown.

The majority of the natural slope here has been modified by the placement of fill which past survey has suggested may have formed steep slope angles of 54^{o} - 72^{o} in the past. It is likely these fills have been placed in periodic episodes, comprising:-

- A lower zone of accumulated deposition of fill related to the presence of the concrete batching plant. The accumulated fill materials comprised concrete, bricks and rounded gravels) and were located all over the steep slope area.
- An upper zone comprising clean fill (possibly sourced onsite from more recent local cut/fill.

In some areas on the slope the fill materials have undergone small rotational failures up to 4m^{3} that have likely been caused by uncontrolled surface water flowing down the slope from above. It is also likely that the steep area of 48^{o} (noted above) may have a veneer of fill reducing its slope from some steeper angle. Overall the fill materials have measured slopes of 10^{o} - 35^{o} across the western slope face.

No seepages or wet areas were located on the natural or fill slopes in the area from the toe to the crest line which includes the border between the subject property and Lot 9 (No.572 Pennant Hills Rd). It is noted that groundwater and seepage conditions can vary depending on weather and seasonal conditions.

The slope vegetation here is dominated by weed species, privet and camphor laurels. The vegetation is sparser on the steeper scarp slope but is generally dense over the rest of the slope.

5.3.2 Southern Area (G4) and Northern Area (G1), Lot 8

The ground surface is predominantly smoothly contoured, grassed and featureless, with slope gradients in the range of 6^{o} to 8^{o} (southern area) and 9^{o} to 13^{o} (northern area). Fill of about 1.5m maximum depth has been present on the southern area since the time of our initial field investigations in 1997.

5.3.3 Central Ridge Area (G2, G3), Lot 3 and Lot 8

The central ridge area has moderate to steeper slopes on shallow shale bedrock. Slope gradients are in the range of 8° to 14° with locally steeper areas to 24°.

Apart from an old narrow access track that has been formed along the southern side-slope of the ridge, the ground surface in this area of the site is smoothly contoured.

Some surface features seen on the 1943 aerial photograph in Figure 3 are possibly evidence of shallow soil movements (terracettes) on the steeper sideslope area in Zone G3. They may also be the result of land management or farming at the time.

The southern side-slope of the ridge is now thickly overgrown with small trees and bush re-growth. This area was originally cleared of all vegetation as can be seen in the 1943 aerial photograph.

5.4 Geotechnical Zones

The site has been differentiated into zones of similar geotechnical characteristics, as shown on Figure 7. The zone characteristics are described in Table 5 below.

5.5 Geotechnical Model & Analysis

The interpretation of subsurface conditions, the slope morphology and limited knowledge of the site history are discussed below in developing the geotechnical model of the landslide affecting the southern portion of the site, to enable analysis to be undertaken.

The results of the geotechnical analyses are provided in Appendix E (Slope/W) and Appendix F (Seep/W). Selected examples of the analysis outputs are provided in Figures 8 – 11.

5.5.1 Interpretation and Development of the Landslide Model

As noted in Section 2.4 above, part of the site falls within the E-3_m and E-1,3_m extreme hazard categories mapped by the NSW Soil Conservation Service (SCS). The slope features of the site are consistent with that mapping and with other areas within the West Pennant Hills, Castle Hill and Glenhaven localities that exhibit landslide characteristics and active landsliding.

Coffey Partners International Pty Ltd (reference 7) (Coffey) have prepared a plan (Drawing No. S10723/1-1 dated 24 April 1997) which marks their interpreted "boundary of landslide" extending across Oratava Ave and down to Glenvale Close, south of the site. In relation to that plan and drawing, Coffey explain:

> *Based on a number of other studies carried out in the vicinity of Oratava Ave since 1975, our present knowledge of the area indicates that the landslide probably extends from near the intersection of Oratava Ave and Pennant Hills Rd to the sharp corner in Oratava Ave about 300m west. It is believed to extend up to 100m uphill and downhill of Oratava Ave, with the maximum depths of sliding material about 6 to 8m. The attached drawing No. S10723/1-1 shows the inferred approximate location of this landslide area.*

The Coffey plan indicates their interpreted "boundary of landslide" extends across part of the subject site at 39 – 55 Oratava Ave. That demarcation is indicated on Figure A (Attachment 2 herewith).

TABLE 5 – Geotechnical Zones

ZONE	TYPICAL SLOPE GRADIENT	SURFACE FEATURES	SUMMARY OF GEOLOGY AND SOIL CONDITIONS	SCS URBAN CAPABILITY (Ref. 1)	IMPLICATIONS FOR DEVELOPMENT
G1	$9^o – 13^o$	Side-slope with a minor ridge crest aligned NW. Moderate gradients. Minor surface depression developing at southern side, falling NW.	Typically 1.5m Silty Clay soils overlying Siltstone/Laminite bedrock. Glenorie erosional soil landscape.	$C\text{-}1,3_m$	Good engineering practices suitable for hillside construction required. Engineering controls are required. Lot development and footing design for conventional residential structures based on site classification procedures/requirements as detailed in AS2870-2011. Geotechnical assessment/review or specific investigation of individual lot development recommended. Engineering appraisal and design required for development bordering or across drainage lines.
G2	$8^o – 14^o$	Moderate upper ridge slopes (8^o) and dominant ridge spur ($8^o – 10^o$) aligned east-west. Side-slopes $12^o – 14^o$.	Typically 1.5m Silty Clay soils overlying Siltstone/Laminite bedrock Glenorie erosional soil landscape.	A-3 B-1 and $B\text{-}1,3_m$ $C\text{-}1,3_m$	
G3	$14^o – 24^o$	Steeper ridge side slope, falling to south-west	Generally shallow depth of Silty Clay soils overlying Siltstone/Laminite bedrock Glenorie erosional soil landscape.	$E\text{-}1,3_m$	All requirements as for G1/G2. Development feasible, requiring strategic and detailed geotechnical investigation and design.
G4	$6^o – 8^o$	Gently to moderately sloping, slightly concave benched slope. Locally steeper (14^o)	Relic landslide colluvium/disturbed slope, typically 3m - 6m, overlying 2m(+) of clay and shale, overlying Siltstone/Laminite bedrock. Fill present, 1.0 – 2.0m thickness West Pennant Hills colluvial soil landscape.	$B\text{-}1,3_m$ $E\text{-}3_m$	Major subsurface drainage required for stability improvement prior to subdivision. Remove or improve uncontrolled fill. Engineering controls are required. Geotechnical assessment/review of individual lot development required. Specific investigation may be needed.
G5	$25^o – 35^o$	Steep to very steep side slope bordering upper ridge/plateau area. Locally steeper (48^o) where fill is present and local failures have occurred	Steep shale bedrock slope, possible area of denuded relic scarp slope. Uncontrolled fill typically shallow veneer (<1m) but up to 2m thick at shoulder of slope, over Siltstone/Laminite bedrock. Glenorie erosional soil landscape.	$E\text{-}1,3_m$	Development feasible, requiring strategic and detailed geotechnical investigation and design.

Information was supplied to us by Rod Jeffery (Jeffery & Katauskas Pty Ltd) from investigations undertaken by that firm in or around 1997 on land downhill of Oratava Ave (Lot B, Project Ref. 12633J) opposite the site of 39 – 55 Oratava Ave, for a proposed residential subdivision and development. The data from the J&K test pit investigations describes observations of slickensided surfaces and zones, shear planes, and generally disturbed clays overlying the shale bedrock, similar to the Coffey data elsewhere on the larger-scale landslide area.

The data from Coffey and J&K are considered relevant to the landslide history of the locality, and particularly relevant to the geotechnical slope model for the site currently under investigation.

The following interpretations of the subsurface conditions within the inferred landslide area have been made from our own logging of the boreholes drilled for the current investigation, and to a limited extent from the 1997 test pit data:-

- The soil and rock profile comprises weathered silty clay with traces of gravel, grading to a silty clay with gravel to a gravelly clay at the insitu bedrock level. The gravels are a mixture of randomly orientated, sub-rounded to sub-angular, highly to moderately weathered siltstone and laminate.
- The entire soil profile shows some degree of disturbance. The weathered siltstone that would normally exist in bands, appears as randomly orientated pieces of siltstone and laminate in all levels.
- The profiles are not typical of a colluvial deposition landscape, rather an insitu soil profile that has been altered by a small to moderate sized landslide event in the past.

The landslide may be a single event that has occurred around the current ridgeline, or may have been a combination of multiple events, with a cumulative downslope component of movement of the order of 20m – 30m from the original undisturbed conditions of the slope.

The evidence points towards a landslide comprising a mass movement of the original insitu slope which included the weathered clay zone along the clay/insitu bedrock contact, which would have resulted in a disturbed profile similar to that evident now.

A definable and/or continuous plane of failure or regular profile for the landslide may not be present from the crest to toe of the slope. Parts of the landslide may not be active under currently prevailing groundwater conditions.

However, review of the topography and the drilling and test pitting evidence suggests that the scarp, central zone and toe of the landslide can be distinguished. The overall geometry of the landslide appears to be in the order of 100m – 120m in length and 5m – 6m in depth.

5.5.2 Slope/W Analysis

Three geotechnical slope sections (Sections 1 – 3) were developed from the borehole and test pit data, using the site survey to obtain the correct topographic profiles. The section locations are indicated on the site plan in Figure 2.

The analyses were conducted to test the site stability (factor of safety) on each slope section using assumed shear strength parameters for the presumed (most likely) failure surface geometry.

The likely failure surface geometry was determined from the results of the borehole drilling, matched to the slope morphology and checked by reference to experience and case histories with similar landslide sites in the Castle Hill/West Pennant Hills locality, and to published data (eg, Fell 2006, reference 8).

The geotechnical slope model had been determined initially in 2001/2002 from the first phase of borehole drilling. Slope Sections 1 & 2 had been developed then, and were available for the initial establishment of the Slope/W model and the first round of analyses. The model was confirmed with only minor adjustments, using the results of the second phase of borehole drilling in March 2015. Section 3 was developed for the later round of analysis.

The geotechnical material parameters adopted for the Slope/W analyses are provided in Table 6 below.

The critical parameter for the analysis relevant to established landslides is the residual shear strength at the failure surface. The values adopted in the analyses were selected from direct experience and information available from other practitioners and published data (as noted above), in accordance with usual practice for such analyses.

The range in the residual friction angle φ_r' = 11° – 13° used in the analyses for Unit 2 material covers the anticipated value of 12° and provides a reasonable assessment of the sensitivity in the analysis to variation of this parameter. A non-zero value (1kPa) for the cohesion component at residual strength conditions was adopted for this unit.

The analysis case using the higher strength values of 5kPa and 26° for Unit 2 was to model the slope at a reasonable but conservative upper bound.

TABLE 6 – Geotechnical Parameters

Unit	**Material**	**Parameter Value**		
		Unit Weight	**Cohesion** c’	**Friction Angle** φ’
1	Fill	18kN/m^3	1kPa	24°
2	Stiff clay	19kN/m^3	5kPa	26°
		19kN/m^3	1kPa	11° – 13°
3	Shale	22kN/m^3	7.5kPa	26°
4	Shale	Impenetrable		

The groundwater influence on the stability conditions was modelled using the available monitoring data for the site from the 2001/2002 and the 2015 investigations. The highest recorded piezometric profile of the groundwater at the failure surface over the fourteen years of monitoring data has been determined to be at, or very close to the ground level. Suspicion of slight artesian pressure conditions at some borehole locations was confirmed from the data logger monitoring installed since 22 April 2015.

The groundwater profile “*near ground surface*” represents a limiting condition based on the available data and observations of the slope conditions at the site at the time of the analyses.

The analysis results as at 1 April 2015 are summarised in the tables below.

Slope Section	Shear Strength		GWT Assumed	FOS
	Cohesion (kPa)	Phi (deg)		
1	5	26	Near ground surface	1.790
	1	13	Near ground surface	0.920
			1m below ground surface	1.220
			2m below ground surface	1.450
	1	11	Near ground surface	0.820
			1m below ground surface	1.080
			2 m below ground surface	1.280

Slope Section	Shear Strength		GWT Assumed	FOS
	Cohesion (kPa)	Phi (deg)		
2	5	26	Near ground surface	1.716
	1	13	Near ground surface	1.030
			1m below ground surface	1.284
			2m below ground surface	1.504
	1	11	Near ground surface	0.909
			1 m below ground surface	1.134
			2m below ground surface	1.326

Slope Section	Shear Strength		GWT Assumed	FOS
	Cohesion (kPa)	Phi (deg)		
3	5	26	Near ground surface	2.403
	1	13	Near ground surface	1.021
			1m below ground surface	1.260
			2m below ground surface	1.483
	1	11	Near ground surface	0.878
			1m below ground surface	1.080
			2m below ground surface	1.268

The analyses confirm that the limiting stability case (FS≈1) for each of the three slope sections adopted occurs for the “near ground surface” groundwater profile and residual shear strength parameters 1kPa/13^{o}.

A satisfactory increase in the factor of safety for the slope, to approximately FS=1.5, is achieved by lowering the groundwater profile to a level of 2m below the ground surface along each of the slope sections. That outcome can be adopted as a target for the assessment and design of the proposed improvements to the groundwater regime over the site using subsurface drains.

An assessment of the groundwater conditions and requirements for their improvement has been undertaken as part of this investigation, using Seep/W analysis as described in Section 5.4.2 below, and elsewhere in this report. Whilst a detailed design for the subsurface drainage improvements is yet to be undertaken (proposed as part of the engineering analysis prior to construction) the analyses undertaken so far, summarised above, confirm it is feasible.

The site has been subjected to a significant rainfall event during the course of the current investigation. From the discussion provided in Section 6.2 below, it is concluded that the geotechnical model of the slope conditions in the southern area of the site, as analysed using Slope/W, and particularly the groundwater regime analysed using Seep/W, is reliable for progressing with the proposed subdivision and development.

5.5.3 Seep/W Analysis

As noted in Section 5.4.1 above, three geotechnical slope sections (Sections 1 – 3) were developed for the analyses undertaken as part of the investigation to date. The Seep/W analyses were conducted with the following aims:

- to confirm the groundwater model developed from the investigation and monitoring data, and
- to determine the extent to which the groundwater lowering predicted from the Slope/W analyses for an improved factor of safety for the slope stability could be achieved by a “conventional” arrangement of subsurface drainage trenches.

Analyses were carried out for Section 2 and Section 3 using the same geotechnical model adopted for the Slope/W analysis. Section 1 was considered less critical in terms of groundwater conditions.

One variation was introduced, where a thin layer (Unit 3A) of significantly higher permeability was added at the interface between Unit 3 and Unit 4, creating a more permeable zone, reflecting the borehole drilling observations that indicated groundwater was “trapped” at depth until intersected by the drilling, thence rising within the borehole under excess hydrostatic head.

The proposed arrangement of the subsurface drains was determined from the subdivision layout (lot boundaries and road alignments), with the constraint that the drains were to be located on the shared allotment boundaries or within the proposed road reserves.

A total length of subsurface drainage trenching (3m depth with chimney drain extensions from the base of the trenches) of 640 lineal metres was determined from the preliminary design.

The Seep/W analysis model was developed as follows:-

- Slope Sections 2 and 3 were adopted for analysis, about 130m in length.
- Hydraulic head was assigned at both upstream and downstream boundaries to coincide with the groundwater monitored in relevant boreholes.
- Four units of material were considered in the model. The parameters are summarised in the table below.
- The saturated permeability for each unit was estimated from the field rising water head test data performed in 2002 and 2015.
- Upstream boundary: RL 165m (Section 3), RL 154.5m for Section 2 so as to simulate spring at the toe of steep slope adjacent to end of section.
- Downstream boundary: RL 142m (Section 3), RL133m (Section 2).

- A water infiltration of about 25mm/year due to rain events was included in the model based on past experience from previous projects in this area.

Geotechnical model and parameters

In the Seep/W programme Unit 1 and Unit 2 were modelled with Sat/Unsat material where permeability is allowed to vary with suction. A variable function chosen for Unit 1 and Unit 2 material where a metric suction of 10kPa corresponds to a reduced permeability of two orders of magnitude.

A plot is provided in Appendix F, which shows the unsaturated permeability characteristics of Unit 2 stiff clay.

TABLE 7 – Permeability Values

Unit	Material	Saturation	Saturated Permeability k (m/sec)	
			Base case	Lower bound case
1	Fill	Sat/Unsat	1e-05	1e-05
2	Stiff clay	Sat/Unsat	5e-07	1e-07
3	Shale	Saturated	1e-07	5e-08
3A	High permeable flow layer	Saturated	5e-05	5e-06
4	Shale	Saturated	1e-09	1e-09

A half metre thick high permeable flow layer (unit 3A) was assumed to exist at the interface with the underlying SW/Fr shale.

For Section 2, Trench No's 1, 2 and 3 were located at 10m, 35m and 60m from the right boundary.

Section 2 Results

- Plot 1 - Base model simulation (no trench drains). It is noted that on 29 April 2105 BH2 and BH5, located in the vicinity of Section 2, recorded standing groundwater at 1.29m and 0.0m respectively below ground surface. From the Seep/W output, groundwater level was also analysed to be at or near ground surface.
- Plot 2 - Base model simulation with inclusion of 3m deep trench drains.
- Plot 3 - Base model simulation with inclusion of chimney drains installed at the bottom of trench drains to intercept the permeable layer, ie. Unit 3A.
- Plot 4 - Base model with use of lower-bound permeability for Unit 2, Unit 3 and Unit 3A. Groundwater level was analysed to be at or near the ground surface.
- Plot 5 - As for Plot 4, but with inclusion of 3m deep trench drains. Highest groundwater at about 2.0m was analysed at the western (downhill) end of the slope section, near Oratava Avenue.
- Plot 6 - As for Plot 5, but with inclusion of chimney drains installed at the bottom of the trench drains to intercept the permeable layer, ie. Unit 3A.

Observation

- For Section 2, subject to detailed design, trench drains + chimney drains may only be required at the western end of the slope section.
- Spacing and size of chimney drains to be determined and confirmed in the detailed design phase. Currently it has been assumed that they have the same water carrying capacity as the trench drains.

Section 3 Results

- Plot 1 - Base model simulation (no trench drains). It is noted that on 29 April 2105 BH10, located in the vicinity of Section 3, recorded a groundwater at about 1.9m below ground surface. However groundwater level was analysed to be at about 4.1m below ground surface in the BH10 area. Across and at BH1, which has an offset of about 15m from Section 3, the groundwater table was analysed to be at about 7m below the surface as compared to the field measured 1.5m below ground surface.
- Plot 2 - Base model simulation with inclusion of 3m deep trench drains.
- Plot 3 - Base model simulation with inclusion of chimney drains installed at the bottom of trench drains to intercept the permeable layer, ie. Unit 3A.
- Plot 4 - Base model with use of lower-bound permeability for Unit 2, Unit 3 and Unit 3A. Groundwater level at or near BH10 and BH1was analysed to be at about 2.4m and 4.1m below ground surface respectively.
- Plot 5 - As for Plot 4, but with inclusion of 3m deep trench drains. Highest groundwater at about 2.5m was analysed at the western end of the slope section.
- Plot 6 - As for Plot 5, but with inclusion of chimney drains installed at the bottom of the trench drains to intercept the permeable layer, ie. Unit 3A.

Observation

- For Section 3, subject to detailed design, trench drains + chimney drains may only be required at the western end of the slope section.
- Spacing and size of chimney drains to be determined and confirmed in detailed design phase. Currently it has been assumed that they have the same water carrying capacity as the trench drains.
- Section 2 appears more critical than Section 3, and needs to be analysed due to observed springs and measured high static groundwater

6. DISCUSSION & RECOMMENDATIONS

6.1 Slope Stability

Part of the site lies within an area mapped by the Soil Conservation Service of NSW (SCS) in 1977 for urban capability (reference 3). The steep slope bordering the eastern side of the property is judged to be an area of extreme hazard (E-1,3_m) defined by the SCS, having potential for mass movement. Areas of moderate and high hazard are also present within the site based on the SCS mapping

The Hills Shire Council 2012 LEP maps part of the site within its “Landslide Risk” area (Figure A in Attachment 2 herewith).

Our report R97024.A dated 6 June 1997 delineated an area of ***high risk*** around the eastern side of the property. The high risk zone is in the area of the steep slope and uncontrolled fill on naturally steep side slope (18° to 31°), with suspected local slump failures of the fill batter.

Other zones within the site were classed then as ***low risk***, ***medium risk*** or ***medium to high risk***. Definition of these risk zones and the terminology used in 1997 were based on the accepted risk classification system determined by the Australian Geomechanics Society in 1985 (reference 4), in common use at that time.

The risk assessment methodology and terminology have changed since that time. Current risk assessment guidelines, which are now used for geotechnical assessment of residential development, are published by the Australian Geomechanics Society in March 2007 (reference 5). The risk assessment methodology is based on :

- consideration of the likely slope failure mechanisms and likely initiating circumstances which could affect the elements at the site. The type or mode of landslide failure is classified.
- for each case, the potential consequences with respect to existing or future development are considered. The assessed/estimated probability of occurrence of each hazard event is determined on a qualitative basis. The consequences and probability of occurrence are combined for each case to provide the risk assessment.

Risk to property causing economic loss is expressed qualitatively (low/moderate/high risk). Risk in regard to loss of life is determined quantitatively. The current risk assessment for this site is summarised in Table Z1 from Appendix Z.

TABLE 8 - Preliminary Risk Assessment (Property)

Hazard Failure Mechanism	**Severity of Failure**	**Estimated Likelihood of Occurrence**	**Estimated Consequence Level**	**Measure of Consequence**	**Estimated Risk**	
					No Slope Improvements	**With Management** (Note 1)
F1	(a)	ALMOST CERTAIN (10^{-1})	A(-)	INSIGNIFICANT	M	L
		LIKELY (10^{-2})	A	MINOR	M	M (Note 2)
	(b)	POSSIBLE (10^{-3})	B	MEDIUM	M	L
	(c)	UNLIKELY (10^{-4})	C	MEDIUM to MAJOR	L – M	L
F2	--	POSSIBLE (10^{-3})	--	MINOR to MEDIUM	M	L (Note 3)

[Refer to Table G1 in Appendix G for notes]

The previously determined low risk category for the site would have similar meaning and implications for the site and future development compared with an assessment under the current AGS Guidelines. However, the higher levels of risk outcome may have different meaning for the development compared to the older terminology.

The approval/local government authority determines risk acceptance criteria for residential development. Guidelines for risk acceptance are provided in AGS 2007.

6.2 Geotechnical Analysis

The site has been subjected to a significant rainfall event during the course of the current investigation (21 – 23 April 2015).

Monitoring of the inclinometer installations in BH7, BH8 and BH9 (refer Section 5.2.2 above) indicates minor slope movements have occurred in response to the rainfall event, down to depths consistent with the developed geotechnical model of the slope instability. The movements have reduced since the rainfalls have ceased.

The slope movements reflect characteristic "stick-slip" type ground movements at a depth consistent with the interpreted base of the landslide model adopted for the Slope/W analysis.

It is concluded that the geotechnical model of the slope conditions in the southern area of the site, as analysed using Slope/W, and particularly the groundwater regime analysed using Seep/W, is reliable for progressing with the proposed subdivision and development.

Localised spring activity was observed at the time of the rainfall event experienced in Sydney in late April 2015. Rainfall records from the BOM stations at Castle Hill (67100) and Baulkham Hills (67109) recorded in excess of 300mm of rainfall over an 8-day period (16/4/15 – 23/4/15). The recorded rainfalls in the 3-day period 21/4/15 – 23/4/15 were 317mm at Castle Hill and 294mm at Baulkham Hills.

The source of the spring was traced to the base of the steeper slope rising near BH2. The level of the spring flow on 22/4/15 was estimated to be approximately RL152.4m, about 1m higher than the ground level at BH2 (near the base of slope). The spring flow persisted for at least 1 week with diminishing level and flow rate.

The significance of the spring activity was "tested" in regard to a potential impact on the analysis results. Although not positively defined from the observations at the time, it is believed the spring represents a perched water source in the shale strata near the level of the base of slope at BH2. The piezometric level observed at the location of the spring (close to the ground surface on the rising slope above BH2) is consistent with the general assumed worst case for groundwater as modelled, ie "*near ground surface*".

If the observed spring activity resulted from a general increase in hydrostatic pressure at the failure surface at depth (influenced by the intense rainfalls, preceding and occurring at that time), say by 1m above ground surface, either locally or along the entire slope section as modelled, the fact is that no change in the slope conditions have occurred on this occasion or in the past when previous spring activity at this same location can now be assumed to have occurred.

The analysis for limiting stability conditions (FS=1.0) using a general groundwater profile 1m above the "*near ground surface*" level adopted would simply mean that a higher value for the shear strength on the failure surface would need to be applied in the Slope/W analysis to balance the numerical effect of the higher hydrostatic pressure along the slope section.

Intuitively, this means the residual shear strength value adopted for the above analyses ($\varphi_r' \approx 12^o$) can be confidently accepted, and the Slope/W analyses are reliable.

6.3 Groundwater/Subsurface Drainage

The proposed network of subsurface drainage trenches is indicated on the subdivision layout plan, included herewith as Attachment 1. A total length of subsurface drainage trenching of 640 lineal metres was determined from the preliminary design.

A typical section of the proposed trench drain construction is provided in Figure 12.

The flows to be discharged into the Council stormwater system from the subsurface drainage are in addition to normal stormwater discharge from the property. Flow rates from the subsurface drainage system will be determined from the detailed geotechnical drainage design.

Detailed hydraulic design assessment for the subdivision will need to be undertaken as part of the engineering design for construction.

6.4 Subdivision Design

6.4.1 Block & Road Layout

The proposed subdivision layout is shown on the plan provided as Attachment 1. There are 31 residential allotments ranging in size between 500m^2 and 688m^2.

An engineering design for the road alignments has been prepared by Craig & Rhodes. This is provided separately as part of the Planning Proposal documentation.

6.4.2 Earthworks

The road design includes excavation in order to achieve the controlling longitudinal gradients in accordance with anticipated Council specifications. Excavation depths at the road boundaries generally range up to 1.0 – 1.4m maximum, and at one location reach 1.9 – 2.1m depth (approximate CH100 to CH110 around the cul-de-sac on Road No.402).

It is anticipated the deeper areas of road excavation as designed will extend close to or into shale bedrock.

Detailed design of excavation batters and retaining wall support (where indicated on the engineering design, or otherwise where required) is to be undertaken for the final design.

Engineered fill earthworks may be utilised for certain areas of the road support where the design requires. This would be assessed and specified at the detailed design stage.

In locations where the required fill is considered excessively deep or appropriate batter design cannot be achieved, or possibly for economy (eg, cut-to-fill earthworks balance issues) the road structure will be supported by engineered retaining walls or pier-and-beam construction.

6.4.3 Drainage

It is anticipated that the road drainage, stormwater and roofwater disposal for the subdivision will be designed and piped to discharge into the existing stormwater systems in Oratava Ave to the south, and in Brett Place to the north, in accordance with the normal requirements of Hills Shire Council.

For drainage disposal from Lot 8 to Brett Place, an easement already exists across adjoining property from earlier subdivision of the land, benefitting Lot 8.

Road No.404 crosses a minor drainage alignment within Zone G1. It is anticipated that additional subsurface drainage at the uphill side of the road would be required for maintaining dry conditions for the road subgrade as part of normal design requirements.

Sections of the internal roads in the southern area of the site will have subsurface drainage constructed within the road reserves, as part of the geotechnical drainage system in Zone G4 (preliminary drainage layout shown in Attachment 1). This drainage will be entirely separate from the normal stormwater drainage for the subdivision, until the point of discharge into the existing street drainage systems as noted above.

Residential stormwater drainage, overflow from rainwater tanks and discharge from OSD on all the residential allotments is to be piped to the subdivision stormwater system, or directly to Oratava Ave where this is possible. Inter-allotment drainage facilities are to be provided as part of the subdivision works.

6.4.4 Existing Fill

Uncontrolled fill exists within Zone G4 and Zone G5. More than likely, this fill would be (at least partly) removed as part of the subdivision earthworks for general site improvement. Assessment of potential contamination issues and waste classification will be required, either for retaining the fill on the site, or for removal of the fill materials from the site.

Suggested improvements for Zone G5 that could be undertaken as part of the subdivision works are indicated in concept form in Figure 13 herewith.

6.4.5 Geotechnical Review/Controls

Geotechnical review of the engineering design at preliminary and final stages is necessary prior to commencement of the subdivision construction. Where appropriate, geotechnical design input may be required and should be provided as the design progresses.

Geotechnical analysis of the groundwater conditions and predicted improvements from the proposed subsurface drainage construction (increased factor of safety for the landslide model as discussed elsewhere in this report), using appropriate numerical modelling techniques, is a necessary component of the detailed engineering design for the subdivision.

Geotechnical involvement should be continued through the construction works as part of the engineering site supervision and monitoring.

6.5 Future Building Developments

6.5.1 Foundation Conditions

Uncontrolled fill is present on this site (refer Section 6.4.4 above). If existing fill is to be kept on site, it will need to be remediated to a suitable engineering standard for the future site developments.

The natural soil conditions (Unit 2 material) comprise medium to high plasticity clay with interlayered bands of extremely weathered, extremely low strength siltstone/shale. The stratum extends to depths varying from 3m to 6m - 7m below present surface levels. The clays and interlayered shales are disturbed in the southern area of the site (Zone G4) as a result of landslide history.

Shale/laminite bedrock underlies the site below depths varying from 3.0m to approximately 6m, grading from Class IV to Class III, and to Class I/II at depths generally below 7m - 8m from surface. The rock classification system used is explained in Pells et al 1998 (reference 6).

6.5.2 Footing Systems

In Zones G1 – G3 (refer Figure 7 and Table 5), footing design for conventional residential structures will be based on site classification procedures and requirements as detailed in AS2870-2011 Residential Slabs and Footings, supported by soil sampling and testing to determine potential shrink-swell reactivity.

Geotechnical assessment and review, strategic and detailed geotechnical investigation and design for individual lot development are recommended minimum requirements.

In Zone G1, the minor drainage alignment crossing several allotments will require engineering appraisal and design for the building footings. It is anticipated that additional subsurface drainage would need to be included.

In Zone G4, we recommend that the building developments should be supported on footings piered to Unit 4 shale bedrock. This is due to the generally disturbed nature of the overlying clay soils in this zone, but would be beneficial from a soil reactivity perspective, considering the significant depth of the clay soil profile.

An alternative shallow footing system may be considered for Zone G4, comprising a heavily stiffened concrete raft platform. In this case, possible surface movements need to be assessed and taken into account in the engineering design of the raft footing system. Design will be based on site classification procedures and requirements as detailed in AS2870-2011, supported by soil sampling and testing to determine potential shrink-swell reactivity.

In Zone G5, the slope gradients are steep and shale bedrock is generally at shallow depth. Building structures and elevated driveways will be required to be supported on footings taken to undisturbed bedrock. Piles or piers would generally be suitable, with drilled sockets in confirmed undisturbed shale.

Where significant soil depth and/or weak/weathered bedrock is present overlying the undisturbed bedrock, a potential for creep of the overburden profile should be considered in the engineering design of the footing system. In this case, the piles/piers should be designed and constructed with structural capacity and adequate socket depth to resist the potential creep. Alternatively, “blade wall” footings with their bases extending into undisturbed shale may be suitable and could be considered.

6.5.3 Basement Excavation

Basements can be considered for individual residences. Temporary support of the basement excavations during construction must be assessed and detailed as part of the engineering design.

The basement walls must be provided with a permanent drainage system to prevent build-up of hydrostatic pressure against the walls from groundwater seepage. Drainage by gravity to the stormwater system is preferred and recommended where this can be achieved. Pumping from a sump in or adjacent to the basement is possible. Alternatively, the basement should be designed and constructed as a “tanked basement”, with allowance for hydrostatic pressure around the basement walls and uplift on the basement floor to be included in the design.

6.5.4 Landscaping

A geotechnical engineer must review any slope modifications proposed as part of the development, whether for landscaping or building construction, prior to commencement.

The review should assess appropriate limitations on depths of benching, batter slopes, requirements for retaining wall support and drainage, and materials to be used for any earthworks.

6.5.5 Drainage and Services

Residential stormwater drainage, overflow from rainwater tanks and discharge from OSD on all the residential allotments is to be piped to the subdivision stormwater system, either directly or via inter-allotment drainage easements. Where allotments have a frontage onto Oratava Ave, the stormwater would be piped directly to the existing street stormwater system.

In Zone G4, use of flexible jointing for stormwater lines, sewer lines and water services is a likely requirement to allow for the possibility of pipe movements.

6.5.6 Geotechnical Controls

Geotechnical controls will be required for individual building developments. The following are anticipated:-

- confirmation of the foundation conditions on a lot-by-lot basis, including individual site classifications in accordance with AS2870-2011;
- limitation on excavations and filling appropriate for the individual site conditions;
- assessment and design advice for building footings, retaining walls and management of groundwater;

6.6 General Geotechnical Requirements

The engineering designs for subdivision and lot developments should be subjected to geotechnical review prior to issue of the Construction Certificate.

Pier drilling for the building footings or other groundworks should be inspected by a suitably experienced geotechnical engineer during their construction progress, to verify achievement of the design founding levels, end bearing and/or socket requirements nominated for the structural design.

The design details for landscaping, civil earthworks and stormwater drainage are to be reviewed by the geotechnical engineer prior to issue of the Construction Certificate, in terms of impact on slope stability conditions and any special requirements for long-term maintenance.

The slope stability/risk outcome is to be confirmed at completion of the development by a suitably experienced and qualified geotechnical practitioner in landslide risk assessment, with the expectation that the development will meet Council's acceptable risk criteria.

6.7 Further Work

6.7.1 Monitoring

Current groundwater monitoring and inclinometer monitoring should be continued over at least the period up to commencement of construction.

The need for additional monitoring installations may be reviewed to provide supplementary data.

6.7.2 Additional Investigation

Boreholes and test pits are recommended in the northern and north-eastern areas of the site as follows:-

a) to supplement the limited information available from the 1997 test pits (Zone G1 and parts of Zones G2 and G3),

b) assess subsurface drainage conditions within depression down southern side of Zone G1, and

c) provide data on the ground conditions in Lot 3 (No.570 Pennant Hills Rd, Zones G2 and G3) which was not investigated previously (the property has only recently been included in the subdivision).

Excavator trenches are recommended on the steep slope (Zone G5) at the eastern boundary area of the site, adjoining Lot 9 (No.572 Pennant Hills Rd), for purposes of identifying the depths of fill and the underlying shale bedrock conditions.

6.8 Alternative Stabilisation and Development

A “Big Dig” design is a possible alternative for stabilisation of the site, but has not been pursued in any detail.

A partial improvement by groundwater lowering, but not to the level adopted herein for the current proposal, whilst less costly at the subdivision stage, is not considered appropriate due to the potentially higher geotechnical risk levels likely for the outcome, and the associated uncertainty transferred to the developments on individual allotments.

The current E4 (Environmental Living) zoning and previous zoning provisions of the site restricted development to minimum 2000m^2 allotments for residential purposes. This was the earlier (2002) basis for a preliminary design for site drainage improvements. If that form of development was to be undertaken, the slope stabilisation requirements for this site would be no different from those associated with the proposed rezoning to R2 (Low Density Residential).

The existing E4 zoning controls, while in part addressing the landslide risk, do not necessarily contemplate the high cost of stablisation works. As a consequence, the particular development controls have been an impediment to development of the site. Development controls that permit a higher lot yield but still recognising the landslide risk would make development more feasible.

For the current E4 zoning, the subsurface drainage layouts may be different from those proposed for the current application, to suit building footprints and/or allotment boundaries and access road alignments. However, the intensity, purpose and design elements of the required subsurface drainage or other associated geotechnical improvement works, and hence the costs of the works, would be anticipated to be essentially the same.

The Hills Shire Council requires justification as follows (email from Brent Woodhams dated 29 May 2015):

> *The planning proposal documentation will need to include preliminary costings for the stabilisation of the slope. As the principal justification for the planning proposal is the need for additional yield to offset the cost of managing the geotechnical constraints, you will need to provide some details on the estimated costs of slope stabilisation.*

A preliminary cost estimate has been developed by Craig & Rhodes for the geotechnical stabilisation works as part of an overall estimate for the subdivision. The value of the geotechnical improvement works (Item 6) is estimated to be $545,700 (with 20% contingency but excluding GST). As noted by Craig & Rhodes, the figures are estimates only and are subject to design and tender.

When spread across the limited building sites (8 allotments) under the current zoning, this amounts to a premium cost, on average, of up to $68,200 per allotment. If spread over the proposed 31 allotments under an R2 zoning approval, the average premium cost amounts to approximately $17,600 per allotment.

7. SUMMARY AND LIMITATIONS

The assessment discussed in the above report provides geotechnical information from investigations at No.39 – 55 Oratava Ave and part of No.570 Pennant Hills Rd in West Pennant Hills, for a proposed subdivision and residential development involving 31 building allotments that is subject to a planning proposal to rezone the land.

Data from previous investigations on the site in the period 1997 through to 2002 have also been used to determine anticipated subsurface conditions and limitations and requirements in regard to the past slope history of the site.

The following primary conclusions and recommendations arise from the investigation:-

- The landslide history of part of the site has been investigated and a reliable geotechnical model developed for analysis.
- Geotechnical monitoring and analysis have confirmed that stabilisation of the landslide-affected area of the site is feasible and practical by means of subsurface drainage improvements.
- A preliminary design has been developed for the subsurface drainage improvements utilising trench drains and chimney drains, sufficient to verify feasibility and costs at a preliminary level.
- Further geotechnical analyses will be undertaken, and engineering design subsequently completed for construction, after Council's approval of the current re-zoning planning proposal and associated subdivision application.
- Following stabilisation of the site, the proposed subdivision and residential development can be undertaken with engineering controls that are considered suitable and appropriate.
- Subdivision and development of the remainder of the site requires normal engineering design and construction.
- Geotechnical involvement is a necessary requirement through the design and construction phases of the development, to ensure the recommendations in this report are appropriately incorporated in the development.

Appendix H – Limitations of This Report – is provided for further understanding of the context of the investigation undertaken, and the limits of the recommendations provided in the report.

We will be pleased to assist with any further advice or geotechnical services required.

DAVIES GEOTECHNICAL Pty Ltd

Davies

Warwick N Davies MIEAust CPEng NPER (Civil)
Principal Geotechnical Engineer

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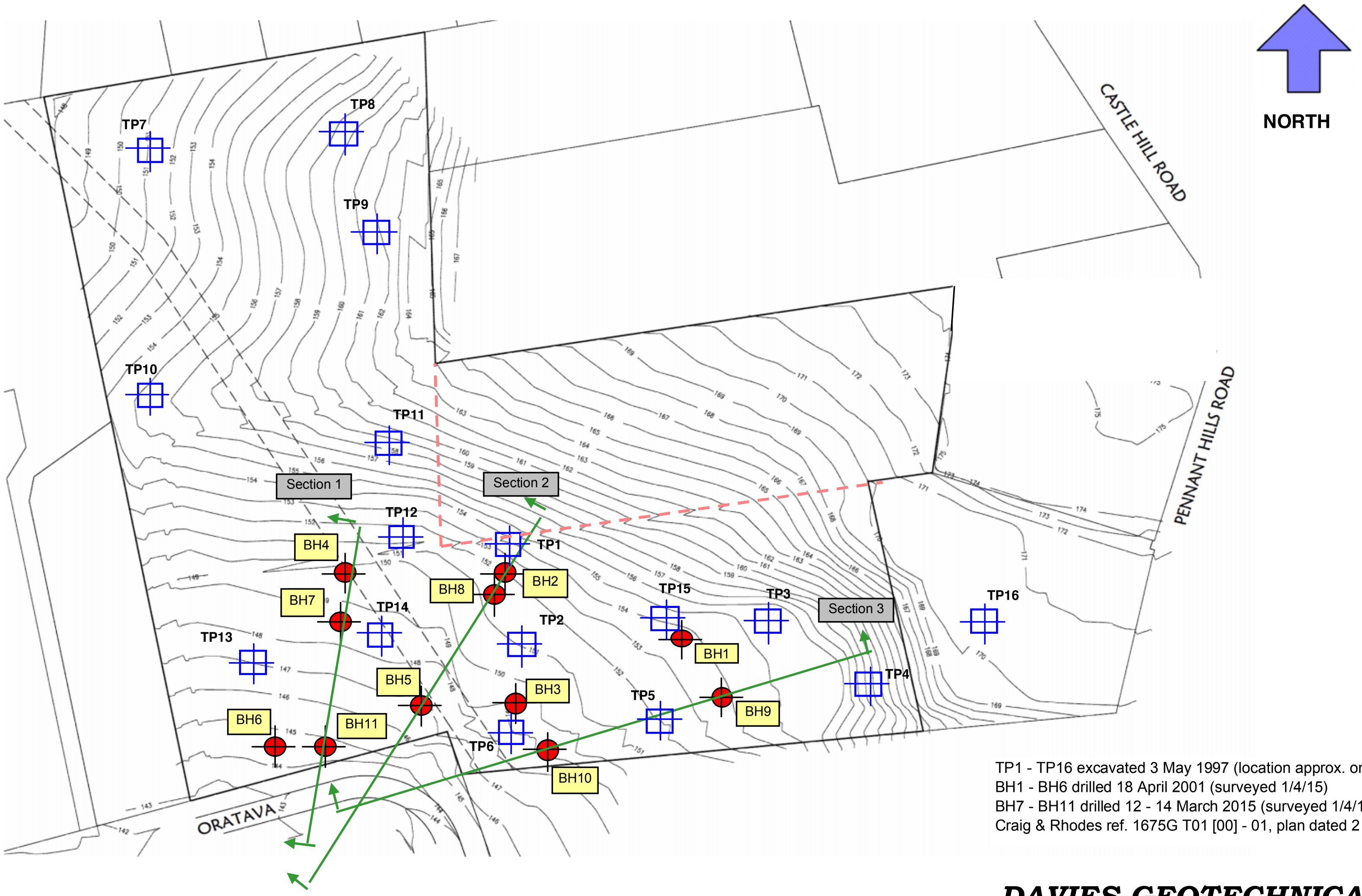
1. Geol. Sur. NSW, Dept Min Resources (1983). *Geological Series Sheet 9130 (Sydney) 1:100,000*.
2. Chapman, G.A. and Murphy, C.L. (1989), *Soil Landscapes of the Sydney 1:100,000 sheet*. Soil Conservation Service of NSW, Sydney.
3. Soil Conservation Service of NSW. *Urban Capability Study, West Pennant Hills*. February 1977, and accompanying maps.
4. Walker et al (1985). *Geotechnical Risks Associated with Hillside Development.* Australian Geomechanics News, No.10, December 1985.
5. *Practice Note Guidelines for Landslide Risk Management 2007 [and Commentary],* Australian Geomechanics, Vol.42, No.1, March 2007.
6. Pells P J N, Mostyn G and Walker B F (1998). "*Foundations on Sandstone and Shale in the Sydney Region*" Australian Geomechanics, Number 33 Part 3 Dec.1998.
7. Coffey Partners International Pty Ltd. *Geotechnical Review – Lot 23 DP261585 (No.12) and Lot 101 DP739167 (No.18) Glenvale Close, West Pennant Hills.* Letter Report to Baulkham Hills Shire Council, ref. S10723/1-AB PLV, dated 24 April 1997.
8. Fell, R *Landslides in the Wianamatta Group, Baulkham Hills Shire, Sydney, Australian Geomechanics, Vol.41, No.1, March 2006.*

DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

Project No:	15-004	**Scale:**	as shown	LOCALITY PLAN NO.39 - 55 0RATAVA AV WEST PENNANT HILLS NSW (Kai Ling (Australia) Pty Ltd)	**Figure 1**
Drawn:	wnd	**Date:**	21 May 15		



TP1 - TP16 excavated 3 May 1997 (location approx. only)
BH1 - BH6 drilled 18 April 2001 (surveyed 1/4/15)
BH7 - BH11 drilled 12 - 14 March 2015 (surveyed 1/4/15)
Craig & Rhodes ref. 1675G T01 [00] - 01, plan dated 2 April 2015

Base survey plan prepared by Craig & Rhodes Pty Ltd, ref. 1675G T02 [00] dated
21 May 2015

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Project No:	15-004	**Scale:**	as shown	SURVEY PLAN & TEST LOCATIONS NO.39 - 55 0RATAVA AV WEST PENNANT HILLS NSW (Kai Ling (Australia) Pty Ltd)	**Figure 2**
Drawn:	wnd	**Date:**	21 May 15		

Image from Six Maps, NSW Land & Property Information

DAVIES GEOTECHNICAL
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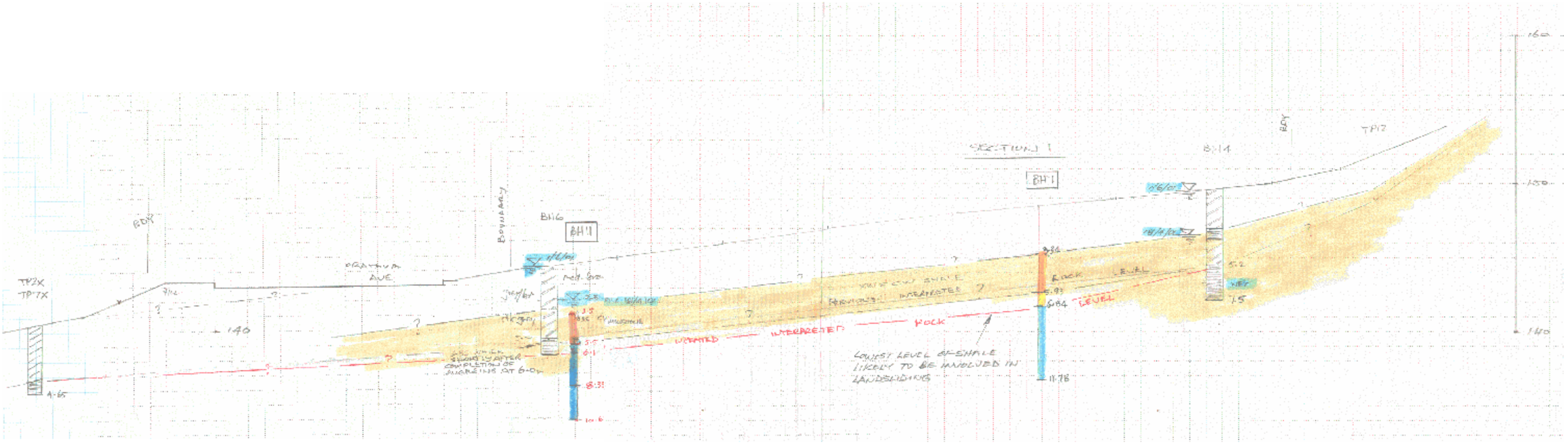
Project No:	15-004	**Scale:**	as shown	1943 AERIAL PHOTOGRAPH NO.39 - 55 0RATAVA AV WEST PENNANT HILLS NSW (Kai Ling (Australia) Pty Ltd)	**Figure 3**
Drawn:	wnd	**Date:**	21 May 15		



Section location shown on Figure 2.
Section drawn originally at 1:200 scale H & V.
Survey data from Craig & Rhodes Pty Ltd, ref. 1675, various dates of survey.
Elevation to Australian Height Datum (AHD).

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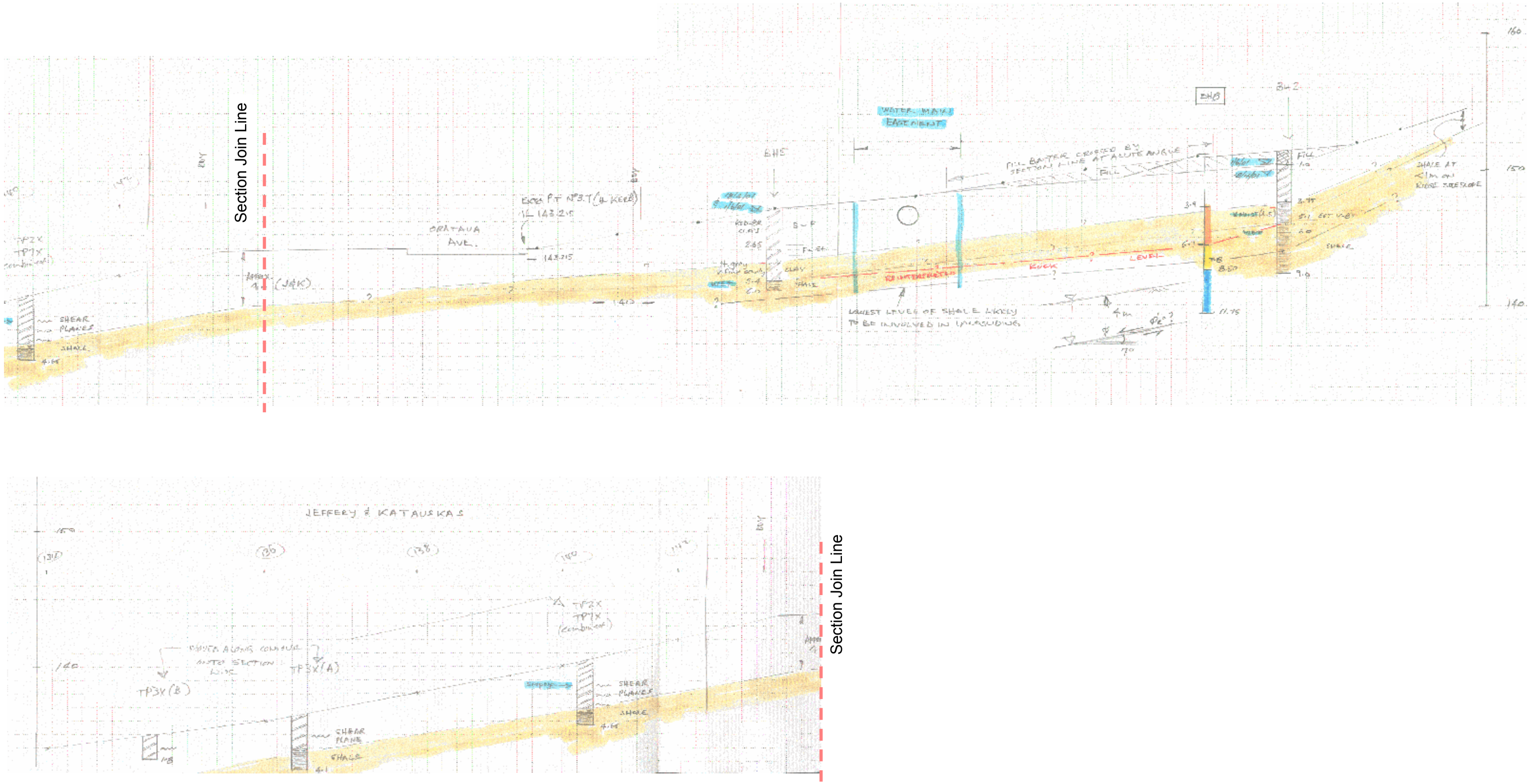
CONSULTING ENGINEERS

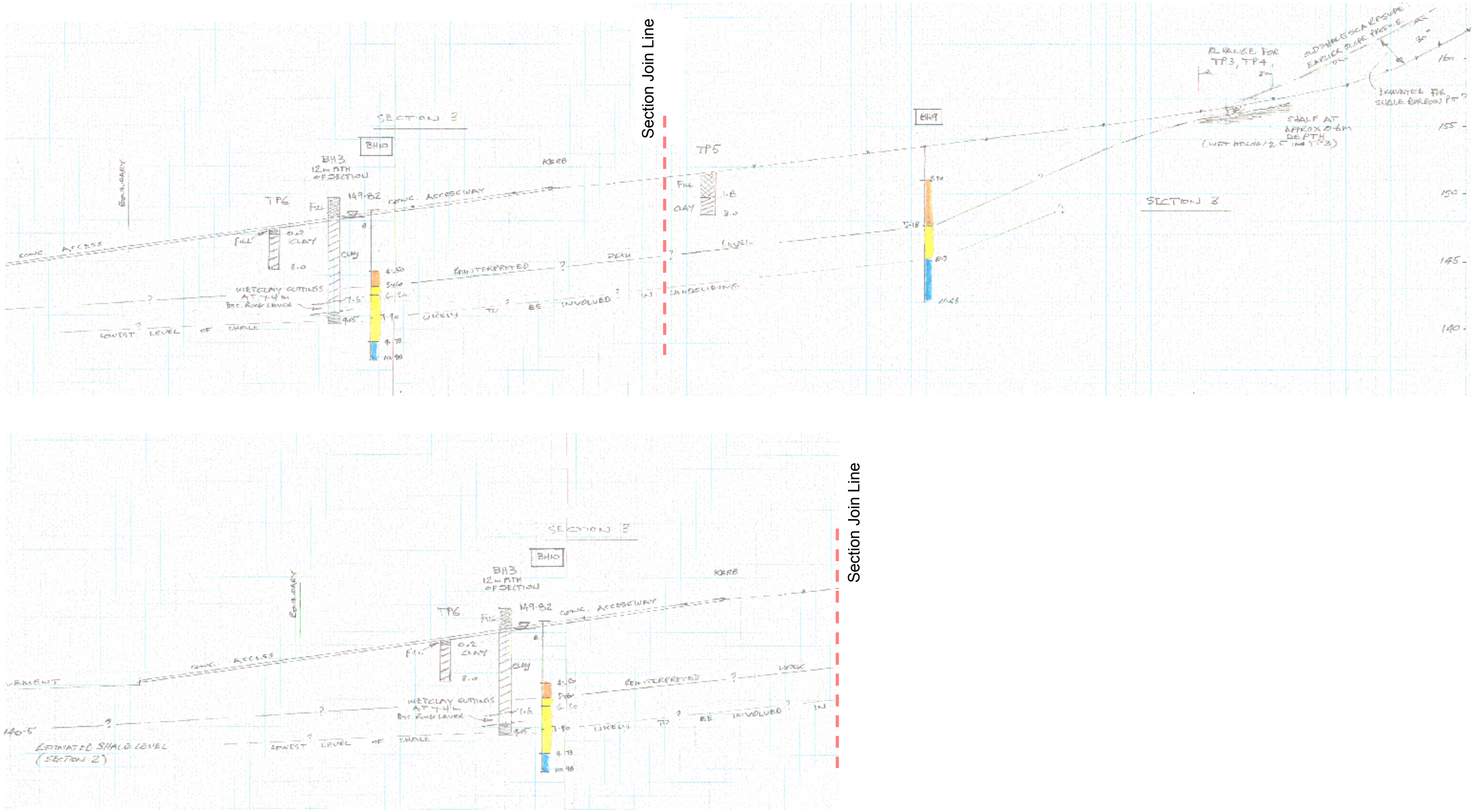
Project No:	15-004	**Scale:**	as shown	GEOTECHNICAL SLOPE SECTION 1 NO.39 - 55 0RATAVA AV WEST PENNANT HILLS NSW (Kai Ling (Australia) Pty Ltd)	**Figure 4**
Drawn:	wnd	**Date:**	21 May 15		



Section location shown on Figure 2.
Section drawn originally at 1:200 scale H & V.
Survey data from Craig & Rhodes Pty Ltd, ref. 1675, various dates of survey.
Elevation to Australian Height Datum (AHD).

DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

Project No:	15-004	**Scale:**	as shown	GEOTECHNICAL SLOPE SECTION 2 NO.39 - 55 0RATAVA AV WEST PENNANT HILLS NSW (Kai Ling (Australia) Pty Ltd)	**Figure 5**
Drawn:	wnd	**Date:**	21 May 15		



Section location shown on Figure 2.
Section drawn originally at 1:200 scale H & V.
Survey data from Craig & Rhodes Pty Ltd, ref. 1675, various dates of survey.
Elevation to Australian Height Datum (AHD).

DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

Project No:	15-004	**Scale:**	as shown	GEOTECHNICAL SLOPE SECTION 3 NO.39 - 55 0RATAVA AV WEST PENNANT HILLS NSW (Kai Ling (Australia) Pty Ltd)	**Figure 6**
Drawn:	wnd	**Date:**	21 May 15		

Base survey plan prepared by Craig & Rhodes Pty Ltd, ref. 1675G T02 [00] dated
21 May 2015
Refer to report for description of Geotechnical Zones G1 - G5

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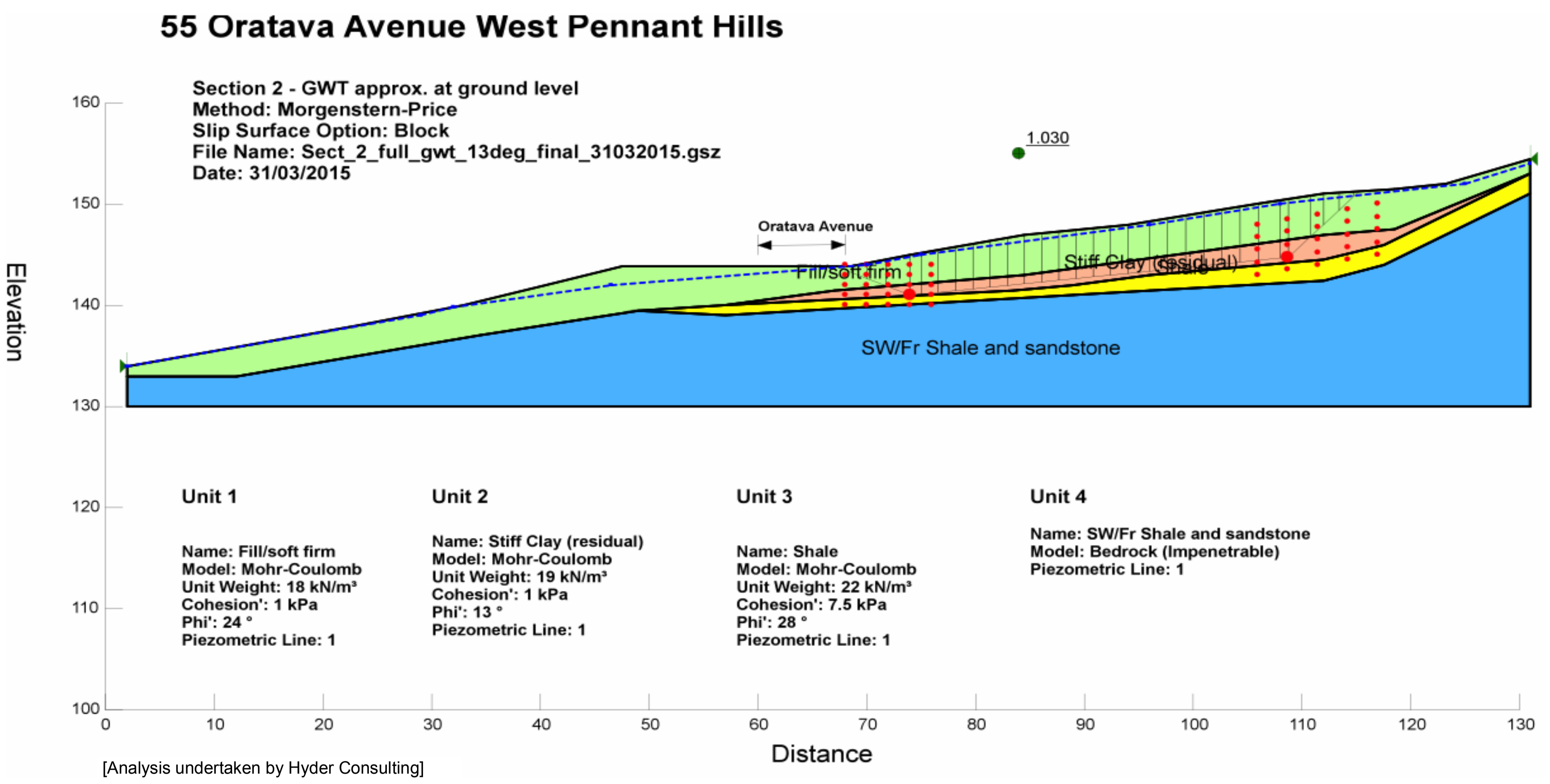
Project No:	15-004	**Scale:**	as shown	GEOTECHNICAL ZONES NO.39 - 55 0RATAVA AV WEST PENNANT HILLS NSW (Kai Ling (Australia) Pty Ltd)	**Figure 7**
Drawn:	wnd	**Date:**	21 May 15		



[Analysis undertaken by Hyder Consulting]

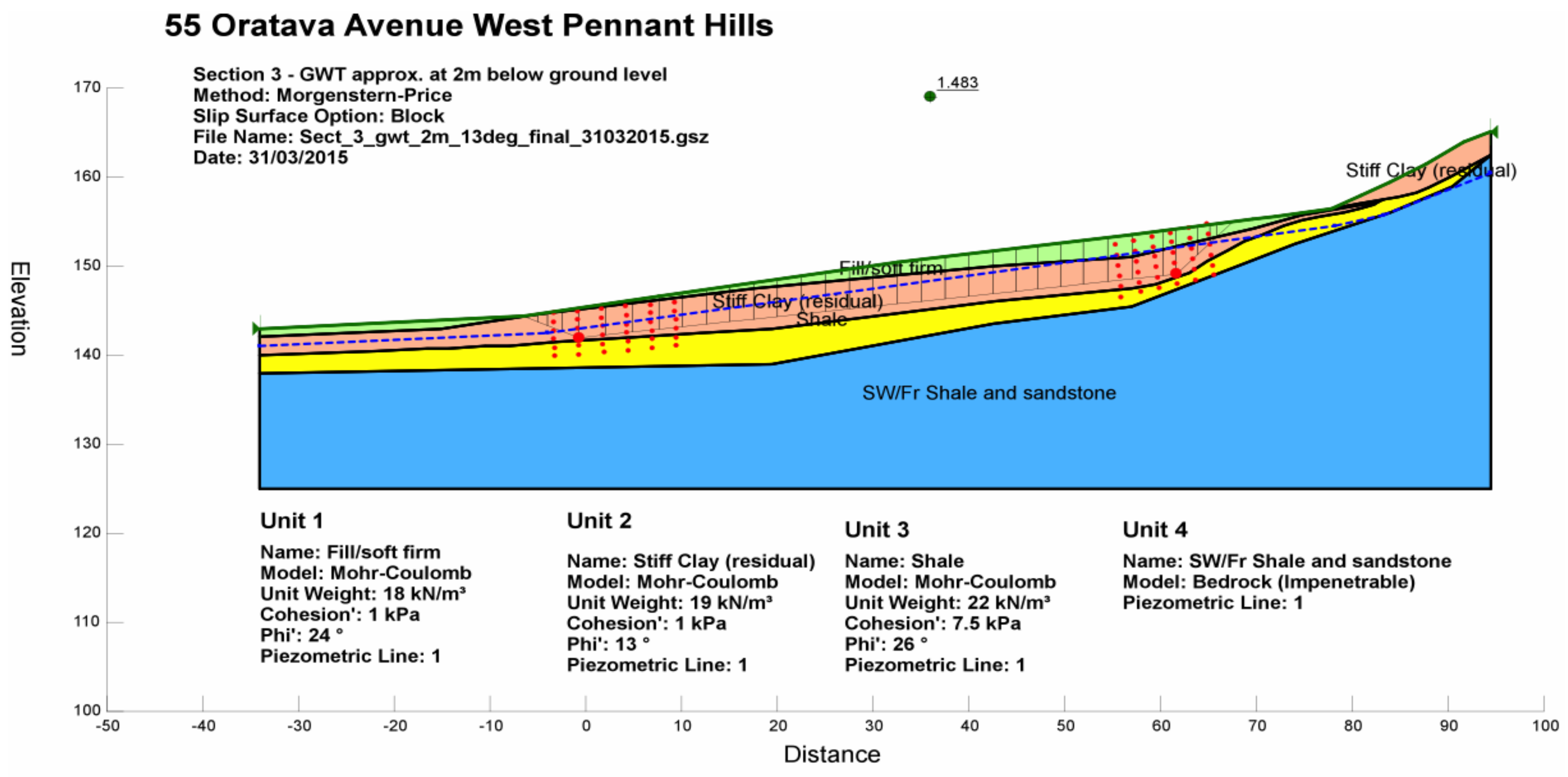
Analysis model developed from Slope Section 2 (presented on Figure 5)
All analysis outputs presented in Appendix E

DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

Project No: 15-004
Scale: as shown
Drawn: wnd
Date: 21 May 15

SLOPE / W ANALYSIS - Section 2
NO.39 - 55 0RATAVA AV WEST PENNANT HILLS NSW
(Kai Ling (Australia) Pty Ltd)

Figure 8

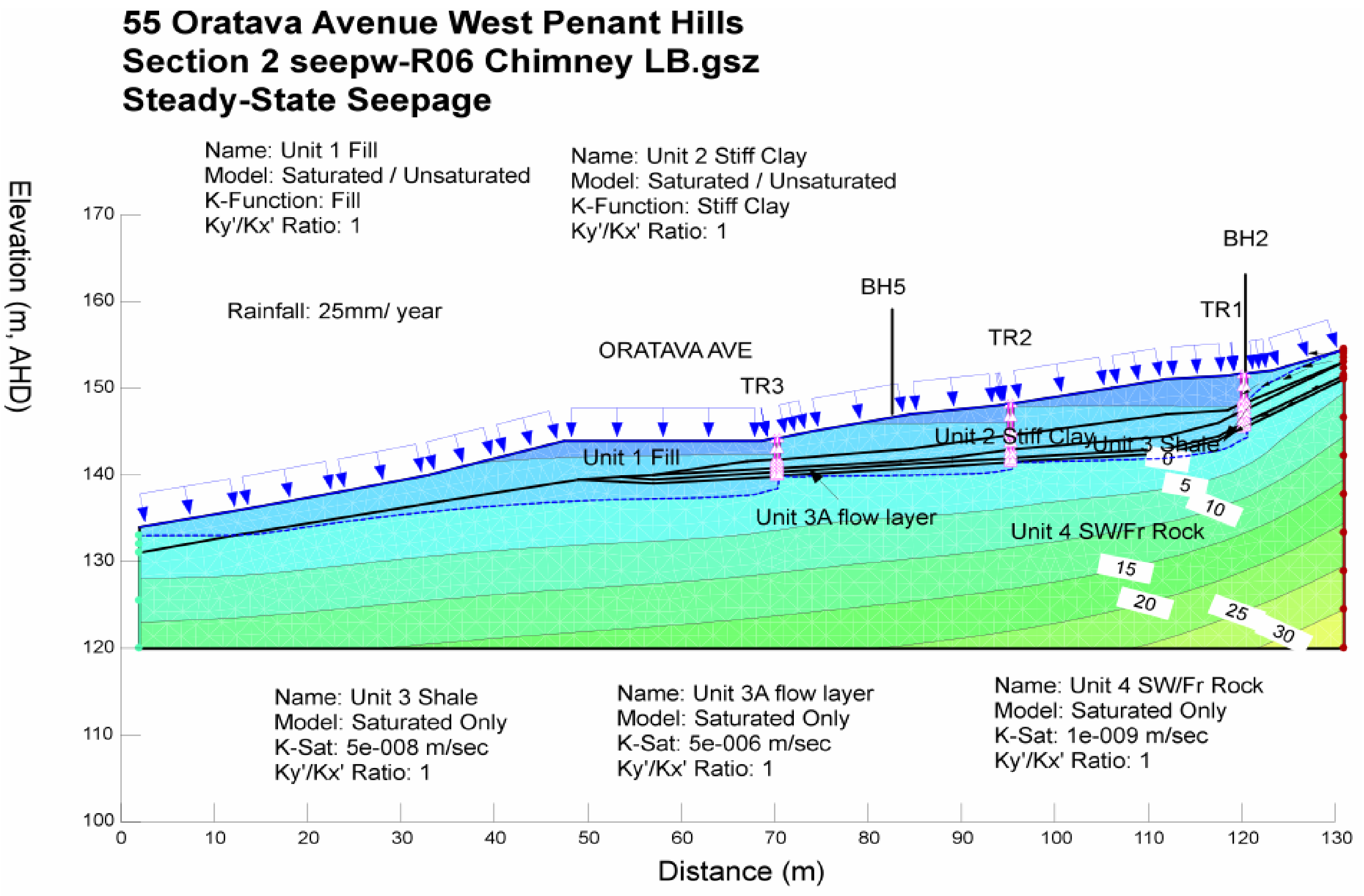


[Analysis undertaken by Hyder Consulting]

Analysis model developed from Slope Section 3 (presented on Figure 6)
All analysis outputs presented in Appendix E

DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

Project No:	15-004	**Scale:**	as shown	SLOPE / W ANALYSIS - Section 3 NO.39 - 55 0RATAVA AV WEST PENNANT HILLS NSW (Kai Ling (Australia) Pty Ltd)	**Figure 9**
Drawn:	wnd	**Date:**	21 May 15		



[Analysis undertaken by Hyder Consulting]

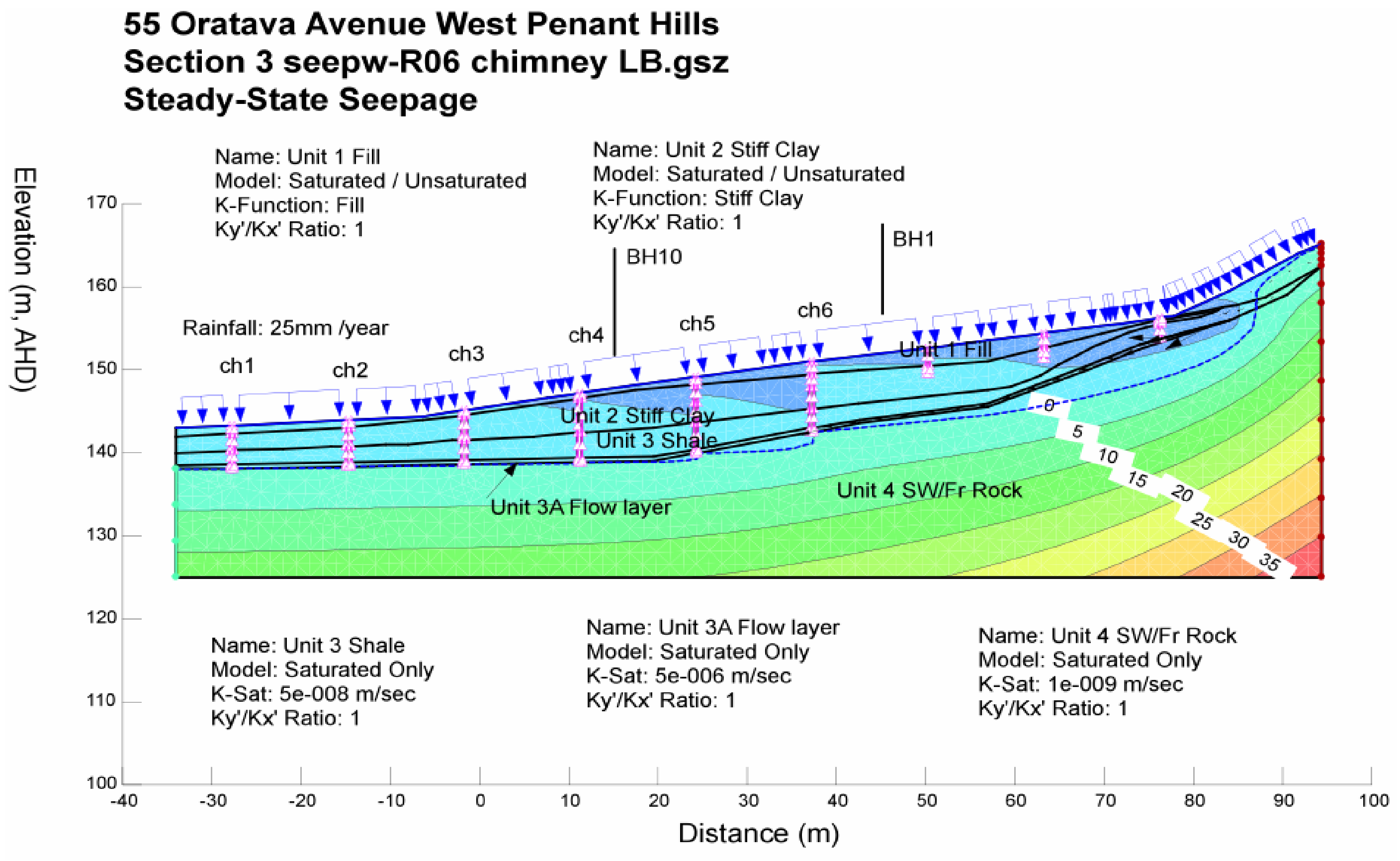
Analysis model developed from Slope Section 2 (presented on Figure 5)
All analysis outputs presented in Appendix F

DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

Project No: 15-004
Scale: as shown
Drawn: wnd
Date: 21 May 15

SEEP / W ANALYSIS - Section 2
NO.39 - 55 0RATAVA AV WEST PENNANT HILLS NSW
(Kai Ling (Australia) Pty Ltd)

Figure 10

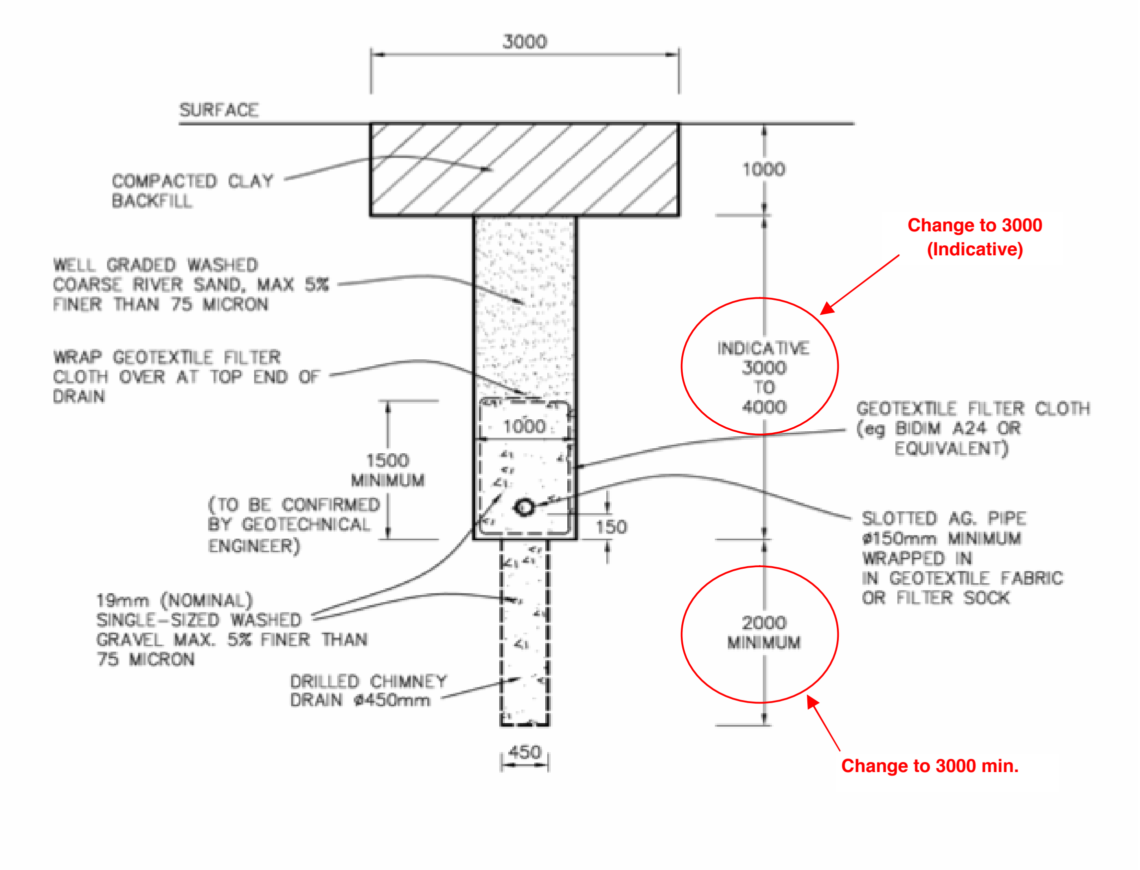


[Analysis undertaken by Hyder Consulting]

Analysis model developed from Slope Section 3 (presented on Figure 6)
All analysis outputs presented in Appendix F

DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

Project No:	15-004	**Scale:**	as shown	SEEP / W ANALYSIS - Section 3 NO.39 - 55 0RATAVA AV WEST PENNANT HILLS NSW (Kai Ling (Australia) Pty Ltd)	**Figure 11**
Drawn:	wnd	**Date:**	21 May 15		



SUB SOIL DRAINAGE
SECTION A-A

NOT TO SCALE

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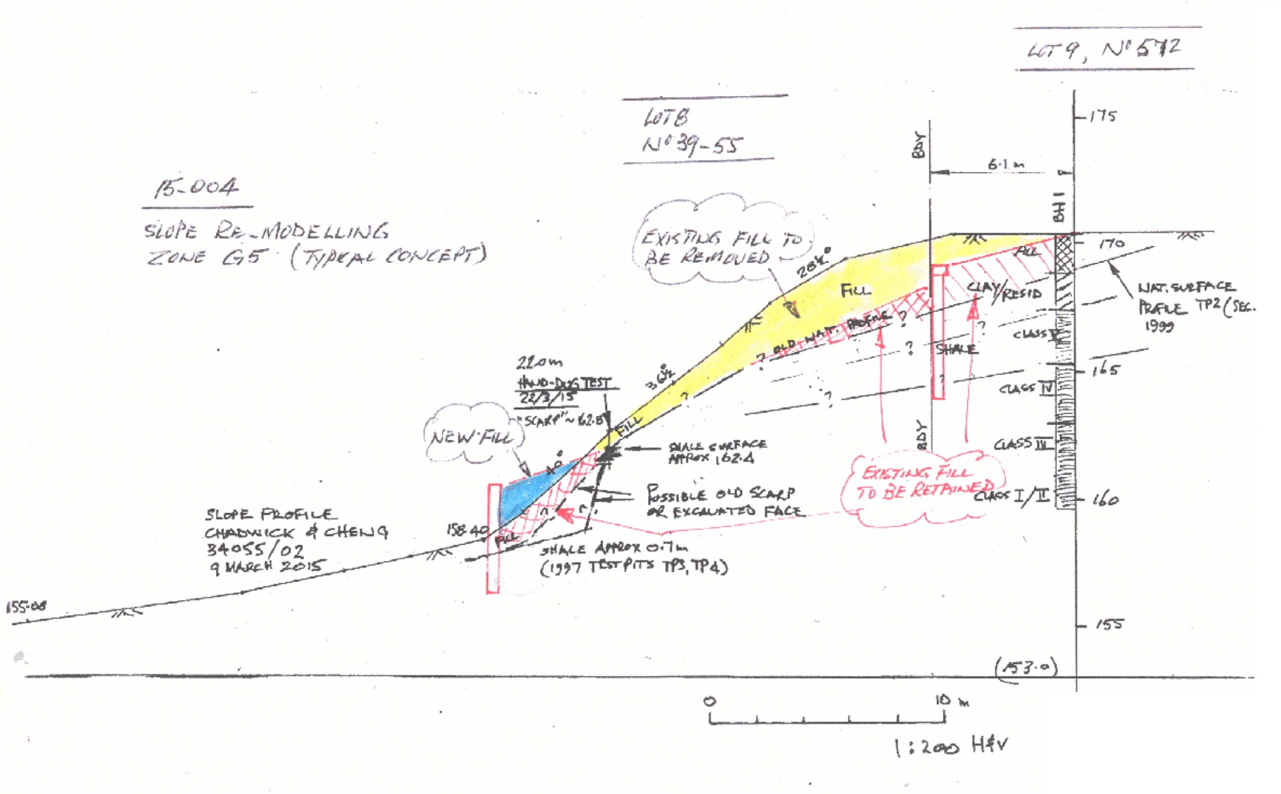
Project No: 15-004	**Scale:** NTS	TYPICAL TRENCH DRAIN SECTION NO.39 - 55 0RATAVA AV WEST PENNANT HILLS NSW (Kai Ling (Australia) Pty Ltd)	**Fig. 12**
Drawn: wnd	**Date:** 23 Jun 15		

NORTH



DAVIES GEOTECHNICAL
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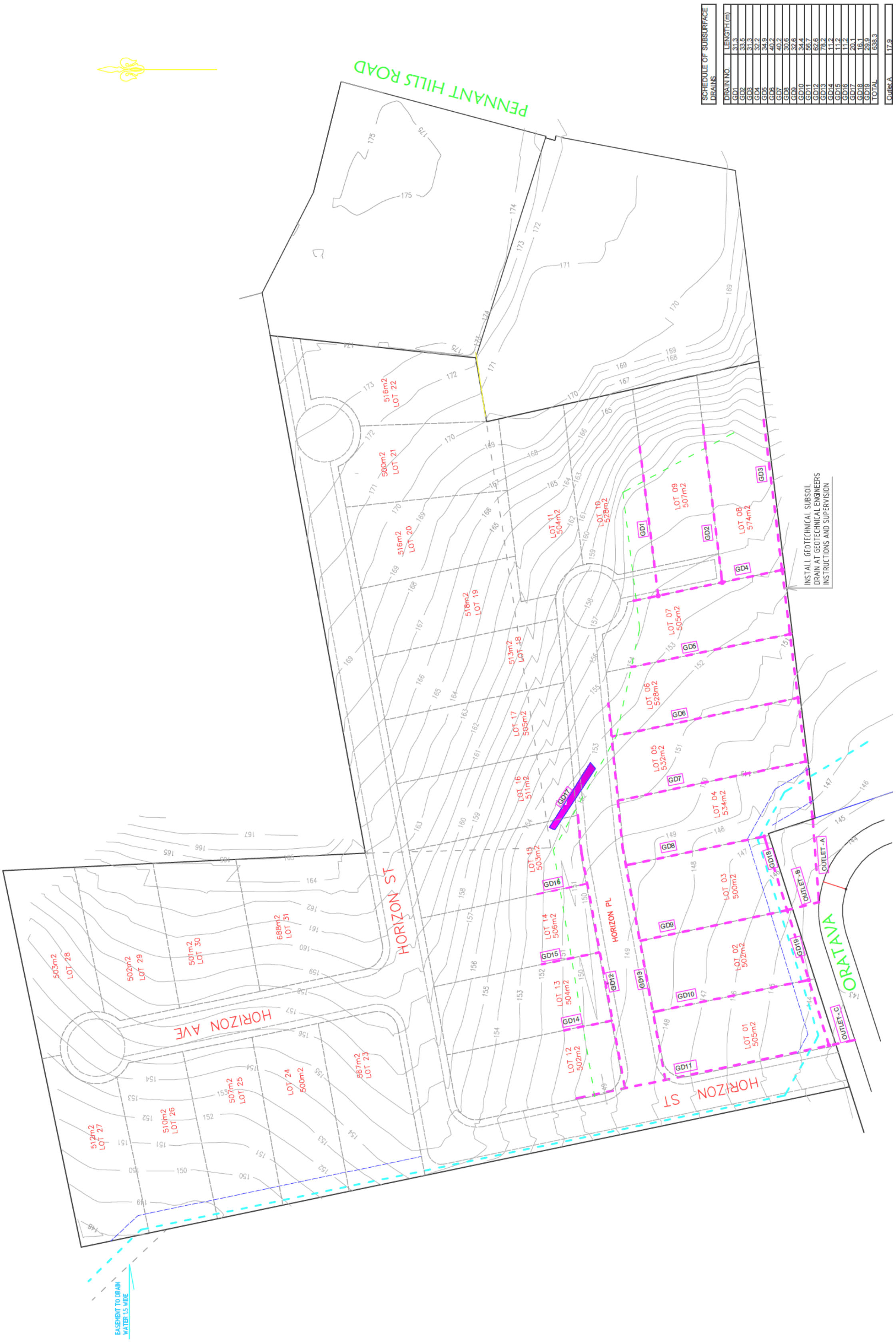
Project No:	15-004	**Scale:**	as shown	SLOPE REMODELLING ZONE G5 - CONCEPT NO.39 - 55 0RATAVA AV WEST PENNANT HILLS NSW (Kai Ling (Australia) Pty Ltd)	**Figure 13**
Drawn:	wnd	**Date:**	25 May 15		

ATTACHMENT 1

Subdivision Plan & Preliminary Geotechnical Drainage



SCHEDULE OF SUBSURFACE DRAINS

DRAIN NO.	LENGTH (m)
GD1	31.3
GD2	33.5
GD3	31.3
GD4	32.2
GD5	34.9
GD6	40.2
GD7	40.2
GD8	30.6
GD9	32.6
GD10	34.4
GD11	56.7
GD12	62.6
GD13	78.2
GD14	11.2
GD15	11.2
GD16	11.2
GD17	20.1
GD18	16.1
GD19	29.9
TOTAL	638.3
Outlet A	17.9

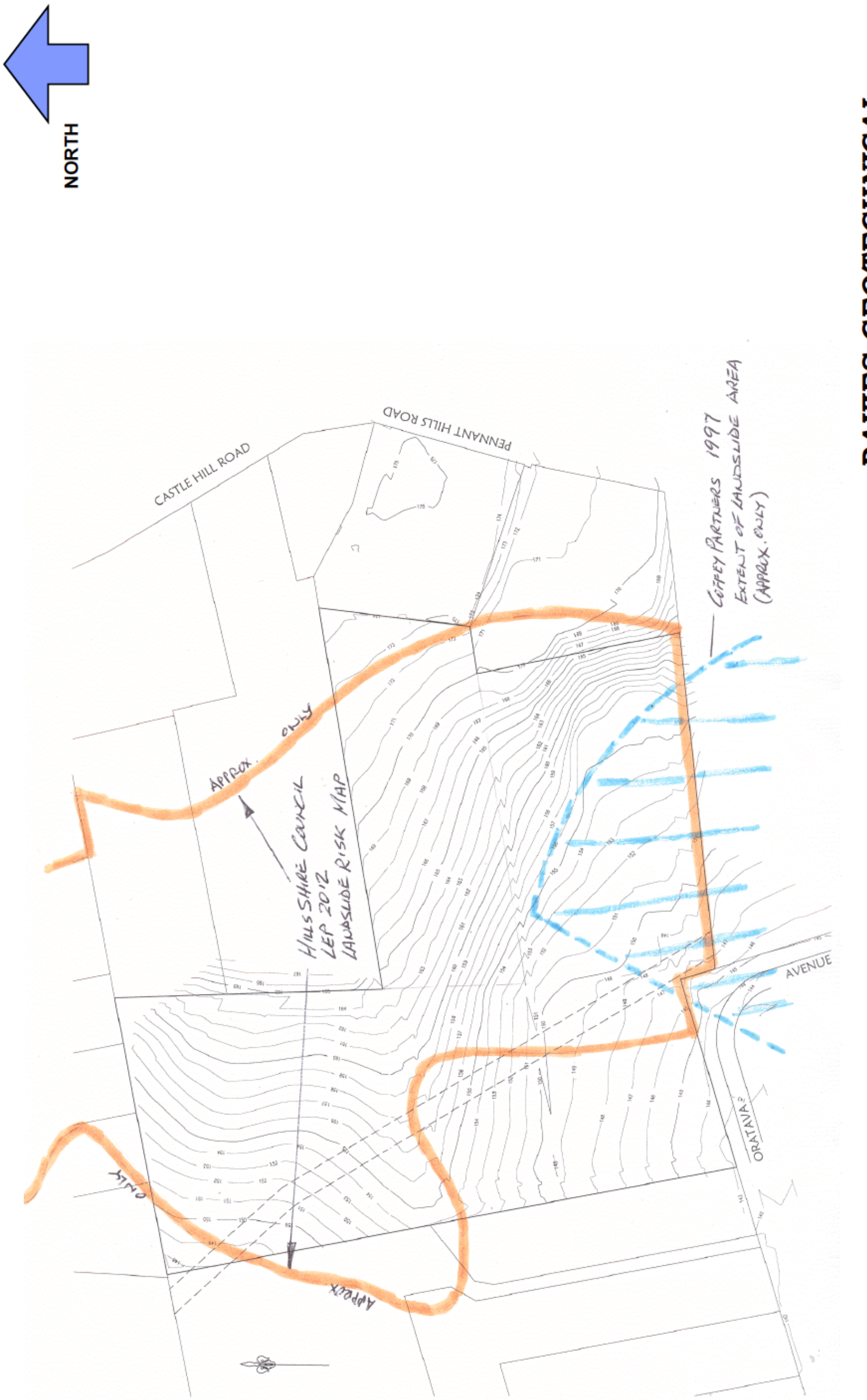
SCHEDULE OF SUBSURFACE DRAINS

DRAIN NO.	LENGTH (m)
GD1	31.3
GD2	33.5
GD3	31.3
GD4	32.2
GD5	34.9
GD6	40.2
GD7	40.2
GD8	30.6
GD9	32.6
GD10	34.4
GD11	56.7
GD12	62.6
GD13	78.2
GD14	11.2
GD15	11.2
GD16	11.2
GD17	20.1
GD18	16.1
GD19	29.9
TOTAL	638.3

Outlet A	17.9
Outlet B	5.8
Outlet C	4.5

Refer to Figure 12 for typical drain cross section

ATTACHMENT 2
Hills Shire Council 2012 LEP Landslide Risk Map



PRELIMINARY

Base survey plan prepared by Craig & Rhodes Pty Ltd, ref. 1675G T02 [01] dated 21 May 2015

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Figure A

LEP 2012 LANDSLIDE RISK MAP OVERLAY
NO.39 - 55 ORATAVA AV WEST PENNANT HILLS NSW
(Kai Ling (Australia) Pty Ltd)

Project No:	15-004	**Scale:**	as shown
Drawn:	wnd	**Date:**	25 May 15

APPENDIX A

Test Pit Logs TP1 – TP16 (1997)
Explanatory Notes (2 sheets)

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EXCAVATION LOG

PIT NUMBER 1
SHEET No. 1 OF 1

	JOB NUMBER: 97024
CLIENT: J. Papaluca	PIT COMMENCED:3/5/97
PROJECT: Sub-Division at West Pennant Hills	PIT COMPLETED:3/5/97
	SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan	LOGGED BY: APL

EQUIPMENT TYPE AND MODEL:	Sumitomo SH60	R.L SURFACE:	153.5
EXCAVATION DIMENSIONS:	3m LONG 0.6m WIDE	DATUM:	AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil	GNE	PP >600				FILL; Silty Clay, medium plasticity, red-brown mottled pale brown, with fine to medium gravel, ash and root fibres.	D <PL	H	Fill appears moderately compacted.
			PP >600 PP >600 PP >600	1			SILTY CLAY; medium to high plasticity, pale brown and orange brown with fine to medium ironstone gravel.	D <PL	H	
				2			GRAVELLY CLAY; medium plasticity, grey and red-brown, with extremely weathered to distinctly weathered, low strength shale gravel.	D <PL	H	
							END EXCAVATION @ 2.0m			
				3			pit excavated at base of steep slope fill encountered is associated with track on side slope			

KEY TO LOG		WATER	SAMPLES & NOTES	CONSISTENCY / DENSITY	
	▼	WATER LEVEL	U63 - UNDISTURBED TUBE	VS - VERY SOFT	FR - FRIABLE
METHOD	▶	WATER INFLOW	SAMPLE 63mm DIAMTER	S - SOFT	VL - VERY LOOSE
N - NATURAL EXPOSURE	◀	WATER OUTFLOW	D - DISTURBED SAMPLE	F - FIRM	L - LOOSE
E - EXISTING EXCAVATION	GNE	GROUNDWATER NOT	B - BULK SAMPLE	ST - STIFF	MD - MEDIUM DENSE
BE - BUCKET EXCAVATION		ENCOUNTERED	SV - INSITU SHEAR VANE TEST (kPa)	VST - VERY STIFF	D - DENSE
B - BULLDOZER BLADE			pp - HAND PENETROMETER TEST (kPa)	H - HARD	VD - VERY DENSE
SUPPORT			MOISTURE CONDITION		
T - TMBERING			D - DRY		
			M - MOIST		
			W - WET		

DAVIES GEOTECHNICAL PTY LTD

CONSULTING ENGINEERS

EXCAVATION LOG

PIT NUMBER 2
SHEET No. 1 OF 1

JOB NUMBER: 97024
CLIENT: J. Papaluca
PIT COMMENCED:3/5/97
PROJECT: Sub-Division at West Pennant Hills
PIT COMPLETED:3/5/97
SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan
LOGGED BY: APL

EQUIPMENT TYPE AND MODEL: Sumitomo SH60
R.L SURFACE: 151.0
EXCAVATION DIMENSIONS: 3m LONG 0.6m WIDE
DATUM: AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil			0.05			TOPSOIL; Clayey silt, low plasticity, brown with root fibres.	D <PL		Grass cover.
			pp >600				FILL; Silty Clay, medium to high plasticity, orange brown, with bands of extremely weathered, extremely low strength shale.	M >PL	H	Fill appears moderately compacted.
			1.0 D 1.5	1						
				2						
				2.2		ML	CLAYEY SILT; low to medium plasticity, grey brown.			Natural Topsoil?
				2.5		CL -CH	SILTY CLAY; medium to high plasticity, red brown and grey.	M >PL	VSt -H	
				3						
		▶	very slow seepage				End Excavation at 3.5m			

KEY TO LOG

METHOD
N - NATURAL EXPOSURE
E - EXISTING EXCAVATION
BE - BUCKET EXCAVATION
B - BULLDOZER BLADE

WATER
▼ WATER LEVEL
▶ WATER INFLOW
◀ WATER OUTFLOW
GNE GROUNDWATER NOT ENCOUNTERED

SAMPLES & NOTES
U63 - UNDISTURBED TUBE SAMPLE 63mm DIAMTER
D - DISTURBED SAMPLE
B - BULK SAMPLE
SV - INSITU SHEAR VANE TEST (kPa)
pp - HAND PENETROMETER TEST (kPa)

CONSISTENCY / DENSITY

VS - VERY SOFT	FR - FRIABLE
S - SOFT	VL - VERY LOOSE
F - FIRM	L - LOOSE
ST - STIFF	MD - MEDIUM DENSE
VST - VERY STIFF	D - DENSE
H - HARD	VD - VERY DENSE

SUPPORT
T - TMBERING

MOISTURE CONDITION
D - DRY
M - MOIST
W - WET

DAVIES GEOTECHNICAL PTY LTD

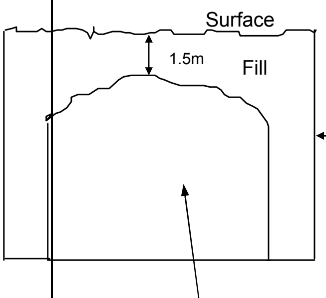
CONSULTING ENGINEERS

EXCAVATION LOG

PIT NUMBER 3
SHEET No. 1 OF 1

JOB NUMBER: 97024
CLIENT: J. Papaluca
PIT COMMENCED:3/5/97
PROJECT: Sub-Division at West Pennant Hills
PIT COMPLETED:3/5/97
SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan
LOGGED BY: APL

EQUIPMENT TYPE AND MODEL: Sumitomo SH60
R.L SURFACE: 154.5
EXCAVATION DIMENSIONS: 3m LONG 0.6m WIDE
DATUM: AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil						FILL; Gravelly Clay, medium plasticity, grey brown, with medium to coarse shale gravel, concrete fragments, bricks, metal.	D <PL		Fill appears poorly to moderately compacted
				0.6			SHALE; grey, yellow brown and orange brown, with bands of clay, extremely to distinctly weathered, extremely low to very low strength.	D		
				1						
				2				M		Face logged
		▶	noticeable seepage					W		
				3			Area containing collasping material,heterogenous in appearance - suspect old trench			Excavation collasping in from sides.

KEY TO LOG

METHOD
N - NATURAL EXPOSURE
E - EXISTING EXCAVATION
BE - BUCKET EXCAVATION
B - BULLDOZER BLADE

SUPPORT
T - TMBERING

WATER
▼ WATER LEVEL
▶ WATER INFLOW
◀ WATER OUTFLOW
GNE GROUNDWATER NOT ENCOUNTERED

SAMPLES & NOTES
U63 - UNDISTURBED TUBE SAMPLE 63mm DIAMTER
D - DISTURBED SAMPLE
B - BULK SAMPLE
SV - INSITU SHEAR VANE TEST (kPa)
pp - HAND PENETROMETER TEST (kPa)

MOISTURE CONDITION
D - DRY
M - MOIST
W - WET

CONSISTENCY / DENSITY
VS - VERY SOFT
S - SOFT
F - FIRM
ST - STIFF
VST - VERY STIFF
H - HARD
FR - FRIABLE
VL - VERY LOOSE
L - LOOSE
MD - MEDIUM DENSE
D - DENSE
VD - VERY DENSE

DAVIES GEOTECHNICAL PTY LTD

CONSULTING ENGINEERS

EXCAVATION LOG

PIT NUMBER 4
SHEET No. 1 OF 1

	JOB NUMBER: 97024
CLIENT: J. Papaluca	PIT COMMENCED:3/5/97
PROJECT: Sub-Division at West Pennant Hills	PIT COMPLETED:3/5/97
	SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan	LOGGED BY: APL

EQUIPMENT TYPE AND MODEL:	Sumitomo SH60				R.L SURFACE:	157.7
EXCAVATION DIMENSIONS:	3m	LONG	0.6m	WIDE	DATUM:	AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil	GNE	pp >600				SILTY CLAY; medium to high plasticity; pale brown and orange brown.	M >PL	H	Side of excavation indicates a fill profile.
			pp >600	0.4			SHALE; grey, orange brown , with bands of clay, extremely to distinctly weathered, extremely low to very low strength.	D		
				1						
								M		
				2						
							End Excavation at 2.2m			
				3						

KEY TO LOG

METHOD	WATER	SAMPLES & NOTES	CONSISTENCY / DENSITY	
	WATER LEVEL	U63 - UNDISTURBED TUBE	VS - VERY SOFT	FR - FRIABLE
	WATER INFLOW	SAMPLE 63mm DIAMTER	S - SOFT	VL - VERY LOOSE
N - NATURAL EXPOSURE	WATER OUTFLOW	D - DISTURBED SAMPLE	F - FIRM	L - LOOSE
E - EXISTING EXCAVATION	GNE GROUNDWATER NOT	B - BULK SAMPLE	ST - STIFF	MD - MEDIUM DENSE
BE - BUCKET EXCAVATION	ENCOUNTERED	SV - INSITU SHEAR VANE TEST (kPa)	VST - VERY STIFF	D - DENSE
B - BULLDOZER BLADE		pp - HAND PENETROMETER TEST (kPa)	H - HARD	VD - VERY DENSE

SUPPORT
T - TMBERING

MOISTURE CONDITION
D - DRY
M - MOIST
W - WET

DAVIES GEOTECHNICAL PTY LTD

CONSULTING ENGINEERS

EXCAVATION LOG

PIT NUMBER 5
SHEET No. 1 OF 1

	JOB NUMBER: 97024
CLIENT: J. Papaluca	PIT COMMENCED:3/5/97
PROJECT: Sub-Division at West Pennant Hills	PIT COMPLETED:3/5/97
	SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan	LOGGED BY: APL

EQUIPMENT TYPE AND MODEL:	Sumitomo SH60			R.L SURFACE:	151.5
EXCAVATION DIMENSIONS:	3m LONG	0.6m WIDE		DATUM:	AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil	GNE	pp >600	0.4			FILL; Gravelly Clay, medium plasticitity, pale brown and orange brown, with medium to coarse shale gravel.	D <PL	H	Recycled asphalt cover 300mm. Fill appears moderately compacted.
			0.5 D 1.0	1				D		
								M		
				1.8						
				2		ML	CLAYEY SILT; low to medium plasticity, grey.	M >PL	St	Natural Topsoil?
			2.0 D 2.5			CL -CH	SILTY CLAY; medium to high plasticity, orange brown and grey, with a trace of fine shale gravel.	M >PL	VSt -H	
				3						
							End Excavation at 3.0m			

KEY TO LOG

	WATER	**SAMPLES & NOTES**	**CONSISTENCY / DENSITY**
	▼ WATER LEVEL	U63 - UNDISTURBED TUBE	VS - VERY SOFT FR - FRIABLE
METHOD	→ WATER INFLOW	SAMPLE 63mm DIAMTER	S - SOFT VL - VERY LOOSE
N - NATURAL EXPOSURE	← WATER OUTFLOW	D - DISTURBED SAMPLE	F - FIRM L - LOOSE
E - EXISTING EXCAVATION	GNE GROUNDWATER NOT	B - BULK SAMPLE	ST - STIFF MD - MEDIUM DENSE
BE - BUCKET EXCAVATION	ENCOUNTERED	SV - INSITU SHEAR VANE TEST (kPa)	VST - VERY STIFF D - DENSE
B - BULLDOZER BLADE		pp - HAND PENETROMETER TEST (kPa)	H - HARD VD - VERY DENSE
SUPPORT		**MOISTURE CONDITION**	
T - TMBERING		D - DRY	
		M - MOIST	
		W - WET	

DAVIES GEOTECHNICAL PTY LTD

CONSULTING ENGINEERS

EXCAVATION LOG

PIT NUMBER 6
SHEET No. 1 OF 1

JOB NUMBER: 97024
CLIENT: J. Papaluca
PIT COMMENCED:3/5/97
PROJECT: Sub-Division at West Pennant Hills
PIT COMPLETED:3/5/97
SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan
LOGGED BY: APL

EQUIPMENT TYPE AND MODEL: Sumitomo SH60
R.L SURFACE: 147.5
EXCAVATION DIMENSIONS: 3m LONG 0.6m WIDE
DATUM: AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil	GNE	pp >600 pp >300	0.2			FILL; Silty Clay, medium plastictity, orange brown and grey.	M >PL	H	Fill appears moderately compacted.
				0.4		ML	CLAYEY SILT; low to medium plasticity, grey	M	VSt	
			0.5 pp =350 D pp =410 1.0	1 2 3		CL -CH	SILTY CLAY; medium to high plasticity, orange brown and grey.	M >PL	VSt -H	
							End Excavation at 3.0m			

KEY TO LOG

METHOD
N - NATURAL EXPOSURE
E - EXISTING EXCAVATION
BE - BUCKET EXCAVATION
B - BULLDOZER BLADE

WATER
WATER LEVEL
WATER INFLOW
WATER OUTFLOW
GNE GROUNDWATER NOT ENCOUNTERED

SAMPLES & NOTES
U63 - UNDISTURBED TUBE SAMPLE 63mm DIAMTER
D - DISTURBED SAMPLE
B - BULK SAMPLE
SV - INSITU SHEAR VANE TEST (kPa)
pp - HAND PENETROMETER TEST (kPa)

CONSISTENCY / DENSITY

VS - VERY SOFT	FR - FRIABLE
S - SOFT	VL - VERY LOOSE
F - FIRM	L - LOOSE
ST - STIFF	MD - MEDIUM DENSE
VST - VERY STIFF	D - DENSE
H - HARD	VD - VERY DENSE

SUPPORT
T - TMBERING

MOISTURE CONDITION
D - DRY
M - MOIST
W - WET

DAVIES GEOTECHNICAL PTY LTD

CONSULTING ENGINEERS

EXCAVATION LOG

PIT NUMBER 7
SHEET No. 1 OF 1

JOB NUMBER: 97024
CLIENT: J. Papaluca
PROJECT: Sub-Division at West Pennant Hills
PIT COMMENCED:3/5/97
PIT COMPLETED:3/5/97
SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan
LOGGED BY: APL

EQUIPMENT TYPE AND MODEL: Sumitomo SH60
EXCAVATION DIMENSIONS: 3m LONG 0.6m WIDE
R.L SURFACE: 151.0
DATUM: AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil	GNE	pp >600 D	0.5		CL	SILTY CLAY; medium plasticity, brown and pale brown.	D <PL	H	Grass cover.
				1			SHALE; grey and orange brown, extremely to distinctly weathered, very low to low strength.			
				2 3			End Excavation at 1.3m			High Excavator Resistance.

KEY TO LOG

METHOD
N - NATURAL EXPOSURE
E - EXISTING EXCAVATION
BE - BUCKET EXCAVATION
B - BULLDOZER BLADE

SUPPORT
T - TMBERING

WATER
WATER LEVEL
WATER INFLOW
WATER OUTFLOW
GNE GROUNDWATER NOT ENCOUNTERED

SAMPLES & NOTES
U63 - UNDISTURBED TUBE SAMPLE 63mm DIAMTER
D - DISTURBED SAMPLE
B - BULK SAMPLE
SV - INSITU SHEAR VANE TEST (kPa)
pp - HAND PENETROMETER TEST (kPa)

MOISTURE CONDITION
D - DRY
M - MOIST
W - WET

CONSISTENCY / DENSITY
VS - VERY SOFT
S - SOFT
F - FIRM
ST - STIFF
VST - VERY STIFF
H - HARD
FR - FRIABLE
VL - VERY LOOSE
L - LOOSE
MD - MEDIUM DENSE
D - DENSE
VD - VERY DENSE

DAVIES GEOTECHNICAL PTY LTD

CONSULTING ENGINEERS

EXCAVATION LOG

PIT NUMBER 8
SHEET No. 1 OF 1

JOB NUMBER: 97024
CLIENT: J. Papaluca
PIT COMMENCED:3/5/97
PROJECT: Sub-Division at West Pennant Hills
PIT COMPLETED:3/5/97
SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan
LOGGED BY: APL

EQUIPMENT TYPE AND MODEL: Sumitomo SH60
R.L SURFACE: 159.0
EXCAVATION DIMENSIONS: 3m LONG 0.6m WIDE
DATUM: AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil	GNE	pp >600 pp >600	0.9		CL	SILTY CLAY; medium plasticity, brown and pale brown.	D <PL	H	Grass cover.
			1.0 D 1.5	1		CL	CLAY; medium plasticity, grey and orange brown with bands of extremely weathered, very low strength shale.	M <PL	H	
				2			SHALE; grey and orange brown, extremely to distinctly weathered, very low to low strength.			
				3			End Excavation at 2.0m			High Excavator Resistance.

KEY TO LOG

METHOD
N - NATURAL EXPOSURE
E - EXISTING EXCAVATION
BE - BUCKET EXCAVATION
B - BULLDOZER BLADE

WATER
▼ WATER LEVEL
→ WATER INFLOW
← WATER OUTFLOW
GNE GROUNDWATER NOT ENCOUNTERED

SAMPLES & NOTES
U63 - UNDISTURBED TUBE SAMPLE 63mm DIAMTER
D - DISTURBED SAMPLE
B - BULK SAMPLE
SV - INSITU SHEAR VANE TEST (kPa)
pp - HAND PENETROMETER TEST (kPa)

CONSISTENCY / DENSITY

VS - VERY SOFT	FR - FRIABLE
S - SOFT	VL - VERY LOOSE
F - FIRM	L - LOOSE
ST - STIFF	MD - MEDIUM DENSE
VST - VERY STIFF	D - DENSE
H - HARD	VD - VERY DENSE

SUPPORT
T - TMBERING

MOISTURE CONDITION
D - DRY
M - MOIST
W - WET

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CONSULTING ENGINEERS

EXCAVATION LOG

PIT NUMBER 9
SHEET No. 1 OF 1

JOB NUMBER: 97024
CLIENT: J. Papaluca
PIT COMMENCED:3/5/97
PROJECT: Sub-Division at West Pennant Hills
PIT COMPLETED:3/5/97
SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan
LOGGED BY: APL

EQUIPMENT TYPE AND MODEL: Sumitomo SH60
R.L SURFACE: 161.0
EXCAVATION DIMENSIONS: 3m LONG 0.6m WIDE
DATUM: AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil	GNE		0.2		ML	TOPSOIL; Clayey Silt; low plasticity, grey brown.	D <PL	H	Grass cover.
			pp >600 pp >600	1 1.4		CL	SILTY CLAY; medium plasticity, brown and pale brown.	D <PL	H	
				2			SHALE; grey and orange brown, extremely to distinctly weathered, very low to low strength.			
				3			End Excavation at 2.0m			High Excavator Resistance.

KEY TO LOG

METHOD
N - NATURAL EXPOSURE
E - EXISTING EXCAVATION
BE - BUCKET EXCAVATION
B - BULLDOZER BLADE

WATER
WATER LEVEL
WATER INFLOW
WATER OUTFLOW
GNE GROUNDWATER NOT ENCOUNTERED

SAMPLES & NOTES
U63 - UNDISTURBED TUBE SAMPLE 63mm DIAMTER
D - DISTURBED SAMPLE
B - BULK SAMPLE
SV - INSITU SHEAR VANE TEST (kPa)
pp - HAND PENETROMETER TEST (kPa)

CONSISTENCY / DENSITY
VS - VERY SOFT
S - SOFT
F - FIRM
ST - STIFF
VST - VERY STIFF
H - HARD
FR - FRIABLE
VL - VERY LOOSE
L - LOOSE
MD - MEDIUM DENSE
D - DENSE
VD - VERY DENSE

SUPPORT
T - TMBERING

MOISTURE CONDITION
D - DRY
M - MOIST
W - WET

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CONSULTING ENGINEERS

EXCAVATION LOG

PIT NUMBER 10
SHEET No. 1 OF 1

JOB NUMBER: 97024
CLIENT: J. Papaluca
PIT COMMENCED:3/5/97
PROJECT: Sub-Division at West Pennant Hills
PIT COMPLETED:3/5/97
SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan
LOGGED BY: APL

EQUIPMENT TYPE AND MODEL: Sumitomo SH60
R.L SURFACE: 155.0
EXCAVATION DIMENSIONS: 3m LONG 0.6m WIDE
DATUM: AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil	GNE		0.2		ML	TOPSOIL; Clayey Silt; low plasticity, grey brown.	D <PL	H	Grass cover.
			pp >600 pp >600	1		CL -CH	SILTY CLAY; medium to high plasticity,yellow brown and orange brown, with fine ironstone gravel.	D <PL	H	
			pp >600	1.6		CL -CH	as above but grey and red brown, with medium to coarse shale gravel.	M <PL	H	
				2			SHALE; grey and orange brown, extremely to distinctly weathered, very low to low strength.			
							as above but low to medium strength.			High resistance.
				3			End Excavation at 2.4m			

KEY TO LOG

METHOD
N - NATURAL EXPOSURE
E - EXISTING EXCAVATION
BE - BUCKET EXCAVATION
B - BULLDOZER BLADE

SUPPORT
T - TMBERING

WATER
▼ WATER LEVEL
▶ WATER INFLOW
◀ WATER OUTFLOW
GNE GROUNDWATER NOT ENCOUNTERED

SAMPLES & NOTES
U63 - UNDISTURBED TUBE SAMPLE 63mm DIAMTER
D - DISTURBED SAMPLE
B - BULK SAMPLE
SV - INSITU SHEAR VANE TEST (kPa)
pp - HAND PENETROMETER TEST (kPa)

MOISTURE CONDITION
D - DRY
M - MOIST
W - WET

CONSISTENCY / DENSITY
VS - VERY SOFT
S - SOFT
F - FIRM
ST - STIFF
VST - VERY STIFF
H - HARD
FR - FRIABLE
VL - VERY LOOSE
L - LOOSE
MD - MEDIUM DENSE
D - DENSE
VD - VERY DENSE

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EXCAVATION LOG

PIT NUMBER 11
SHEET No. 1 OF 1

	JOB NUMBER: 97024
CLIENT: J. Papaluca	PIT COMMENCED:3/5/97
PROJECT: Sub-Division at West Pennant Hills	PIT COMPLETED:3/5/97
	SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan	LOGGED BY: APL

EQUIPMENT TYPE AND MODEL:	Sumitomo SH60			R.L SURFACE:	158.5
EXCAVATION DIMENSIONS:	3m LONG	0.6m WIDE		DATUM:	AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil	GNE	pp >600			CL -CH	SILTY CLAY; medium to high plasticity,yellow brown and orange brown, with medium shale gravel.	D <PL	H	Grass cover.
			pp >600 pp >600	0.7 1			SHALE; grey and orange brown, extremely to distinctly weathered, very low to low strength.			
							as above but slightly weathered, medium strength.			
							End Excavation at 1.7m			
				2						
				3						

KEY TO LOG	WATER	SAMPLES & NOTES	CONSISTENCY / DENSITY	
	WATER LEVEL	U63 - UNDISTURBED TUBE	VS - VERY SOFT	FR - FRIABLE
METHOD	WATER INFLOW	SAMPLE 63mm DIAMTER	S - SOFT	VL - VERY LOOSE
N - NATURAL EXPOSURE	WATER OUTFLOW	D - DISTURBED SAMPLE	F - FIRM	L - LOOSE
E - EXISTING EXCAVATION GNE	GROUNDWATER NOT	B - BULK SAMPLE	ST - STIFF	MD - MEDIUM DENSE
BE - BUCKET EXCAVATION	ENCOUNTERED	SV - INSITU SHEAR VANE TEST (kPa)	VST - VERY STIFF	D - DENSE
B - BULLDOZER BLADE		pp - HAND PENETROMETER TEST (kPa)	H - HARD	VD - VERY DENSE
SUPPORT		MOISTURE CONDITION		
T - TMBERING		D - DRY		
		M - MOIST		
		W - WET		

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CONSULTING ENGINEERS

EXCAVATION LOG

PIT NUMBER 12
SHEET No. 1 OF 1

	JOB NUMBER: 97024
CLIENT: J. Papaluca	PIT COMMENCED:3/5/97
PROJECT: Sub-Division at West Pennant Hills	PIT COMPLETED:3/5/97
	SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan	LOGGED BY: APL

EQUIPMENT TYPE AND MODEL:	Sumitomo SH60	R.L SURFACE:	151.5
EXCAVATION DIMENSIONS:	3m LONG 0.6m WIDE	DATUM:	AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil	GNE				ML	TOPSOIL; Clayey Silt, low plasticity, grey brown.	M >PL	VSt	Grass cover.
			pp >600	1		CL	SILTY CLAY; medium plasticity,yellow brown and orange brown, with medium shale gravel.	M >PL	H	
			pp >600	2		CL	as above but grey and red brown.	M >PL	H	
				3			SHALE; grey and orange brown, extremely to distinctly weathered, very low to low strength. as above but slightly weathered, medium strength.			
							End Excavation at 3.0m.			

KEY TO LOG		WATER	SAMPLES & NOTES	CONSISTENCY / DENSITY	
	▼	WATER LEVEL	U63 - UNDISTURBED TUBE	VS - VERY SOFT	FR - FRIABLE
METHOD	▶	WATER INFLOW	SAMPLE 63mm DIAMTER	S - SOFT	VL - VERY LOOSE
N - NATURAL EXPOSURE	◀	WATER OUTFLOW	D - DISTURBED SAMPLE	F - FIRM	L - LOOSE
E - EXISTING EXCAVATION	GNE	GROUNDWATER NOT ENCOUNTERED	B - BULK SAMPLE	ST - STIFF	MD - MEDIUM DENSE
BE - BUCKET EXCAVATION			SV - INSITU SHEAR VANE TEST (kPa)	VST - VERY STIFF	D - DENSE
B - BULLDOZER BLADE			pp - HAND PENETROMETER TEST (kPa)	H - HARD	VD - VERY DENSE
SUPPORT			MOISTURE CONDITION		
T - TMBERING			D - DRY		
			M - MOIST		
			W - WET		

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CONSULTING ENGINEERS

EXCAVATION LOG

PIT NUMBER 13
SHEET No. 1 OF 1

	JOB NUMBER: 97024
CLIENT: J. Papaluca	PIT COMMENCED:3/5/97
PROJECT: Sub-Division at West Pennant Hills	PIT COMPLETED:3/5/97
	SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan	LOGGED BY: APL

EQUIPMENT TYPE AND MODEL:	Sumitomo SH60			R.L SURFACE:	147.0
EXCAVATION DIMENSIONS:	3m	LONG	0.6m WIDE	DATUM:	AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil	GNE				ML	TOPSOIL; Clayey Silt, low plasticity, grey brown.	M <PL	VSt	Grass cover.
			pp >600 pp >600			CL	SILTY CLAY; medium plasticity,brown and orange brown.	M >PL	H	
			pp >600 pp >600	1 2		CL	as above but grey, orange brown and red brown.	M >PL	H	
				3			End Excavation at 2.9m			

KEY TO LOG

METHOD
N - NATURAL EXPOSURE
E - EXISTING EXCAVATION
BE - BUCKET EXCAVATION
B - BULLDOZER BLADE

SUPPORT
T - TMBERING

WATER
▼ WATER LEVEL
WATER INFLOW
WATER OUTFLOW
GNE GROUNDWATER NOT ENCOUNTERED

SAMPLES & NOTES
U63 - UNDISTURBED TUBE SAMPLE 63mm DIAMTER
D - DISTURBED SAMPLE
B - BULK SAMPLE
SV - INSITU SHEAR VANE TEST (kPa)
pp - HAND PENETROMETER TEST (kPa)

MOISTURE CONDITION
D - DRY
M - MOIST
W - WET

CONSISTENCY / DENSITY
VS - VERY SOFT
S - SOFT
F - FIRM
ST - STIFF
VST - VERY STIFF
H - HARD
FR - FRIABLE
VL - VERY LOOSE
L - LOOSE
MD - MEDIUM DENSE
D - DENSE
VD - VERY DENSE

DAVIES GEOTECHNICAL PTY LTD

CONSULTING ENGINEERS

EXCAVATION LOG

PIT NUMBER 14
SHEET No. 1 OF 1

	JOB NUMBER: 97024
CLIENT: J. Papaluca	PIT COMMENCED:3/5/97
PROJECT: Sub-Division at West Pennant Hills	PIT COMPLETED:3/5/97
	SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan	LOGGED BY: APL

EQUIPMENT TYPE AND MODEL:	Sumitomo SH60				R.L SURFACE:	148.5
EXCAVATION DIMENSIONS:	3m	LONG	0.6m	WIDE	DATUM:	AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil					ML	TOPSOIL; Clayey Silt, low plasticity, grey brown, roots.	D <PL	VSt	Grass cover.
			pp >600			CL	SILTY CLAY; medium plasticity,brown and orange brown.	M >PL	H	
			D pp >600	0.8						
				1		CL	as above but grey, orange brown and red brown.	M >PL	H	
			pp >600							
			pp >600							
				2						
		▶	very slow seepage							
							End Excavation at 2.5m			
				3						

KEY TO LOG

METHOD
N - NATURAL EXPOSURE
E - EXISTING EXCAVATION
BE - BUCKET EXCAVATION
B - BULLDOZER BLADE

WATER
▽ WATER LEVEL
▶ WATER INFLOW
◀ WATER OUTFLOW
GNE GROUNDWATER NOT ENCOUNTERED

SAMPLES & NOTES
U63 - UNDISTURBED TUBE SAMPLE 63mm DIAMTER
D - DISTURBED SAMPLE
B - BULK SAMPLE
SV - INSITU SHEAR VANE TEST (kPa)
pp - HAND PENETROMETER TEST (kPa)

CONSISTENCY / DENSITY
VS - VERY SOFT
S - SOFT
F - FIRM
ST - STIFF
VST - VERY STIFF
H - HARD
FR - FRIABLE
VL - VERY LOOSE
L - LOOSE
MD - MEDIUM DENSE
D - DENSE
VD - VERY DENSE

SUPPORT
T - TMBERING

MOISTURE CONDITION
D - DRY
M - MOIST
W - WET

DAVIES GEOTECHNICAL PTY LTD

CONSULTING ENGINEERS

EXCAVATION LOG

PIT NUMBER 15
SHEET No. 1 OF 1

	JOB NUMBER: 97024
CLIENT: J. Papaluca	PIT COMMENCED:3/5/97
PROJECT: Sub-Division at West Pennant Hills	PIT COMPLETED:3/5/97
	SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan	LOGGED BY: APL

EQUIPMENT TYPE AND MODEL:	Sumitomo SH60			R.L SURFACE:	153.5
EXCAVATION DIMENSIONS:	3m	LONG	0.6m WIDE	DATUM:	AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil		pp >600 D pp >600	0.7			FILL; Shale, brown and grey, low to medium strength, with clay and dry silt.	D	L	Grass cover. Fill appears poorly compacted.
			pp >600	1 1.2		ML	TOPSOIL; Clayey Silt, low plasticity, grey brown, roots.	D <PL		
			pp >600	1.8		CL	SILTY CLAY; medium plasticity,brown and orange brown, with medium shale gravel.	M >PL	St -VSt	
		▶	noticeable seepage	2 3		CL	as above but grey, orange brown and red brown.			
							SHALE; grey, distinctly weathered, fractured, low to medium strength.			
							End Excavation at 3.3m			

KEY TO LOG		WATER	SAMPLES & NOTES	CONSISTENCY / DENSITY	
	▽	WATER LEVEL	U63 - UNDISTURBED TUBE	VS - VERY SOFT	FR - FRIABLE
METHOD	▶	WATER INFLOW	SAMPLE 63mm DIAMTER	S - SOFT	VL - VERY LOOSE
N - NATURAL EXPOSURE	◀	WATER OUTFLOW	D - DISTURBED SAMPLE	F - FIRM	L - LOOSE
E - EXISTING EXCAVATION	GNE	GROUNDWATER NOT	B - BULK SAMPLE	ST - STIFF	MD - MEDIUM DENSE
BE - BUCKET EXCAVATION		ENCOUNTERED	SV - INSITU SHEAR VANE TEST (kPa)	VST - VERY STIFF	D - DENSE
B - BULLDOZER BLADE			pp - HAND PENETROMETER TEST (kPa)	H - HARD	VD - VERY DENSE
SUPPORT			MOISTURE CONDITION		
T - TMBERING			D - DRY		
			M - MOIST		
			W - WET		

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EXCAVATION LOG

PIT NUMBER 16
SHEET No. 1 OF 1

	JOB NUMBER: 97024
CLIENT: J. Papaluca	PIT COMMENCED:3/5/97
PROJECT: Sub-Division at West Pennant Hills	PIT COMPLETED:3/5/97
	SUPERVISED BY: APL
PIT LOCATION: Refer to Site Plan	LOGGED BY: APL

EQUIPMENT TYPE AND MODEL:	Sumitomo SH60	R.L SURFACE:	170.2
EXCAVATION DIMENSIONS:	3m LONG 0.6m WIDE	DATUM:	AHD

METHOD	SUPPORT	WATER	NOTES SAMPLES TESTS	DEPTH (m)	GRAPHIC LOG	U.S. CL SYMBOL	MATERIAL SOIL TYPE:PLASTICITY OR PARTICLE CHARACTERISTICS:COLOUR SECONDARY & MINOR COMPONENTS	MOISTURE CONDITION	CONSISTENCY	STRUCTURE TEST RESULTS AND ADDITIONAL OBSERVATIONS
BE	Nil	GNE	pp >600 pp >600	1 1.1			FILL; Gravelly Clay; medium plasticity, grey and yellow brown, with medium to coarse gravel.	D <PL	H	AC cover 20mm thick Fill appears moderately compacted.
			pp >600	1.5		CL	SILTY CLAY; medium plasticity,red brown and orange brown, with medium shale gravel.	M >PL	H	
			pp >600	2 2.1			as above but; grey and red brown.	M >PL	H	
				2.5			SHALE; grey and orange brown, extremely weathered, very low to low strength.	W		
							as above but; slightly weathered, medium strength.			High Excavator Resistance.
				3			End Excavation at 2.6m			

KEY TO LOG	WATER	SAMPLES & NOTES	CONSISTENCY / DENSITY
	WATER LEVEL	U63 - UNDISTURBED TUBE	VS - VERY SOFT FR - FRIABLE
METHOD	WATER INFLOW	SAMPLE 63mm DIAMTER	S - SOFT VL - VERY LOOSE
N - NATURAL EXPOSURE	WATER OUTFLOW	D - DISTURBED SAMPLE	F - FIRM L - LOOSE
E - EXISTING EXCAVATION	GNE GROUNDWATER NOT	B - BULK SAMPLE	ST - STIFF MD - MEDIUM DENSE
BE - BUCKET EXCAVATION	ENCOUNTERED	SV - INSITU SHEAR VANE TEST (kPa)	VST - VERY STIFF D - DENSE
B - BULLDOZER BLADE		pp - HAND PENETROMETER TEST (kPa)	H - HARD VD - VERY DENSE
SUPPORT		MOISTURE CONDITION	
T - TMBERING		D - DRY	
		M - MOIST	
		W - WET	

SOIL AND ROCK DESCRIPTION

TYPICAL REPRESENTATION AND TERMS USED FOR SOILS

		Group Symbol	Description
COARSE GRAINED SOILS (<50% passing 0.075mm sieve)	gravels	▨ GW	Well graded gravels and gravel-sand mixtures, little or no fines.
		▨ GP	Poorly graded gravels and gravel-sand mixtures-little or no fines, uniform gravels.
	gravelly soils	▨ GM	Silty gravels, gravel-sand-silt mixtures.
		▨ GC	Clayey gravels, gravel-sand-clay mixtures.
	sands	▨ SW	Well graded sands and gravelly sands; little or no fines, uniform sands.
		▨ SP	Poorly graded sands, gravelly sands, little or no fines, uniform gravels.
	sandy soils	▨ SM	Silty sands, sand-silt mixtures.
		▨ SC	Clayey sands, sand-clay mixtures.

		Group Symbol	Description
FINE GRAINED SOILS (>50% passing 0.075mm sieve)	LL<50%	▨ ML	Inorganic silts and very fine sands, rock flour or clayey fire sands or clayey silts with slight plasticity.
		▨ CL/CI	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		▨ OL	Organic silts and organic silty clays of low plasticity.
	LL>50%	▨ MH	Inorganic silts, micaeous or diatomaceous fine sandy or silty soils, organic silts.
		▨ CH	Inorganic clays of high plasticity, fat clays.
		▨ OH	Organic clays of medium to high plasticity, organic silts.
		▨ Pt	Peat and other highly organic soils.
		▨	Fill.

CONSISTENCY - NON-COHESIVE SOILS

Field Test	Easily excavated with a spade	Some resistance to spade or penetration with hand bar	Considerable resistance to spade or penetration with hand bar	No penetration with a hand bar; requires pick for excavation	High resistance to a pick
SPT 'N' VALUE (blows/300mm)	0	4	10	30	50
Designation	Very Loose (VL)	Loose (L)	Medium dense (MD)	Dense (D)	Very Dense (VD)
Relative Density	0	15	35	65	85 100

CONSISTENCY - COHESIVE SOILS

Field Test	Exudes between the fingers when squeezed in hand	Can be moulded by light finger pressure	Can be moulded by strong finger pressure	Cannot be moulded by fingers. Can be indented by thumb	Can be indented by thumb nail	Can be indented with difficulty by thumb nail
Designation	Very Soft (VS)	Soft (S)	Firm (F)	Stiff (St)	Very Stiff (VSt)	Hard (H)
Undrained Shear Strength (C_u kPa)		12	25	50	100	200

GRAIN SIZE

Field Test	i Not visible with x10 lens ii Does not dilate on shaking iii Adheres to fingers when dry	i Particles >10 µm visible with x 10 lens ii Dilates on shaking iii Does not adhere to fingers when dry iv Feels gritty on teeth	i Particles >75 µm visible to naked eye ii Fine grained sand feels gritty in the fingers			Visual Identification				
Designation	CLAY	SILT	SAND			GRAVEL			COBBLES	BOULDERS
			Fine (f)	Medium (m)	Coarse (c)	Fine (f)	Medium (m)	Coarse (c)		
Grain Size		2	75	200	600	2.36	6	20	63	200
	Microns					Millimetres				

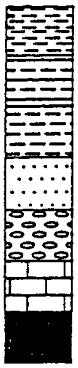
MOISTURE CONDITION

Dry (D)	Cohesive soils; hard and friable or, well dry of plastic limit. Granular soils; cohesion less and full running.
Moist (M)	Soil feels cool, darkened in colour; cohesive soils can be moulded. Granular soils tend to cohere.
Wet (W)	As above. Cohesive soils, free water collects on hands when handling.

SOIL AND ROCK DESCRIPTION

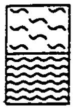
TYPICAL REPRESENTATION AND TERMS USED FOR ROCK

SEDIMENTARY



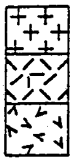
Mudstone
Shale
Siltstone
Sandstone
Conglomerate
Limestone
Coal

METAMORPHIC



Low grade: slate, schist etc.
High grade: quartzite, gneiss, marble etc.

IGNEOUS



Plutonic (generally coarse grained): granite gabbro etc.
Hypabyssal (generally medium grained): micro granite, dolerite etc.
Volcanic (generally fine grained): rhyolite andesite, basalt, pyroclastic etc.

STRENGTH

Field Test	Easily remoulded by hand to a material with soil properties	Material crumbles under firm blows with sharp end of pick; can be peeled with knife.Pieces up to 3cm thick can be broken by finger pressure.	Easily scored with knife; 1mm to 3mm indentations with pick point; dull sound under hammer.	Readily scored with knife; core 50mm dia broken by hand with difficulty.	Core 50mm dia not broken by hand but by pick with single firm blow; rock rings under hammer.	Break with pick after more than one blow; rock rings under hammer.	Requires many blows with geological pick to break; rock rings under hammer.
Point Load Strength Index Is (50) MPa	0.03	0.1	0.3	1	3	10	
Designation	Extremely Low (EL)	Very Low (VL)	Low (L)	Medium (M)	High (H)	Very High (VH)	Extremely High (EH)
Unconfined Compressive Strength (Q_u MPa)	0.7	2.4	7.2	24	72	240	

GRAIN SIZE

Equivalent Soil Size	Clay	Silt	Sand	Gravel	Cobbles-Boulders
Sedimentary	Argillaceous		Arenaceous fine | medium | coarse	Rudaceous	
Metamorphic/ Igneous	Fine		Medium	Coarse	
Grain Size	2	60	200 600	2	60
	Microns			Millimetres	

WEATHERING

Residual Soils (RS)	Extremely weathered rock (XW)	Distinctly weathered rock (DW)	Slightly weathered rock (SW)	Fresh rock (FR)
Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.	Rock is weathered to such an extent that it has 'soil' properties, i.e. it either disintegrates or can be remoulded, in water.	Rock strength usually changed by weathering. The rock may be highly discoloured, usually be ironstaining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.	Rock is slightly discoloured but shows little or no change of strength from fresh rock.	Rock shows no sign of decomposition or staining.

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APPENDIX B

2001 Borehole Logs BH1 – BH6
2015 Borehole Logs BH7 – BH11
Explanatory Notes (2 sheets)

Borehole Log Report

Davies Geotechnical Pty Ltd
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DAVIES GEOTECHNICAL
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Hole ID.	**BH1**
Hole Depth:	**6.00 m**
Sheet:	**1 of 1**

Project Name:	**Oratava Avenue - West Pennant Hills (Papaluca)**	Project Number:	**00-027**
Location / Site:	**Lot 7 middle**	Client:	**Craig and Rhodes Pty Ltd**

Drilling Company:		Date Started:	**18/04/2001**	Ground Level:	----------
Drill Method:	**TC auger - screw and pull**	Date Completed:	**18/04/2001**	Easting:	----------
Equipment:	**Truck mounted rig**			Northing:	----------

Method	Water Level	Depth (m)	RL (m)	Graphic Log	USCS Symbol	Material Type	Material Description	Consistency / Density	Moisture	Observations / Comments
							Surface: fill			
TC auger - screw and pull						Fill	**FILL**- Clay and Sand, dark brown.	pushed in	slightly moist	
		1.0				Natural	**GRAVEL**- 20mm, gravels are shaley.	easy		
	2.7m 5.10pm	2.0								
		3.0					- increase in auger resistance.	firm	wet	
	4.65m 9.40am	4.0								
		5.0				Bedrock	**SILTSTONE**- Layer, dark grey, fresh, gravel size cuttings.	becoming stiffer to very hard		
							SHALE- fresh.	hard		
		6.0					**Hole Terminated at 6.00m**			

Moisture	
D	Dry
Dp	Damp
SM	Slightly Moist
M	Moist
VM	Very Moist
W	Wet
Sd	Saturated

Additional Comments

Piezometer installed to 5.78m
Slotted screen/sock: 1.38 - 5.78m
Sand: 1.10 - 5.78m
Bentonite pellets: 1.00 - 1.10m

Logged By:	**Warwick Davies**	Date:	**18/04/2001**	Checked By:	**Matthew Kilham**	Date:	**17/03/2015**

Borehole Log Report

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Hole ID.	**BH1A**
Hole Depth:	**4.85 m**
Sheet:	**1 of 1**

Project Name:	**Oratava Avenue - West Pennant Hills (Papaluca)**	Project Number:	**00-027**
Location / Site:	**Lot 7, 1.65m SE from BH1**	Client:	**Craig and Rhodes Pty Ltd**

Drilling Company:		Date Started:	**18/04/2001**	Ground Level:	----------
Drill Method:	**TC auger - screw and pull**	Date Completed:	**18/04/2001**	Easting:	----------
Equipment:	**Truck mounted rig**			Northing:	----------

Method	Water Level	Depth (m)	RL (m)	Graphic Log	USCS Symbol	Material Type	Material Description	Moisture	Samples / Tests SPT	Observations / Comments
							Surface: fill			
TC auger - screw and pull				▨		Fill	**FILL**- Sandy Clay and Gravel, lumps of concrete.			
		1.0		▨		Natural	**FILL**- Shaly Fill.		2 3 3 N=6	
		2.0		▨						
		3.0		▨			- clayey shale, horizontally bedded, looks natural, dry.	dry to moist bands	5 4 5 N=9	
		4.0		▨			- dry powdered shale, steady augering, grinding.			
				▨			- highly weathered and weak, moderately weathered shale, horizontally bedded.	dry	14 34 R	
		5.0					**Hole Terminated at 4.85m**			

Moisture		Additional Comments
D	Dry	
Dp	Damp	
SM	Slightly Moist	
M	Moist	
VM	Very Moist	
W	Wet	
Sd	Saturated	

Logged By:	**Warwick Davies**	Date:	**18/04/2001**	Checked By:	**Matthew Kilham**	Date:	**17/03/2015**

Borehole Log Report

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Hole ID.	**BH2**
Hole Depth:	**9.00 m**
Sheet:	**1 of 1**

Project Name:	**Oratava Avenue - West Pennant Hills (Papaluca)**	Project Number:	**00-027**
Location / Site:		Client:	**Craig and Rhodes Pty Ltd**

Drilling Company:		Date Started:	**18/04/2001**	Ground Level:	----------
Drill Method:	**TC auger - screw and pull**	Date Completed:	**18/04/2001**	Easting:	----------
Equipment:	**Truck mounted rig**			Northing:	----------

Method	Water Level	Depth (m)	RL (m)	Graphic Log	USCS Symbol	Material Type	Material Description	Consistency / Density	Moisture	Observations / Comments
							Surface: fill			
TC auger - screw and pull						Fill	**FILL**- Clay, red/brown.			
	1.8m 5.10pm ▼	1.0 2.0				Natural	**TOPSOIL**- Grass.			
		3.0					**CLAY**- red/brown, with fine gravel (ironstone, shale - weathered).	stiff	moist slightly moist	
		4.0 5.0					**SHALE**- grey, slightly weathered to fresh.		very moist	
		6.0					**CLAY**- grey/brown. - becoming brown.	very stiff becoming stiff	moist	
		7.0				Bedrock	**INTERBEDDED SHALE AND CLAY**- tight (thin layer only).	stiff very stiff hard		
		8.0 9.0					**SHALE**- dark grey, fresh (chips up to 25mm).	hard		
							Hole Terminated at 9.00m			

Moisture	
D	Dry
Dp	Damp
SM	Slightly Moist
M	Moist
VM	Very Moist
W	Wet
Sd	Saturated

Additional Comments

Piezometer installed to 5.95m
Slotted screen/sock: 1.45 - 5.95m
Sand: 0.40 - 5.95m
Bentonite pellets: 0.30 - 0.40m

Logged By:	**Warwick Davies**	Date:	**18/04/2001**	Checked By:	**Matthew Kilham**	Date:	**9/03/2015**

Borehole Log Report

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DAVIES GEOTECHNICAL
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Hole ID.	**BH3**
Hole Depth:	**9.05 m**
Sheet:	**1 of 1**

Project Name:	**Oratava Avenue - West Pennant Hills (Papaluca)**	Project Number:	**00-027**
Location / Site:		Client:	**Craig and Rhodes Pty Ltd**

Drilling Company:		Date Started:	**18/04/2001**	Ground Level:	----------
Drill Method:	**TC auger - screw and pull**	Date Completed:	**18/04/2001**	Easting:	----------
Equipment:	**Truck mounted rig**			Northing:	----------

Method	Water Level	Depth (m)	RL (m)	Graphic Log	USCS Symbol	Material Type	Material Description	Consistency / Density	Moisture	Observations / Comments
							Surface: fill			
TC auger - screw and pull		1.0				Fill	**FILL**- Clay and Gravel, grey, 20mm blue metal.		slightly moist	
		2.0					**TOPSOIL**- Clayey Silt, dark brown.			
	2.25m 5.15pm 2.3m 2.45pm	3.0 4.0				Natural	**CLAY**- red/brown, with occasional fine gravels (ironstone, siltstone).	stiff		
		5.0					- as above.			
		6.0					- clay as above.	firm to stiff	moist to very moist	
		7.0				Bedrock		less stiff		
		8.0					7.55 - 7.65m: possible V-bit refusal.	stiff	wet	
							SHALE- dark grey, fresh, chips with weaker layers.	very stiff		
		9.0					**SHALE**- red/brown, weathered interbedded clay.	stiff		
							Hole Terminated at 9.05m			

Moisture	
D	Dry
Dp	Damp
SM	Slightly Moist
M	Moist
VM	Very Moist
W	Wet
Sd	Saturated

Additional Comments

Piezometer installed to 9.05m
Slotted screen/sock: 3.00 - 9.05m
Sand: 1.50 - 9.05m
Bentonite pellets: 1.40 - 1.50m

Logged By:	**Warwick Davies**	Date:	**18/04/2001**	Checked By:	**Matthew Kilham**	Date:	**17/03/2015**

Borehole Log Report

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Hole ID. **BH4**
Hole Depth: **7.50 m**
Sheet: **1 of 1**

Project Name: **Oratava Avenue - West Pennant Hills (Papaluca)**
Project Number: **00-027**
Location / Site:
Client: **Craig and Rhodes Pty Ltd**

Drilling Company:
Drill Method: **TC auger - screw and pull**
Equipment: **Truck mounted rig**
Date Started: **18/04/2001**
Date Completed: **18/04/2001**
Ground Level: ----------
Easting: ----------
Northing: ----------

Method	Water Level	Depth (m)	RL (m)	Graphic Log	USCS Symbol	Material Type	Material Description	Consistency / Density	Moisture	Observations / Comments
TC auger - screw and pull		1.0 2.0				Natural	**CLAY**- red/brown.			
							Shaly SILTSTONE.	stiff		
	3.1m 5.25pm 3.55m 4.05pm	3.0 4.0 5.0					**CLAY**- brown/grey/yellow.			
						Bedrock	**SHALE**.	firm		
		6.0 7.0					**Consistent SHALE**- grey, fresh and slightly weathered chips, cuttings are tight grey clay with brown clay layers, possible completely weathered shale/siltstone.	hard hard		
		8.0					**Hole Terminated at 7.50m**			

Moisture

D	Dry
Dp	Damp
SM	Slightly Moist
M	Moist
VM	Very Moist
W	Wet
Sd	Saturated

Additional Comments

Piezometer installed to 6.00m
Slotted screen/sock: 3.00 - 6.00m
Sand: 1.50 - 6.00m
Bentonite pellets: 1.40 - 1.50m

Water level:
4.05pm - water level: 3.55m
5.25pm - water level: 3.10m

Logged By: **Warwick Davies** Date:**18/04/2001**
Checked By: **Matthew Kilham** Date: **17/03/2015**

Borehole Log Report

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DAVIES GEOTECHNICAL
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Hole ID.	**BH5**
Hole Depth:	**6.00 m**
Sheet:	**1 of 1**

Project Name:	**Oratava Avenue - West Pennant Hills (Papaluca)**	Project Number:	**00-027**
Location / Site:		Client:	**Craig and Rhodes Pty Ltd**

Drilling Company:		Date Started:	**18/04/2001**	Ground Level:	----------
Drill Method:	**TC auger - screw and pull**	Date Completed:	**18/04/2001**	Easting:	----------
Equipment:	**Truck mounted rig**			Northing:	----------

Method	Water Level	Depth (m)	RL (m)	Graphic Log	USCS Symbol	Material Type	Material Description	Consistency / Density	Moisture	Observations / Comments
TC auger - screw and pull	0.45m 4.25pm 0.25m 5.25pm			▨		Natural	**CLAY**- red-brown.	soft	moist	
		1.0					- becoming grey/brown and red mottled.			
								soft to firm		
		2.0								
		3.0						firm to stiff		
							- Sandy Clay, light grey red streaking, fine grained sand.		slightly moist	
		4.0								
		5.0								
						Bedrock	**SHALE**- grey, powder, no gravels.	hard	dry	
		6.0					**Hole Terminated at 6.00m**			

GEE DAVIES BH LOG 00-027 ORATAVA AVENUE - WEST PENNANT HILLS.GPJ GEE.GDT 22/3/15 11:30:51 AM

Moisture

D	Dry
Dp	Damp
SM	Slightly Moist
M	Moist
VM	Very Moist
W	Wet
Sd	Saturated

Additional Comments

Piezometer installed to 6.00m
Slotted screen/sock: 3.40 - 6.00m
Sand: 0.85 - 6.00m
Bentonite pellets: 0.75 - 0.85m

Logged By:	**Warwick Davies**	Date:	**18/04/2001**	Checked By:	**Matthew Kilham**	Date:	**17/03/2015**

Borehole Log Report

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DAVIES GEOTECHNICAL
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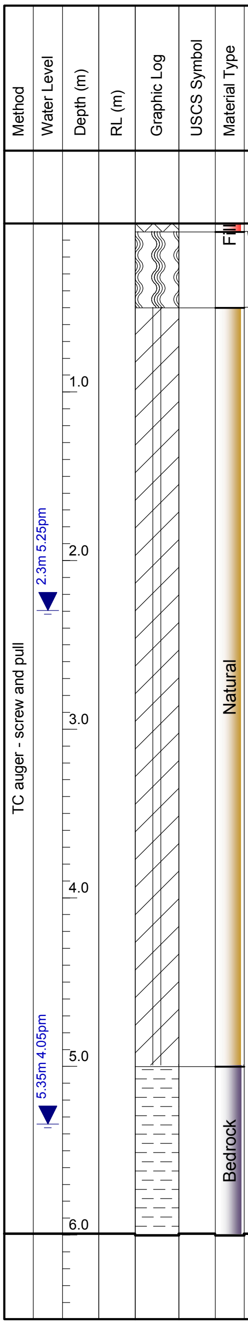
Hole ID.	**BH6**
Hole Depth:	**6.00 m**
Sheet:	**1 of 1**

Project Name:	**Oratava Avenue - West Pennant Hills (Papaluca)**	Project Number:	**00-027**
Location / Site:		Client:	**Craig and Rhodes Pty Ltd**

Drilling Company:		Date Started:	**18/04/2001**	Ground Level:	----------
Drill Method:	**TC auger - screw and pull**	Date Completed:	**18/04/2001**	Easting:	----------
Equipment:	**Truck mounted rig**			Northing:	----------



Material Description	Consistency / Density	Moisture	Observations / Comments
Surface: fill			
FILL- Gravelly Clay.			
TOPSOIL- Silt, dark brown/grey.			
Clayey SILT- dark brown.			
- becoming Clay - red/brown.		moist	
- becoming grey minor brown mottling, slightly drier.	stiff		
- clay - grey/darker grey, possible completely weathered shale.		damp	
SHALE- dry weak powdered, clayey lumps.	hard		
Hole Terminated at 6.00m			

Moisture

D	Dry
Dp	Damp
SM	Slightly Moist
M	Moist
VM	Very Moist
W	Wet
Sd	Saturated

Additional Comments

Piezometer installed to 5.85m
Slotted screen/sock: 3.50 - 5.85m
Sand: 1.00 - 5.85m
Bentonite pellets: 0.90 - 1.00m

Logged By:	**Warwick Davies**	Date:	**18/04/2001**	Checked By:	**Matthew Kilham**	Date:	**17/03/2015**

Cored Borehole Log Report

Davies Geotechnical Pty Ltd
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DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

Hole ID.	**BH7**
Hole Depth:	**11.78 m**
Sheet:	**1 of 5**

Project Name:	**Townhouse Development**	Project Number:	**15-004**
Location / Site:	**39-55 Oratava Avenue, West Pennant Hills**	Client:	**Kai Ling (Australia) Pty Ltd**

Drilling Company:	**Total Drilling**	Date Started:	**12/03/2015**	Ground Level:	----------
Drill Method:	**Solid Flight Auger**	Date Completed:	**12/03/2015**	Easting:	----------
Equipment:	**Scout Truck Mounted Rig**			Northing:	----------

Method	Water Loss %	Depth (m)	RL (m)	Graphic Log	USCS Symbol	Material Type	Material Description	Moisture	Observations / Comments
SFA						Residual Soil	**TOPSOIL. Silty CLAY**- brown, low plasticity.	damp	
				▨			**Silty CLAY**- red / brown, low to medium plasticity, trace of fine gravel (ironstone).	damp	
		1.0 2.0 3.0					*BH7 continued as cored hole from 0.6m*		

Moisture	
D	Dry
Dp	Damp
SM	Slightly Moist
M	Moist
VM	Very Moist
W	Wet
Sd	Saturated

Additional Comments

Logged By:	**MHK**	Date:	**12/03/2015**	Checked By:	**WND**	Date:	**30/03/2015**

Cored Borehole Log Report

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Hole ID.	**BH7**
Hole Depth:	**11.78 m**
Sheet:	**2 of 5**

Project Name:	**Townhouse Development**	Project Number:	**15-004**
Location / Site:	**39-55 Oratava Avenue, West Pennant Hills**	Client:	**Kai Ling (Australia) Pty Ltd**

Drilling Company:	**Total Drilling**	Date Started:	**12/03/2015**	Ground Level:	----------
Drill Method:	**HQ Coring**	Date Completed:	**12/03/2015**	Easting:	----------
Equipment:	**Scout Truck Mounted Rig**			Northing:	----------

Method	Water Loss %	Depth (m)	RL (m)	Graphic Log	Material Type	Material Description	Weathering	Estimated Strength (MPa) EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH	Is(50) MPa D=diametral A=axial	Core Recovery %	RQD %	Rock Mass Defects: Visual	Defect Spacing (mm) 20 60 200 600 2000	Defect Description type, inclination, thickness, shape, roughness, coating: Specific / General	Depth (m)	Casing & Core Lifts
		0.2 0.4 0.6				*Continued from non-cored borehole from 0.6m*									0.2 0.4 0.6	
HQ Coring		0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0			Residual Soil	**Silty CLAY** - red / brown, low to medium plasticity, trace of fine gravel (ironstone). **Silty CLAY** - grey, some orange and red, medium plasticity, trace of fine to medium gravel (siltstone, highly weathered, brown / red), sub angular.				100 100	N/A N/A			Heterogeneous clay matrix, trace randomly orientated and spaced gravel (laminite / siltstone, generally highly weathered, sub angular). 0.6-3.3m slightly disturbed zone, upper level slide material.	0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0	2.57

Additional Comments

Logged By: **MHK**	Date: **12/03/2015**	Checked By: **WND**	Date: **30/03/2015**

Cored Borehole Log Report

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Hole ID.	**BH7**
Hole Depth:	**11.78 m**
Sheet:	**3 of 5**

Project Name:	**Townhouse Development**	Project Number:	**15-004**
Location / Site:	**39-55 Oratava Avenue, West Pennant Hills**	Client:	**Kai Ling (Australia) Pty Ltd**

Drilling Company:	**Total Drilling**	Date Started:	**12/03/2015**	Ground Level:	----------
Drill Method:	**HQ Coring**	Date Completed:	**12/03/2015**	Easting:	----------
Equipment:	**Scout Truck Mounted Rig**			Northing:	----------

Method: HQ Coring
Material Type: Residual Soil

Depth (m)	Material Description	Weathering
3.05–3.35	**Silty CLAY** - grey, some orange and red, medium plasticity, trace of fine to medium gravel (siltstone, highly weathered, brown / red), sub angular.	
3.35–4.35	**Silty CLAY** - grey / orange, some red, low to medium plasticity, fine to coarse gravel (siltstone, red / brown and dark grey), sub rounded to sub angular.	
4.35–4.75	**LAMINITE** - boulder sized, clast?.	EW-MW HW-MW
4.75–5.21	**Silty CLAY** - orange / grey, low plasticity.	
5.21–5.28	**SHALE / SILTSTONE** - brown, clast?.	HW
5.28–5.35	**Silty CLAY** - grey, low plasticity.	EW
5.35–5.42	**SHALE / SILTSTONE** - grey, clast?.	SW
5.42–5.62	**CORE LOSS**.	
5.62–5.98	**Gravelly CLAY** - grey / orange, fine to medium gravel (siltstone, brown and grey, highly to moderately weathered).	
5.98–	**LAMINITE** - grey / orange, strong iron oxidation.	HW-MW

Casing & Core Lifts	Core Recovery %	RQD %
3.05	100	N/A
3.46	100	N/A
3.82	100	N/A
4.3	100	N/A
5.33	43	N/A
5.75	100	100

Rock Mass Defects

Defect Description – Specific	Defect Description – General
J, 30°, r	Heterogeneous clay matrix, with randomly orientated and spaced gravel (laminite / siltstone, highly to slightly weathered, sub angular clasts). 3.3-5.7m moderately to strongly disturbed zone, mid level slide material.
B	
HB	
J, 10°, r	
	Material description as above, strongly disturbed zone, possible base of slide plane.
	Insitu Bedrock

Additional Comments

Logged By: **MHK**	Date: **12/03/2015**	Checked By: **WND**	Date: **30/03/2015**

Cored Borehole Log Report

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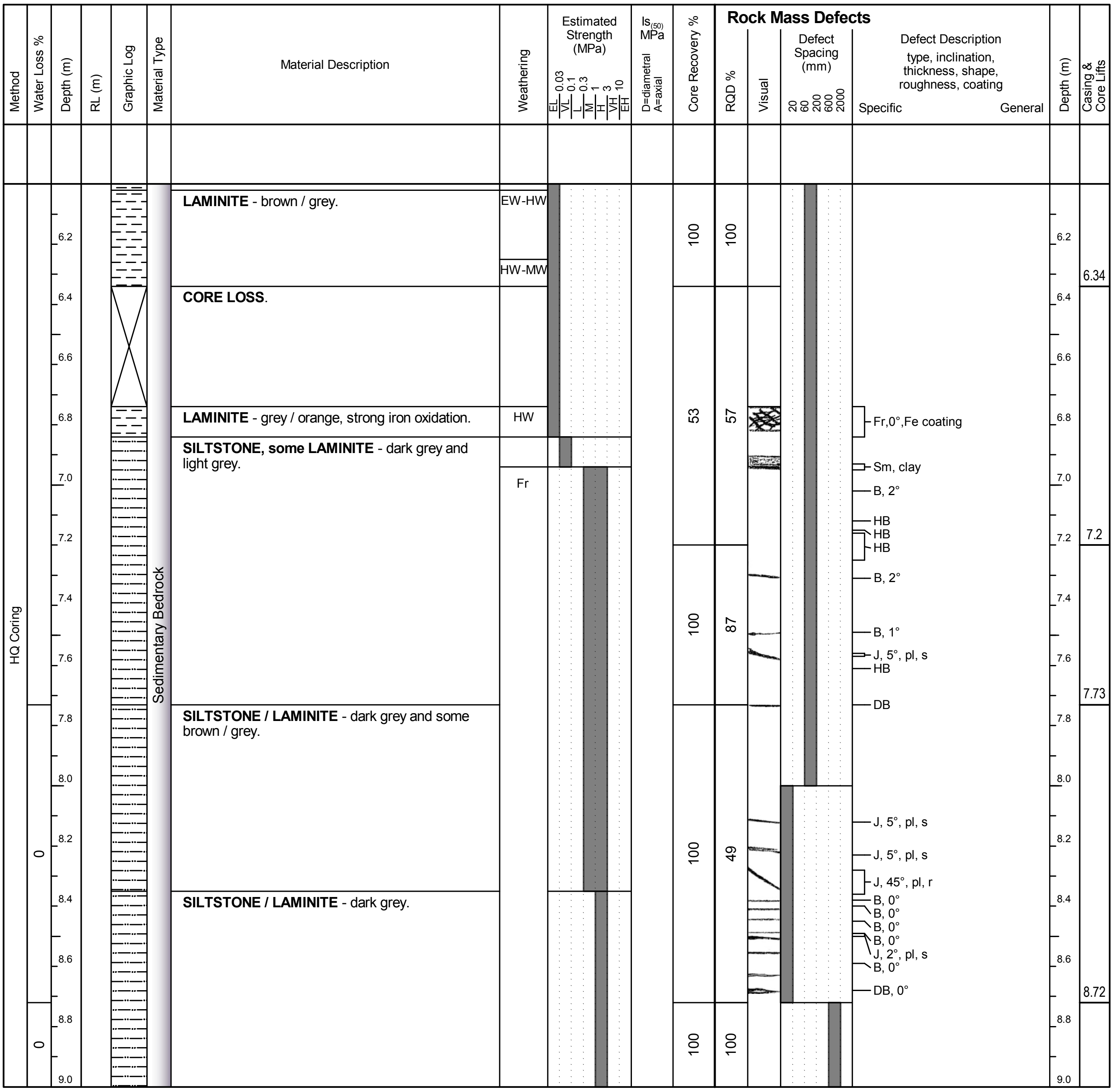
Hole ID. **BH7**
Hole Depth: **11.78 m**
Sheet: **4 of 5**

Project Name: **Townhouse Development**
Project Number: **15-004**
Location / Site: **39-55 Oratava Avenue, West Pennant Hills**
Client: **Kai Ling (Australia) Pty Ltd**

Drilling Company: **Total Drilling**
Date Started: **12/03/2015**
Ground Level: ----------
Drill Method: **HQ Coring**
Date Completed: **12/03/2015**
Easting: ----------
Equipment: **Scout Truck Mounted Rig**
Northing: ----------



Material Description	Weathering
LAMINITE - brown / grey.	EW-HW HW-MW
CORE LOSS.	
LAMINITE - grey / orange, strong iron oxidation.	HW
SILTSTONE, some LAMINITE - dark grey and light grey.	Fr
SILTSTONE / LAMINITE - dark grey and some brown / grey.	
SILTSTONE / LAMINITE - dark grey.	

Casing & Core Lifts	Core Recovery %	RQD %	Water Loss %
6.34	100	100	
7.2	53	57	
7.73	100	87	
8.72	100	49	0
	100	100	0

Defect Description:
- Fr,0°,Fe coating
- Sm, clay
- B, 2°
- HB
- HB
- HB
- B, 2°
- B, 1°
- J, 5°, pl, s
- HB
- DB
- J, 5°, pl, s
- J, 5°, pl, s
- J, 45°, pl, r
- B, 0°
- B, 0°
- B, 0°
- B, 0°
- J, 2°, pl, s
- B, 0°
- DB, 0°

Additional Comments

Logged By: **MHK** Date: **12/03/2015** Checked By: **WND** Date: **30/03/2015**

Cored Borehole Log Report

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Hole ID. **BH7**
Hole Depth: **11.78 m**
Sheet: **5 of 5**

Project Name: **Townhouse Development**
Project Number: **15-004**
Location / Site: **39-55 Oratava Avenue, West Pennant Hills**
Client: **Kai Ling (Australia) Pty Ltd**

Drilling Company: **Total Drilling**
Drill Method: **HQ Coring**
Equipment: **Scout Truck Mounted Rig**
Date Started: **12/03/2015**
Date Completed: **12/03/2015**
Ground Level: ----------
Easting: ----------
Northing: ----------

Method	Water Loss %	Depth (m)	RL (m)	Graphic Log	Material Type	Material Description	Weathering	Estimated Strength (MPa) EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH	Is(50) MPa D=diametral A=axial	Core Recovery %	Rock Mass Defects: RQD %	Visual	Defect Spacing (mm) 20 60 200 600 2000	Defect Description type, inclination, thickness, shape, roughness, coating: Specific	General	Depth (m)	Casing & Core Lifts
HQ Coring	0	9.2			Sedimentary Bedrock	**SILTSTONE / LAMINITE** - dark grey.	Fr			100	100					9.2	
		9.4														9.4	
		9.6												Sm, clay		9.6	
		9.8														9.8	
		10.0														10.0	
		10.2														10.2	
		10.4														10.4	
		10.6														10.6	
		10.8														10.8	
		11.0														11.0	
		11.2														11.2	
		11.4												B, 0°		11.4	
		11.6														11.6	
		11.8														11.8	11.78
		12.0				**End of Hole at 11.78 m**										12.0	

Additional Comments

Logged By: **MHK** Date: **12/03/2015** Checked By: **WND** Date: **30/03/2015**

Cored Borehole Log Report

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Hole ID.	**BH8**
Hole Depth:	**11.73 m**
Sheet:	**1 of 5**

Project Name:	**Townhouse Development**	Project Number:	**15-004**
Location / Site:	**39-55 Oratava Avenue, West Pennant Hills**	Client:	**Kai Ling (Australia) Pty Ltd**

Drilling Company:	**Total Drilling**	Date Started:	**12/03/2015**	Ground Level:	----------
Drill Method:	**Solid Flight Auger**	Date Completed:	**13/03/2015**	Easting:	----------
Equipment:	**Scout Truck Mounted Rig**			Northing:	----------

Method	Water Loss %	Depth (m)	RL (m)	Graphic Log	USCS Symbol	Material Type	Material Description	Observations / Comments
Solid Flight Auger		1.0				Fill	**FILL**- Silty Clay, with fine to coarse gravel, bricks, concrete, glass, wire.	
		2.0 3.0					*BH8 continued as cored hole from 1.42m*	

Moisture	
D	Dry
Dp	Damp
SM	Slightly Moist
M	Moist
VM	Very Moist
W	Wet
Sd	Saturated

Additional Comments

Logged By:	**MHK**	Date:	**13/03/2015**	Checked By:	**WND**	Date:	**30/03/2015**

Cored Borehole Log Report

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Hole ID. **BH8**
Hole Depth: **11.73 m**
Sheet: **2 of 5**

Project Name: **Townhouse Development**
Project Number: **15-004**
Location / Site: **39-55 Oratava Avenue, West Pennant Hills**
Client: **Kai Ling (Australia) Pty Ltd**

Drilling Company: **Total Drilling**
Date Started: **12/03/2015**
Ground Level: ----------
Drill Method: **HQ Coring**
Date Completed: **13/03/2015**
Easting: **----------**
Equipment: **Scout Truck Mounted Rig**
Northing: **----------**

Method	Water Loss %	Depth (m)	RL (m)	Graphic Log	Material Type	Material Description	Weathering	Estimated Strength (MPa) EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH	Is(50) MPa D=diametral A=axial	Core Recovery %	Rock Mass Defects RQD %	Visual	Defect Spacing (mm) 20 60 200 600 2000	Defect Description type, inclination, thickness, shape, roughness, coating Specific General	Depth (m)	Casing & Core Lifts
		0.2 0.4 0.6 0.8 1.0 1.2 1.4				*Continued from non-cored borehole from 1.42m*									0.2 0.4 0.6 0.8 1.0 1.2 1.4	
HQ Coring		1.6			Fill	**FILL** - Gravelly Clay, brown / red, fine to coarse gravel (siltstone).				100	N/A				1.6	
		1.8 2.0 2.2			Residual Soil	**TOPSOIL. Silty CLAY** - dark brown, medium plasticity, fine gravel, roots, becoming red / brown. Becoming brown / grey, some red, trace fine gravel (siltstone, brown / red, <10mm).									1.8 2.0 2.2	2.32
		2.4 2.6 2.8 3.0				**CORE LOSS.**				22	N/A				2.4 2.6 2.8 3.0	

Additional Comments

Logged By: **MHK** Date: **12/03/2015** Checked By: **WND** Date: **30/03/2015**

Cored Borehole Log Report

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Hole ID.	**BH8**
Hole Depth:	**11.73 m**
Sheet:	**3 of 5**

Project Name:	**Townhouse Development**	Project Number:	**15-004**
Location / Site:	**39-55 Oratava Avenue, West Pennant Hills**	Client:	**Kai Ling (Australia) Pty Ltd**

Drilling Company:	**Total Drilling**	Date Started:	**12/03/2015**	Ground Level:	----------
Drill Method:	**HQ Coring**	Date Completed:	**13/03/2015**	Easting:	----------
Equipment:	**Scout Truck Mounted Rig**			Northing:	----------

Method	Water Loss %	Depth (m)	RL (m)	Graphic Log	Material Type	Material Description	Weathering	Estimated Strength (MPa) EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH	Is(50) MPa D=diametral A=axial	Core Recovery %	Rock Mass Defects RQD %	Visual	Defect Spacing (mm) 20 60 200 600 2000	Defect Description type, inclination, thickness, shape, roughness, coating Specific General	Depth (m)	Casing & Core Lifts
HQ Coring		3.2 3.4 3.6 3.8			Residual Soil	**Silty CLAY** - grey / red / orange, medium plasticity, trace fine gravel (siltstone, red / brown, highly weathered), trace charcoal.				22 100 100	N/A N/A N/A			Heterogeneous clay matrix, randomly orientated and spaced gravel (shale / siltstone, generally highly weathered, sub angular). 3.02-4.39m slightly disturbed zone, upper level slide material.	3.2 3.4 3.6 3.8	3.22 3.64
	0	4.0 4.2				**Silty CLAY** - grey / red, trace fine to medium gravel (siltstone, brown, moderately to highly weathered, sub angular). Becoming grey / orange, with fine to coarse gravel (siltstone, brown / red and grey, highly to slightly weathered, sub angular to angular fragments).				64	N/A				4.0 4.2	4.1
		4.4				**CORE LOSS**.								Heterogeneous clay matrix, randomly orientated and spaced gravel (laminite and siltstone, highly to slightly weathered, sub angular clasts). 4.39-5.20m moderate to strongly disturbed zone, mid level slide material.	4.4	4.55
	0	4.6 4.8				**Silty CLAY** - grey / orange, with fine to coarse gravel (siltstone, brown / red and grey, highly to slightly weathered, sub angular to angular fragments).				69	N/A				4.6 4.8	
		5.0				**CORE LOSS**.									5.0	5.2
	0	5.2 5.4 5.6				**Silty CLAY** - grey / orange, with fine to coarse gravel (siltstone, brown / red and grey, highly to slightly weathered, sub angular to angular fragments).				55	N/A			5.20-6.59m Material description as above, strongly disturbed zone, possible base of slide plane.	5.2 5.4 5.6	
		5.8 6.0				**CORE LOSS**.									5.8 6.0	6

Additional Comments

Logged By:	**MHK**	Date:	**12/03/2015**	Checked By:	**WND**	Date:	**30/03/2015**

Cored Borehole Log Report

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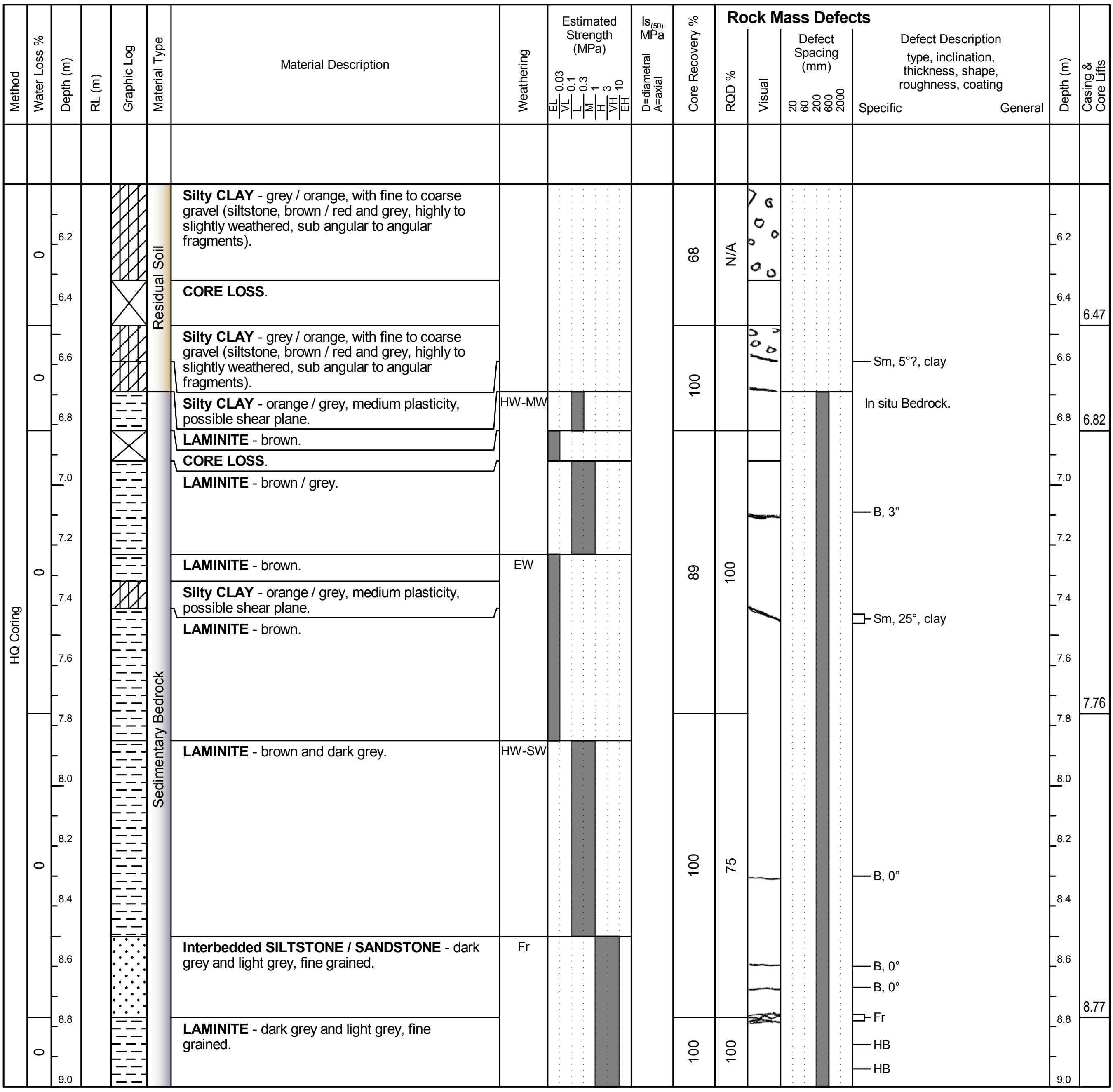
Hole ID. **BH8**
Hole Depth: **11.73 m**
Sheet: **4 of 5**

Project Name:	**Townhouse Development**	Project Number:	**15-004**
Location / Site:	**39-55 Oratava Avenue, West Pennant Hills**	Client:	**Kai Ling (Australia) Pty Ltd**

Drilling Company:	**Total Drilling**	Date Started:	**12/03/2015**	Ground Level:	----------
Drill Method:	**HQ Coring**	Date Completed:	**13/03/2015**	Easting:	----------
Equipment:	**Scout Truck Mounted Rig**			Northing:	----------



Material Type	Material Description	Weathering
Residual Soil	**Silty CLAY** - grey / orange, with fine to coarse gravel (siltstone, brown / red and grey, highly to slightly weathered, sub angular to angular fragments).	
	CORE LOSS.	
	Silty CLAY - grey / orange, with fine to coarse gravel (siltstone, brown / red and grey, highly to slightly weathered, sub angular to angular fragments).	
Sedimentary Bedrock	**Silty CLAY** - orange / grey, medium plasticity, possible shear plane.	HW-MW
	LAMINITE - brown.	
	CORE LOSS.	
	LAMINITE - brown / grey.	
	LAMINITE - brown.	EW
	Silty CLAY - orange / grey, medium plasticity, possible shear plane.	
	LAMINITE - brown.	
	LAMINITE - brown and dark grey.	HW-SW
	Interbedded SILTSTONE / SANDSTONE - dark grey and light grey, fine grained.	Fr
	LAMINITE - dark grey and light grey, fine grained.	

Water Loss %	Core Recovery %	RQD %	Casing & Core Lifts
0	68	N/A	6.47
0	100		6.82
0	89	100	7.76
0	100	75	8.77
0	100	100	

Defect Description:
- Sm, 5°?, clay
- In situ Bedrock.
- B, 3°
- Sm, 25°, clay
- B, 0°
- B, 0°
- B, 0°
- Fr
- HB
- HB

Additional Comments

Logged By:	**MHK**	Date:	**12/03/2015**	Checked By:	**WND**	Date:	**30/03/2015**

Cored Borehole Log Report

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Hole ID. **BH8**
Hole Depth: **11.73 m**
Sheet: **5 of 5**

Project Name:	**Townhouse Development**	Project Number:	**15-004**
Location / Site:	**39-55 Oratava Avenue, West Pennant Hills**	Client:	**Kai Ling (Australia) Pty Ltd**

Drilling Company:	**Total Drilling**	Date Started:	**12/03/2015**	Ground Level:	----------
Drill Method:	**HQ Coring**	Date Completed:	**13/03/2015**	Easting:	----------
Equipment:	**Scout Truck Mounted Rig**			Northing:	----------

Method	Water Loss %	Depth (m)	RL (m)	Graphic Log	Material Type	Material Description	Weathering	Estimated Strength (MPa) EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH	Is(50) MPa D=diametral A=axial	Core Recovery %	RQD %	Visual	Defect Spacing (mm) 20 60 200 600 2000	Defect Description (type, inclination, thickness, shape, roughness, coating) Specific / General	Depth (m)	Casing & Core Lifts
HQ Coring	0	9.2 9.4 9.6 9.8 10.0 10.2 10.4 10.6 10.8 11.0 11.2 11.4 11.6			Sedimentary Bedrock	**LAMINITE** - dark grey and light grey, fine grained.	Fr			100	100			HB HB HB HB B, 0° J, 70°, pl, r HB HB HB	9.2 9.4 9.6 9.8 10.0 10.2 10.4 10.6 10.8 11.0 11.2 11.4 11.6	11.73
		11.8 12.0				**End of Hole at 11.73 m**									11.8 12.0	

Additional Comments

Logged By:	**MHK**	Date:	**12/03/2015**	Checked By:	**WND**	Date:	**30/03/2015**

Cored Borehole Log Report

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Hole ID.	**BH9**
Hole Depth:	**11.43 m**
Sheet:	**1 of 5**

Project Name:	**Townhouse Development**	Project Number:	**15-004**
Location / Site:	**39-55 Oratava Avenue, West Pennant Hills**	Client:	**Kai Ling (Australia) Pty Ltd**

Drilling Company:	**Total Drilling**	Date Started:	**13/03/2015**	Ground Level:	----------
Drill Method:	**Solid Flight Auger**	Date Completed:	**13/03/2015**	Easting:	----------
Equipment:	**Scout Truck Mounted Rig**			Northing:	----------

Method	Water Loss %	Depth (m)	RL (m)	Graphic Log	USCS Symbol	Material Type	Material Description	Observations / Comments
Solid Flight Auger		1.0		☒		Fill	FILL- Silty Clay, trace fine to coarse gravel, bricks, concrete, glass, wire.	
				▨	CL	Residual Soil	**Silty CLAY**- red / brown, medium plasticity, trace fine gravel (siltstone and ironstone), trace charcoal.	
		2.0 3.0					*BH9 continued as cored hole from 1.6m*	

Moisture	
D	Dry
Dp	Damp
SM	Slightly Moist
M	Moist
VM	Very Moist
W	Wet
Sd	Saturated

Additional Comments

Logged By:	**MHK**	Date:	**13/03/2015**	Checked By:	**WND**	Date:	**30/03/2015**

Cored Borehole Log Report

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Hole ID.	**BH9**
Hole Depth:	**11.43 m**
Sheet:	**2 of 5**

Project Name:	**Townhouse Development**	Project Number:	**15-004**
Location / Site:	**39-55 Oratava Avenue, West Pennant Hills**	Client:	**Kai Ling (Australia) Pty Ltd**

Drilling Company:	**Total Drilling**	Date Started:	**13/03/2015**	Ground Level:	----------
Drill Method:	**HQ Coring**	Date Completed:	**13/03/2015**	Easting:	----------
Equipment:	**Scout Truck Mounted Rig**			Northing:	----------

Method	Water Loss %	Depth (m)	RL (m)	Graphic Log	Material Type	Material Description	Weathering	Estimated Strength (MPa) EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH	Is(50) MPa D=diametral A=axial	Core Recovery %	Rock Mass Defects: RQD %	Rock Mass Defects: Visual	Rock Mass Defects: Defect Spacing (mm) 20 60 200 600 2000	Rock Mass Defects: Defect Description type, inclination, thickness, shape, roughness, coating Specific General	Depth (m)	Casing & Core Lifts
		0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6				*Continued from non-cored borehole from 1.6m*									0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6	
HQ Coring		1.8			Residual Soil	**CORE LOSS**.				0	N/A			Heterogeneous clay matrix, trace randomly orientated and spaced gravel (laminite / siltstone, generally highly weathered, sub angular). 1.30-2.75m slightly disturbed zone, upper level slide material.	1.8	1.81
		2.0 2.2 2.4 2.6				**Silty CLAY** - red / brown, medium plasticity, trace fine gravel (siltstone and ironstone), trace charcoal.				100	N/A				2.0 2.2 2.4 2.6	
						Silty CLAY - red / brown, low to medium plasticity, with fine to coarse gravel (siltstone, brown / red / orange), sub angular.										2.75
		2.8 3.0				**CORE LOSS**.				0	N/A			Heterogeneous clay matrix, with gravel and gravelly clay randomly orientated and spaced gravel (laminite and siltstone, highly to slightly weathered, sub	2.8 3.0	

Additional Comments

Logged By:	**MHK**	Date:	**13/03/2015**	Checked By:	**WND**	Date:	**30/03/2015**

Cored Borehole Log Report

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Pennant Hills NSW 1715
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DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

Hole ID.	**BH9**
Hole Depth:	**11.43 m**
Sheet:	**3 of 5**

Project Name:	**Townhouse Development**	Project Number:	**15-004**
Location / Site:	**39-55 Oratava Avenue, West Pennant Hills**	Client:	**Kai Ling (Australia) Pty Ltd**

Drilling Company:	**Total Drilling**	Date Started:	**13/03/2015**	Ground Level:	----------
Drill Method:	**HQ Coring**	Date Completed:	**13/03/2015**	Easting:	----------
Equipment:	**Scout Truck Mounted Rig**			Northing:	----------

Method	Water Loss %	Material Type	Material Description	Weathering	Core Recovery %	RQD %	Defect Description	Casing & Core Lifts
HQ Coring		Residual Soil	**CORE LOSS.**		0	N/A	angular). 2.75-5.36m moderately to strongly disturbed zone, mid level slide material.	3.08
			Silty CLAY - red / brown, low to medium plasticity, with fine to coarse gravel (siltstone, brown / red / orange), sub angular.		64	N/A		
			CORE LOSS.					3.33
	0		**Gravelly CLAY** - red / brown, low plasticity, with fine to coarse gravel (siltstone, grey, brown, brown / red), sub angular.		100	N/A		3.75
					76	N/A		
			CORE LOSS.					4.29
	0		**Gravelly CLAY** - red / brown, low plasticity, with fine to coarse gravel (siltstone, grey, brown, brown / red), sub angular.		58	N/A		
			CORE LOSS.					4.64
	0		**Gravelly CLAY** - red / brown, low plasticity, with fine to coarse gravel (siltstone, grey, brown, brown / red), sub angular.		60	N/A		
			LAMINITE - grey, possible clast?, moderately weathered.					
			CORE LOSS.					
			Gravelly CLAY - red / brown, low plasticity, with fine to coarse gravel.				5.36-5.78m Material description as above, strongly disturbed zone, possible base of slide plane.	
			Gravelly CLAY - grey and orange, low plasticity, with fine to coarse gravel, iron stained, sub angular.					5.78
	0		**LAMINITE** - black / grey / brown.	HW-MW	77	100	In situ Bedrock.	
			CORE LOSS.					

Depth (m): 3.2, 3.4, 3.6, 3.8, 4.0, 4.2, 4.4, 4.6, 4.8, 5.0, 5.2, 5.4, 5.6, 5.8, 6.0

Estimated Strength (MPa): EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH
Is(50) MPa: D=diametral A=axial
Defect Spacing (mm): 20 60 200 600 2000

Additional Comments

Logged By:	**MHK**	Date:	**13/03/2015**	Checked By:	**WND**	Date:	**30/03/2015**

Cored Borehole Log Report

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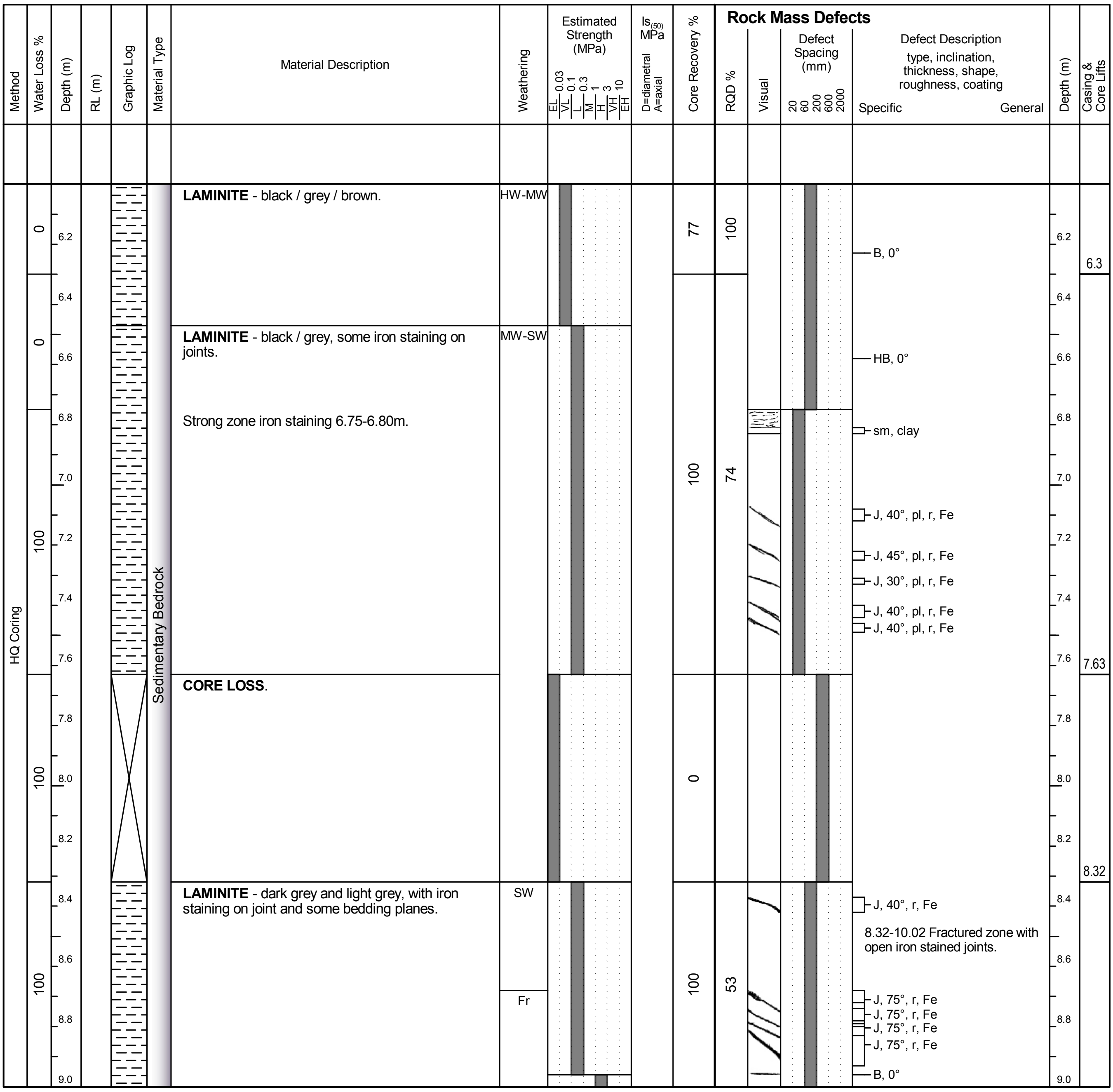
DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

Hole ID.	**BH9**
Hole Depth:	**11.43 m**
Sheet:	**4 of 5**

Project Name:	**Townhouse Development**	Project Number:	**15-004**
Location / Site:	**39-55 Oratava Avenue, West Pennant Hills**	Client:	**Kai Ling (Australia) Pty Ltd**

Drilling Company:	**Total Drilling**	Date Started:	**13/03/2015**	Ground Level:	----------
Drill Method:	**HQ Coring**	Date Completed:	**13/03/2015**	Easting:	----------
Equipment:	**Scout Truck Mounted Rig**			Northing:	----------



Method	Water Loss %	Material Type	Material Description	Weathering	Core Recovery %	RQD %	Defect Description (Specific / General)	Casing & Core Lifts
HQ Coring	0	Sedimentary Bedrock	**LAMINITE** - black / grey / brown.	HW-MW	77	100	B, 0°	6.3
	0		**LAMINITE** - black / grey, some iron staining on joints. Strong zone iron staining 6.75-6.80m.	MW-SW	100	74	HB, 0° sm, clay J, 40°, pl, r, Fe J, 45°, pl, r, Fe J, 30°, pl, r, Fe J, 40°, pl, r, Fe J, 40°, pl, r, Fe	
	100							7.63
	100		**CORE LOSS**.		0			8.32
	100		**LAMINITE** - dark grey and light grey, with iron staining on joint and some bedding planes.	SW Fr	100	53	J, 40°, r, Fe 8.32-10.02 Fractured zone with open iron stained joints. J, 75°, r, Fe J, 75°, r, Fe J, 75°, r, Fe J, 75°, r, Fe B, 0°	

Additional Comments

Logged By:	**MHK**	Date:	**13/03/2015**	Checked By:	**WND**	Date:	**30/03/2015**

Cored Borehole Log Report

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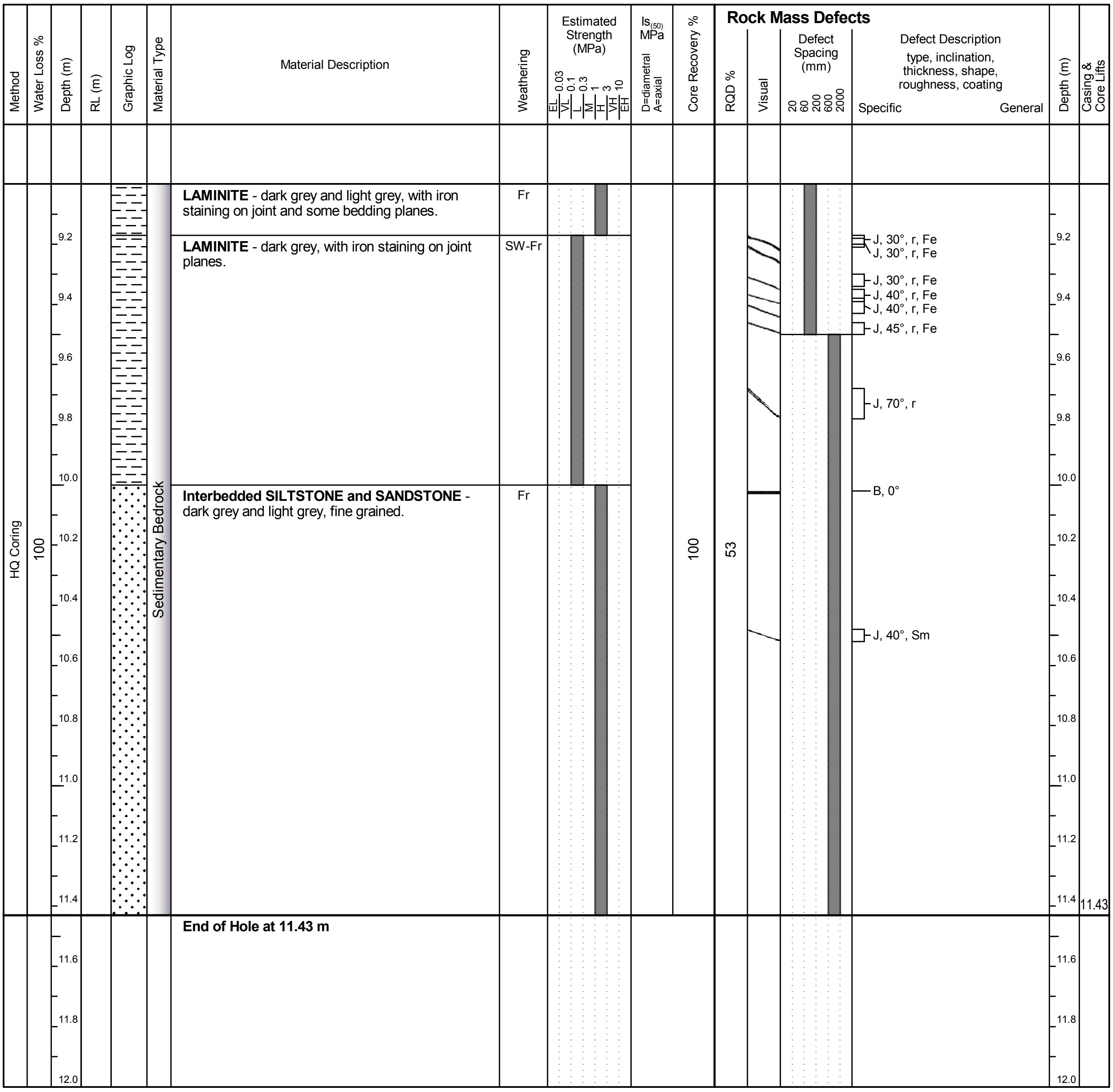
DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

Hole ID. **BH9**
Hole Depth: **11.43 m**
Sheet: **5 of 5**

Project Name:	**Townhouse Development**	Project Number:	**15-004**
Location / Site:	**39-55 Oratava Avenue, West Pennant Hills**	Client:	**Kai Ling (Australia) Pty Ltd**

Drilling Company:	**Total Drilling**	Date Started:	**13/03/2015**	Ground Level:	----------
Drill Method:	**HQ Coring**	Date Completed:	**13/03/2015**	Easting:	----------
Equipment:	**Scout Truck Mounted Rig**			Northing:	----------



Method	Water Loss %	Material Type	Core Recovery %	RQD %
HQ Coring	100	Sedimentary Bedrock	100	53

Material Description	Weathering
LAMINITE - dark grey and light grey, with iron staining on joint and some bedding planes.	Fr
LAMINITE - dark grey, with iron staining on joint planes.	SW-Fr
Interbedded SILTSTONE and SANDSTONE - dark grey and light grey, fine grained.	Fr

End of Hole at 11.43 m

Defect Description (Specific):
- J, 30°, r, Fe
- J, 30°, r, Fe
- J, 30°, r, Fe
- J, 40°, r, Fe
- J, 40°, r, Fe
- J, 45°, r, Fe
- J, 70°, r
- B, 0°
- J, 40°, Sm

Additional Comments

Logged By:	**MHK**	Date:	**13/03/2015**
Checked By:	**WND**	Date:	**30/03/2015**

Borehole Log Report

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DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

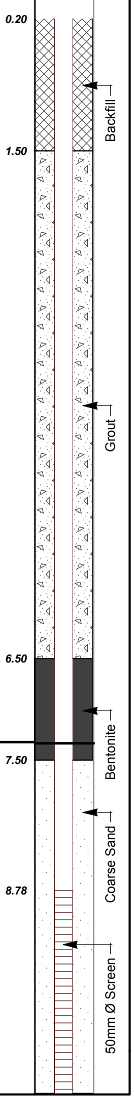
Hole ID.	**BH10**
Hole Depth:	**7.32 m**
Sheet:	**1 of 1**

Project Name:	**Kai Ling (Australia) Pty Ltd**	Project Number:	**15-004**
Location / Site:	**39 - 55 Oratava Avenue, West Pennant Hills**	Client:	**Kai Ling (Australia) Pty Ltd**

Drilling Company:	**Total Drilling**	Date Started:	**14/03/2015**	Ground Level:	----------
Drill Method:	**100mm Solid Flight Auger with TC bit**	Date Completed:	**14/03/2015**	Easting:	----------
Equipment:	**Scout - Truck mounted rig**			Northing:	----------

Method	Water Level	Depth (m)	RL (m)	Graphic Log	USCS Symbol	Material Type	Material Description	Consistency / Density	Moisture	Observations / Comments
							Surface: fill			
100mm Solid Flight Auger with TC bit						Fill	**FILL**- Silty Clay, medium gravel, glass.	soft		
							TOPSOIL- Silty Sand, with clay.			
		1.0			CL	Natural	**Silty CLAY**- red/brown, medium plasticity, trace fine gravel.	firm to stiff	moist	
		2.0					- becoming red/grey, trace fine to medium gravel (ironstone, siltstone fragments).			
		3.0					- becoming grey some red, low plasticity, trace fine gravel <1cm (siltstone, red/brown, highly weathered).	soft to firm	moist to very moist	
		4.0						firm to stiff	moist	
	4.8m				CL		- predominantly grey, low plasticity, trace fine gravel (siltstone).			
		5.0					- band, siltstone, dark grey.	soft to firm	wet	
					CL		- grey/red, low to medium plasticity, fine to medium gravel (siltstone, brown and grey, sub-angular).			
		6.0						stiff	moist to very moist	
					CL		**Silty CLAY**- as above.			
							- silty clay with fine medium gravel (siltstone).			
		7.0					**SILTSTONE**.	very stiff to hard		
							Refusal at 7.32m Practical auger refusal on weathered bedrock			
		8.0								
		9.0								
		10.0								

Well Details / Well Construction



Moisture	
D	Dry
Dp	Damp
SM	Slightly Moist
M	Moist
VM	Very Moist
W	Wet
Sd	Saturated

Additional Comments

Piezometer 50mm PVC installed to 10.78m
Screen with filter sock 8.78 -10.78m
Sand 7.50 - 10.78m
Bentonite 6.50 - 7.50m
Grout 1.50 - 6.50m
Concrete 0.20 - 1.50m

Logged By:	**Matthew Kilham**	Date:	**14/03/2015**	Checked By:	**Warwick Davies**	Date:	**28/03/2015**

Cored Borehole Log Report

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DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

Hole ID.	**BH10**
Hole Depth:	**10.98 m**
Sheet:	**1 of 2**

Project Name: **Townhouse Development**
Project Number: **15-004**
Location / Site: **39-55 Oratava Avenue, West Pennant Hills**
Client: **Kai Ling (Australia) Pty Ltd**

Drilling Company: **Total Drilling**
Date Started: **14/03/2015**
Ground Level: ----------
Drill Method: **HQ Coring**
Date Completed: **14/03/2015**
Easting: ----------
Equipment: **Scout Truck Mounted Rig**
Northing: ----------

Method	Water Loss %	Depth (m)	RL (m)	Graphic Log	Material Type	Material Description	Weathering	Estimated Strength (MPa) EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH	$Is_{(50)}$ MPa D=diametral A=axial	Core Recovery %	RQD %	Visual	Defect Spacing (mm) 20 60 200 600 2000	Defect Description type, inclination, thickness, shape, roughness, coating Specific General	Depth (m)	Casing & Core Lifts
		6.2 – 7.2				*Continued from non-cored borehole from 7.32m*										
HQ Coring		7.4			Sedimentary Bedrock	**SILTSTONE** - brown / grey.	HW			100					7.4	
		7.6				**CLAY** - grey and orange.	EW							clay	7.6	
		7.8 – 8.2				**SILTSTONE** - grey / brown.	HW-MW							J, 20°, pl, r J, 30°, pl, r B, 0° HB J, 20°, pl, r	7.8 – 8.2	
		8.2				**CLAY** - grey and orange.	EW							clay	8.2	
		8.4 – 9.0				**SILTSTONE** - grey / brown.	HW-MW							HB HB HB HB Sm, 0°, clay HB	8.4 – 9.0	

Additional Comments

Logged By: **MHK** Date: **14/03/2015** Checked By: **WND** Date: **30/03/2015**

Cored Borehole Log Report

Davies Geotechnical Pty Ltd
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DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

Hole ID.	**BH10**
Hole Depth:	**10.98 m**
Sheet:	**2 of 2**

Project Name:	**Townhouse Development**	Project Number:	**15-004**
Location / Site:	**39-55 Oratava Avenue, West Pennant Hills**	Client:	**Kai Ling (Australia) Pty Ltd**

Drilling Company:	**Total Drilling**	Date Started:	**14/03/2015**	Ground Level:	----------
Drill Method:	**HQ Coring**	Date Completed:	**14/03/2015**	Easting:	----------
Equipment:	**Scout Truck Mounted Rig**			Northing:	----------

Method	Material Type	Material Description	Weathering
HQ Coring	Sedimentary Bedrock	**SILTSTONE** - grey / brown.	HW-MW
		CLAY - grey and orange.	
		SILTSTONE - dark grey.	Fr
		SILTSTONE - dark grey / brown.	SW
		SILTSTONE - dark grey.	Fr
		End of Hole at 10.98 m	

Core Recovery %: 100; 100

Casing & Core Lifts: 9.54; 10.98

Depth (m): 9.2, 9.4, 9.6, 9.8, 10.0, 10.2, 10.4, 10.6, 10.8, 11.0, 11.2, 11.4, 11.6, 11.8, 12.0

Estimated Strength (MPa): EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH

Is(50) MPa: D=diametral A=axial

Rock Mass Defects

Defect Spacing (mm): 20 60 200 600 2000

Defect Description (type, inclination, thickness, shape, roughness, coating) – Specific / General:

- HB
- Sm, 0°, clay
- Sm, 0°, clay
- B, 0°
- B, 0°
- HB
- HB
- HB

Additional Comments

Logged By: **MHK**	Date: **14/03/2015**	Checked By: **WND**	Date: **30/03/2015**

Borehole Log Report

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DAVIES GEOTECHNICAL
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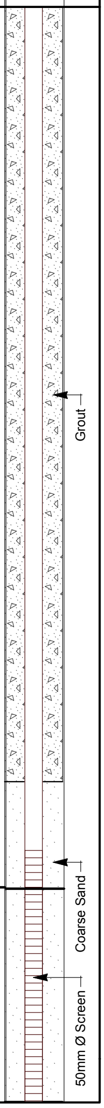
Hole ID. **BH11**
Hole Depth: **8.35 m**
Sheet: **1 of 1**

Project Name: **Kai Ling (Australia) Pty Ltd**
Project Number: **15-004**
Location / Site: **39 - 55 Oratava Avenue, West Pennant Hills**
Client: **Kai Ling (Australia) Pty Ltd**

Drilling Company: **Total Drilling**
Date Started: **14/03/2015**
Ground Level: ----------
Drill Method: **100mm Solid Flight Auger with TC bit**
Date Completed: **14/03/2015**
Easting: ----------
Equipment: **Scout - Truck mounted rig**
Northing: ----------

Method	Water Level	Depth (m)	RL (m)	Graphic Log	USCS Symbol	Material Type	Material Description	Consistency / Density	Moisture	Observations / Comments	Well Details	Well Construction
							Surface: topsoil					
100mm Solid Flight Auger with TC bit							**TOPSOIL**- Silty Clay, dark brown, roots.	soft				
					CL	Natural	**Silty CLAY**- red/brown, low to medium plasticity, trace fine gravel.					
		1.0					- becoming brown/red.	firm	moist			
							- becoming red mottled grey.					
		2.0					- predominantly grey, trace red/pink, trace fine gravel to 1cm.					
		3.0							moist to very moist			
							- grey, low to medium plasticity, trace fine to medium gravel (siltstone, brown, highly weathered).	firm to stiff				
	4.8m during drilling	4.0					- becoming grey/brown, with fine to medium gravel (shale/siltstone, brown/dark grey/brown/red, highly to moderately weathered).					
		5.0					- becoming grey some orange, trace fine gravel (siltstone).	soft to firm	wet			
		6.0				Bedrock	**LAMINITE**.	stiff to very stiff				
		7.0					6.80 - 7.50m: soft band.	soft to firm				
							- slow penetration, grinding.	stiff				
		8.0					- ground siltstone/shale - grey/dark grey-brown.	hard				
		9.0 10.0					**Refusal at 8.35m**					



Moisture	
D	Dry
Dp	Damp
SM	Slightly Moist
M	Moist
VM	Very Moist
W	Wet
Sd	Saturated

Additional Comments

Piezometer 50mm PVC installed to 10.38m
Screen with filter sock 8.00 - 10.38m
Sand 7.35 - 10.38m
Grout 0.00 - 7.35m

Logged By: **Matthew Kilham** Date: **14/03/2015**
Checked By: **Warwick Davies** Date: **28/03/2015**

Cored Borehole Log Report

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DAVIES GEOTECHNICAL
CONSULTING ENGINEERS

Hole ID. **BH11**
Hole Depth: **10.65 m**
Sheet: **1 of 2**

Project Name: **Townhouse Development**
Project Number: **15-004**
Location / Site: **39-55 Oratava Avenue, West Pennant Hills**
Client: **Kai Ling (Australia) Pty Ltd**

Drilling Company: **Total Drilling**
Date Started: **14/03/2015**
Ground Level: ----------
Drill Method: **HQ Coring**
Date Completed: **14/03/2015**
Easting: ----------
Equipment: **Scout Truck Mounted Rig**
Northing: ----------

Method	Water Loss %	Depth (m)	RL (m)	Graphic Log	Material Type	Material Description	Weathering	Estimated Strength (MPa) EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH	Is(50) MPa D=diametral A=axial	Core Recovery %	RQD %	Visual	Defect Spacing (mm) 20 60 200 600 2000	Defect Description type, inclination, thickness, shape, roughness, coating Specific / General	Depth (m)	Casing & Core Lifts
		6.2													6.2	
		6.4													6.4	
		6.6													6.6	
		6.8													6.8	
		7.0													7.0	
		7.2													7.2	
		7.4													7.4	
		7.6													7.6	
		7.8													7.8	
		8.0													8.0	
		8.2				*Continued from non-cored borehole from 8.35m*									8.2	
HQ Coring	0	8.4			Sedimentary Bedrock	**LAMINITE** - dark grey and light grey.	Fr			100	82			J, 10°, pl, r HB	8.4	
		8.6												J, 15°, pl, r B, 4° J, 15°, pl, r	8.6	
		8.8												HB	8.8	
		9.0												HB	9.0	

Additional Comments

Logged By: **MHK** Date: **14/03/2015** Checked By: **WND** Date: **30/03/2015**

Cored Borehole Log Report

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DAVIES GEOTECHNICAL
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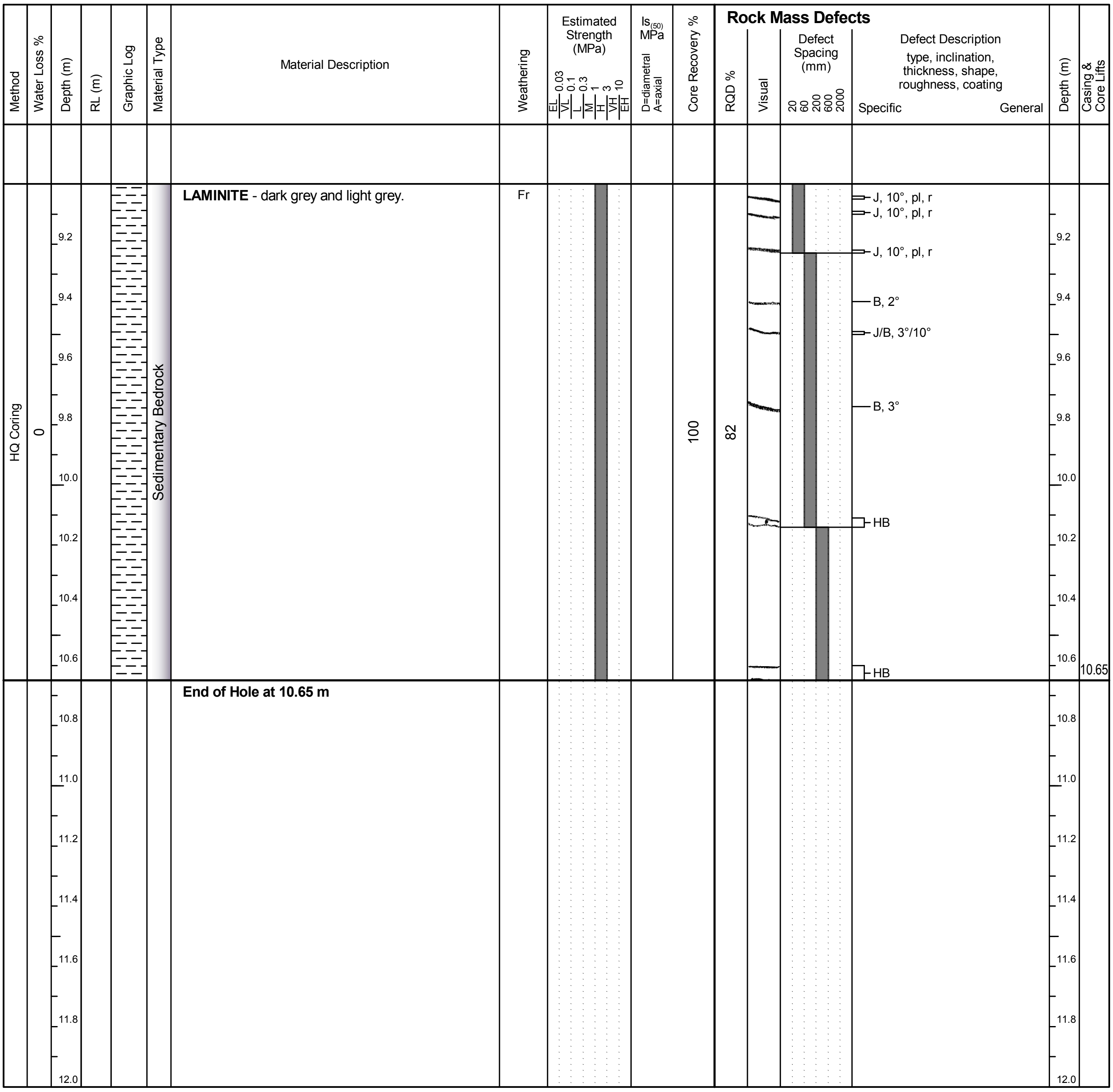
Hole ID. **BH11**
Hole Depth: **10.65 m**
Sheet: **2 of 2**

Project Name: **Townhouse Development**
Project Number: **15-004**
Location / Site: **39-55 Oratava Avenue, West Pennant Hills**
Client: **Kai Ling (Australia) Pty Ltd**

Drilling Company: **Total Drilling**
Date Started: **14/03/2015**
Ground Level: ----------
Drill Method: **HQ Coring**
Date Completed: **14/03/2015**
Easting: ----------
Equipment: **Scout Truck Mounted Rig**
Northing: ----------



Method	Water Loss %	Depth (m)	Material Type	Material Description	Weathering	Core Recovery %	RQD %	Defect Description (type, inclination, thickness, shape, roughness, coating) Specific	Casing & Core Lifts
HQ Coring	0	9.0–10.65	Sedimentary Bedrock	**LAMINITE** - dark grey and light grey.	Fr	100	82	J, 10°, pl, r J, 10°, pl, r J, 10°, pl, r B, 2° J/B, 3°/10° B, 3° HB HB	10.65
		10.65		**End of Hole at 10.65 m**					

Additional Comments

Logged By: **MHK** Date: **14/03/2015** Checked By: **WND** Date: **30/03/2015**

SOIL AND ROCK DESCRIPTION

TYPICAL REPRESENTATION AND TERMS USED FOR SOILS

		Group Symbol	Description
COARSE GRAINED SOILS (<50% passing 0.075mm sieve)	gravels	GW	Well graded gravels and gravel-sand mixtures, little or no fines.
		GP	Poorly graded gravels and gravel-sand mixtures-little or no fines, uniform gravels.
	gravelly soils	GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	sands	SW	Well graded sands and gravelly sands; little or no fines, uniform sands.
		SP	Poorly graded sands, gravelly sands, little or no fines, uniform gravels.
	sandy soils	SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.

		Group Symbol	Description
FINE GRAINED SOILS (>50% passing 0.075mm sieve)	LL<50%	ML	Inorganic silts and very fine sands, rock flour or clayey fire sands or clayey silts with slight plasticity.
		CL/CI	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		OL	Organic silts and organic silty clays of low plasticity.
	LL>50%	MH	Inorganic silts, micaeous or diatomaceous fine sandy or silty soils, organic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
		Pt	Peat and other highly organic soils.
			Fill.

CONSISTENCY - NON-COHESIVE SOILS

Field Test	Easily excavated with a spade	Some resistance to spade or penetration with hand bar	Considerable resistance to spade or penetration with hand bar	No penetration with a hand bar; requires pick for excavation	High resistance to a pick
SPT 'N' VALUE (blows/300mm)	0	4	10	30	50
Designation	Very Loose (VL)	Loose (L)	Medium dense (MD)	Dense (D)	Very Dense (VD)
Relative Density	0	15	35	65	85 100

CONSISTENCY - COHESIVE SOILS

Field Test	Exudes between the fingers when squeezed in hand	Can be moulded by light finger pressure	Can be moulded by strong finger pressure	Cannot be moulded by fingers. Can be indented by thumb	Can be indented by thumb nail	Can be indented with difficulty by thumb nail
Designation	Very Soft (VS)	Soft (S)	Firm (F)	Stiff (St)	Very Stiff (VSt)	Hard (H)
Undrained Shear Strength (C_u kPa)		12	25	50	100	200

GRAIN SIZE

Field Test	i Not visible with x10 lens ii Does not dilate on shaking iii Adheres to fingers when dry	i Particles >10 µm visible with x 10 lens ii Dilates on shaking iii Does not adhere to fingers when dry iv Feels gritty on teeth	i Particles >75 µm visible to naked eye ii Fine grained sand feels gritty in the fingers			Visual Identification				
Designation	CLAY	SILT	SAND			GRAVEL			COBBLES	BOULDERS
			Fine (f)	Medium (m)	Coarse (c)	Fine (f)	Medium (m)	Coarse (c)		
Grain Size		2	75	200	600	2.36	6	20	63	200
	Microns					Millimetres				

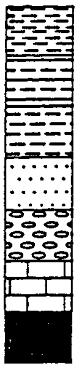
MOISTURE CONDITION

Dry (D)	Cohesive soils; hard and friable or, well dry of plastic limit. Granular soils; cohesion less and full running.
Moist (M)	Soil feels cool, darkened in colour; cohesive soils can be moulded. Granular soils tend to cohere.
Wet (W)	As above. Cohesive soils, free water collects on hands when handling.

SOIL AND ROCK DESCRIPTION

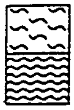
TYPICAL REPRESENTATION AND TERMS USED FOR ROCK

SEDIMENTARY



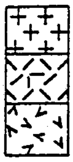
Mudstone
Shale
Siltstone
Sandstone
Conglomerate
Limestone
Coal

METAMORPHIC



Low grade: slate, schist etc.
High grade: quartzite, gneiss, marble etc.

IGNEOUS



Plutonic (generally coarse grained): granite gabbro etc.
Hypabyssal (generally medium grained): micro granite, dolerite etc.
Volcanic (generally fine grained): rhyolite andesite, basalt, pyroclastic etc.

STRENGTH

Field Test	Easily remoulded by hand to a material with soil properties	Material crumbles under firm blows with sharp end of pick; can be peeled with knife. Pieces up to 3cm thick can be broken by finger pressure.	Easily scored with knife; 1mm to 3mm indentations with pick point; dull sound under hammer.	Readily scored with knife; core 50mm dia broken by hand with difficulty.	Core 50mm dia not broken by hand but by pick with single firm blow; rock rings under hammer.	Break with pick after more than one blow; rock rings under hammer.	Requires many blows with geological pick to break; rock rings under hammer.
Point Load Strength Index Is (50) MPa		0.03	0.1	0.3	1	3	10
Designation	Extremely Low (EL)	Very Low (VL)	Low (L)	Medium (M)	High (H)	Very High (VH)	Extremely High (EH)
Unconfined Compressive Strength (Q_u MPa)		0.7	2.4	7.2	24	72	240

GRAIN SIZE

Equivalent Soil Size	Clay	Silt	Sand	Gravel	Cobbles-Boulders
Sedimentary	Argillaceous		Arenaceous fine | medium | coarse	Rudaceous	
Metamorphic/ Igneous	Fine		Medium	Coarse	
Grain Size		2	60 200 600	2	60
	Microns			Millimetres	

WEATHERING

Residual Soils (RS)	Extremely weathered rock (XW)	Distinctly weathered rock (DW)	Slightly weathered rock (SW)	Fresh rock (FR)
Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.	Rock is weathered to such an extent that it has 'soil' properties, i.e. it either disintegrates or can be remoulded, in water.	Rock strength usually changed by weathering. The rock may be highly discoloured, usually be ironstaining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.	Rock is slightly discoloured but shows little or no change of strength from fresh rock.	Rock shows no sign of decomposition or staining.

APPENDIX C

Groundwater Monitoring Data

SUMMARY OF PIEZOMETER INSTALLATIONS AND MONITORING
ORATAVA AVE WEST PENNANT HILLS (PAPALUCA)
2001 - 2002

piezometer no.	RL top of casing	RL ground surface	borehole depth (m)	screen interval (m)	depth to water at dates shown 18/04/2001	29/04/2001	1/06/2001	7/02/2002	8/02/2002	4/12/2002	5/12/2002
BH1	153.55	153.49	6.00	1.10 - 5.78	2.70	2.65	1.75	1.09	1.23	3.51	3.27*
BH2	151.55	151.48	9.00	0.4 - 5.95	1.80	1.40	0.90	0.6	0.77	2.25	2.1*
BH3	149.82	149.82	9.05	1.5 - 9.05	2.25	2.20	1.80	1.55	1.47	3.73	3.52*
BH4	149.61	149.55	7.50	1.5 - 6.0	3.10	at surface	at surface	0.05	0.55*	1.43	1.35*
BH5	147.06	147.02	6.00	0.85 - 6.0	0.25	0.60	at surface	0.15	0.18*	1.28	1.29*
BH6	144.30	144.30	6.00	1.0 - 5.85	2.30	at surface	sl.artesian pressure/overflow at surface	at surface	not measured	not measured	not measured
										↑	
										4/12/02 check Sydney temperatures, bush fires prevalent in NW on this date	

Notes

1. all depths are below ground level
2. depths in brackets are to base of piezometer
3. RL's determied by Craig & Rhodes survey 1/6/01 (ref. No.1675)
4. 1.29* recovery following bailing down and recharge
5. Values highlighted uncertain whether measured from surface level or top of PVC casing

SUMMARY OF PIEZOMETER INSTALLATIONS AND MONITORING
ORATAVA AVE WEST PENNANT HILLS (PAPALUCA)
2015

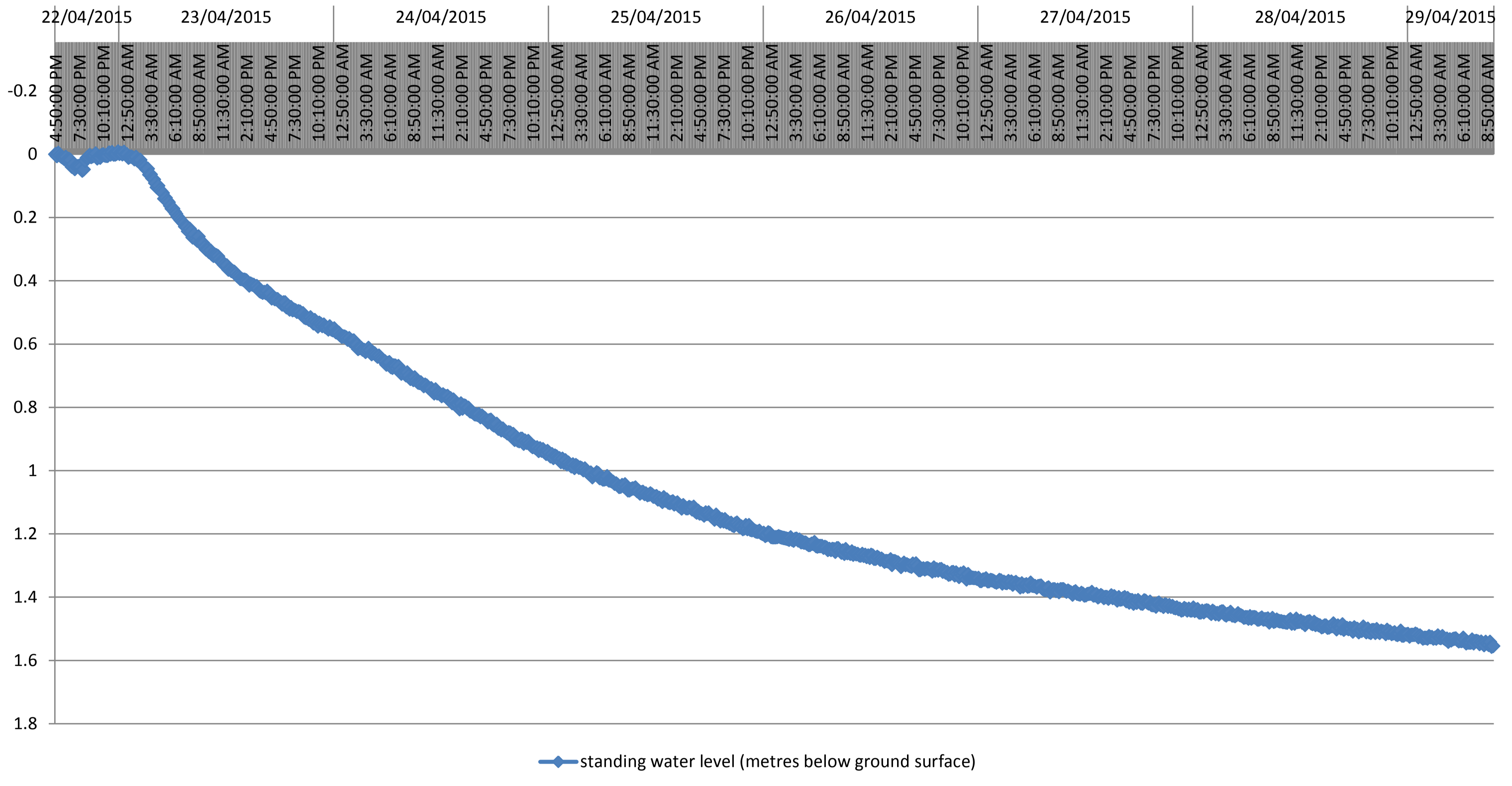
			borehole		depth to water at dates shown			
piezometer no.	RL	RL	depth (m)	screen interval (m)				
	top of casing	ground surface			10/03/2015	12/03/2015	13/03/2015	13/03/2015
BH1	153.55	153.49	6.00	1.10 - 5.78	2.93	2.96		
BH2	151.55	151.48	9.00	0.4 - 5.95	1.63	1.68		1.70 prior to rising head test
BH3	149.82	149.82	9.05	1.5 - 9.05	not found	not found	2.27	
BH4	149.61	149.55	7.50	1.5 - 6.0	1.07	1.20		
BH5	147.06	147.02	6.00	0.85 - 6.0	0.30	0.29		
BH6	144.30	144.30	6.00	1.0 - 5.85	0.24	0.29		
BH10								
BH11								

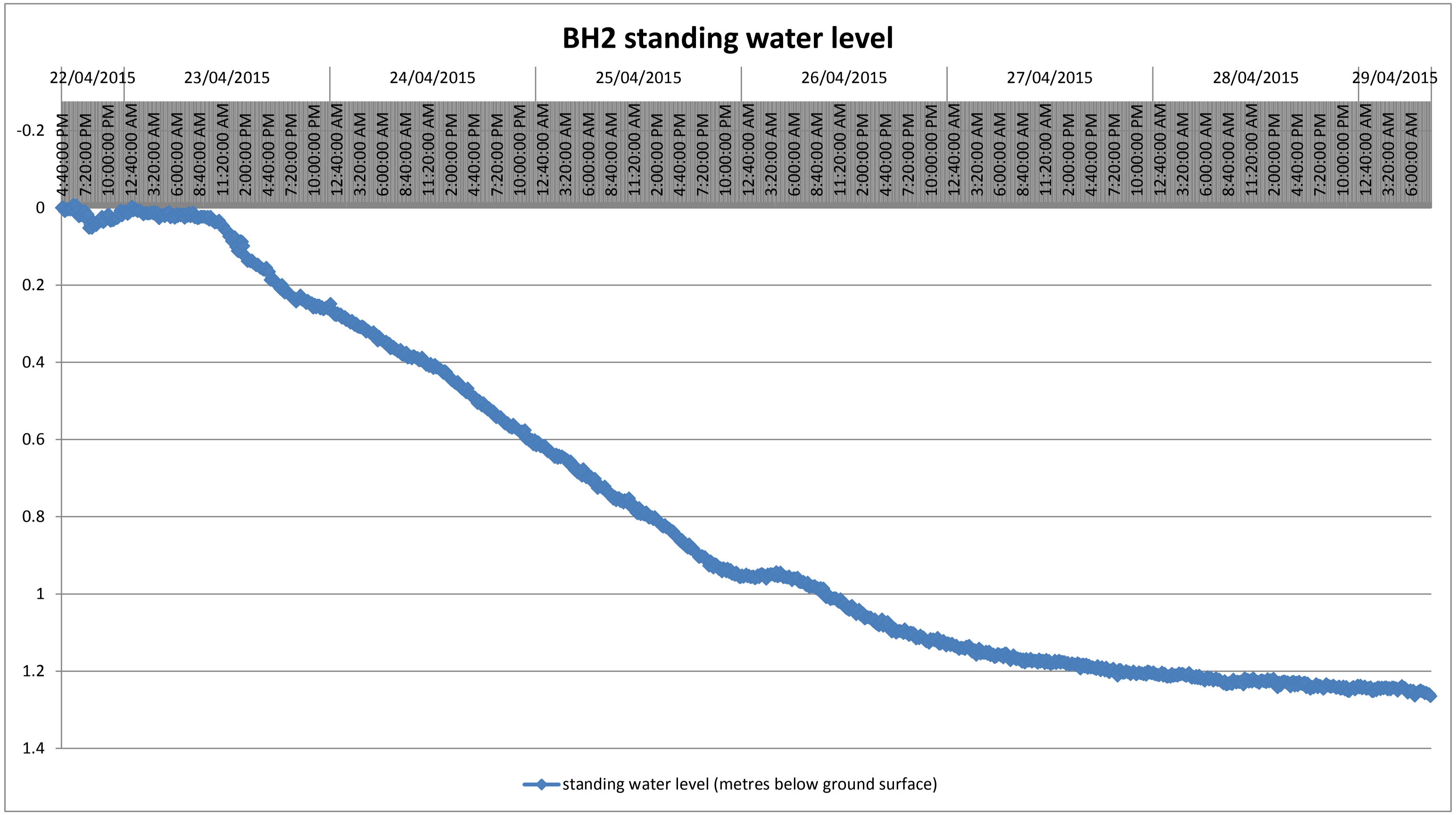
Notes

1. all depths are below ground level
2. depths in brackets are to base of piezometer
3. RL's determined by Craig & Rhodes survey 1/6/01 (ref. No.1675)
4. 1.29* recovery following bailing down and recharge
5. See data below for rising head tests

18/03/2015	19/03/2015	Surface levels re-surveyed 1/4/15 after installation of road covers	1/04/2015	8/04/2015	22/04/2015	29/04/2015 depths are prior to rising head tests (all BH's)	30/04/2015	6/05/2015	19/05/2015
		153.40	2.60	1.90	at surface	1.56	1.65*	1.38	2.15
1.76*		151.48	1.79	1.29	at surface	1.29	1.23*	1.13	1.33
		149.77	2.08	1.68	at surface	1.50	1.38*	1.19	1.76
		149.58	1.34	0.86	0.06	0.03	0.15*	at surface, slight flow	0.38
		146.98	0.15	0.25	at surface	at surface	sl.artesian pressure/overflow at surface	0.01	sl.artesian pressure/overflow at surface
		144.32	0.16	0.13	0.06	0.10	0.14*	0.12	0.1
2.31 prior to rising head test		148.87	2.46	2.25	2.00	1.87	1.93*	1.84	1.97
2.83 prior to rising head test	0.1* anomoly or incorrect reading?	144.39	2.85	2.90	2.93	2.97	4.15*	3.28*	3.28
				Data loggers installed 22/4/15 in BH1, BH2, BH5		Rising head tests in all BH's (see other spreadsheet)			Data loggers retrieved from BH1, BH2, BH5. Data from download and confirmed manually

BH1 standing water level




BH2 standing water level
22/04/2015
23/04/2015
24/04/2015
25/04/2015
26/04/2015
27/04/2015
28/04/2015
29/04/2015
4:40:00 PM
7:20:00 PM
10:00:00 PM
12:40:00 AM
3:20:00 AM
6:00:00 AM
8:40:00 AM
11:20:00 AM
2:00:00 PM
4:40:00 PM
7:20:00 PM
10:00:00 PM
12:40:00 AM
3:20:00 AM
6:00:00 AM
8:40:00 AM
11:20:00 AM
2:00:00 PM
4:40:00 PM
7:20:00 PM
10:00:00 PM
12:40:00 AM
3:20:00 AM
6:00:00 AM
8:40:00 AM
11:20:00 AM
2:00:00 PM
4:40:00 PM
7:20:00 PM
10:00:00 PM
12:40:00 AM
3:20:00 AM
6:00:00 AM
8:40:00 AM
11:20:00 AM
2:00:00 PM
4:40:00 PM
7:20:00 PM
10:00:00 PM
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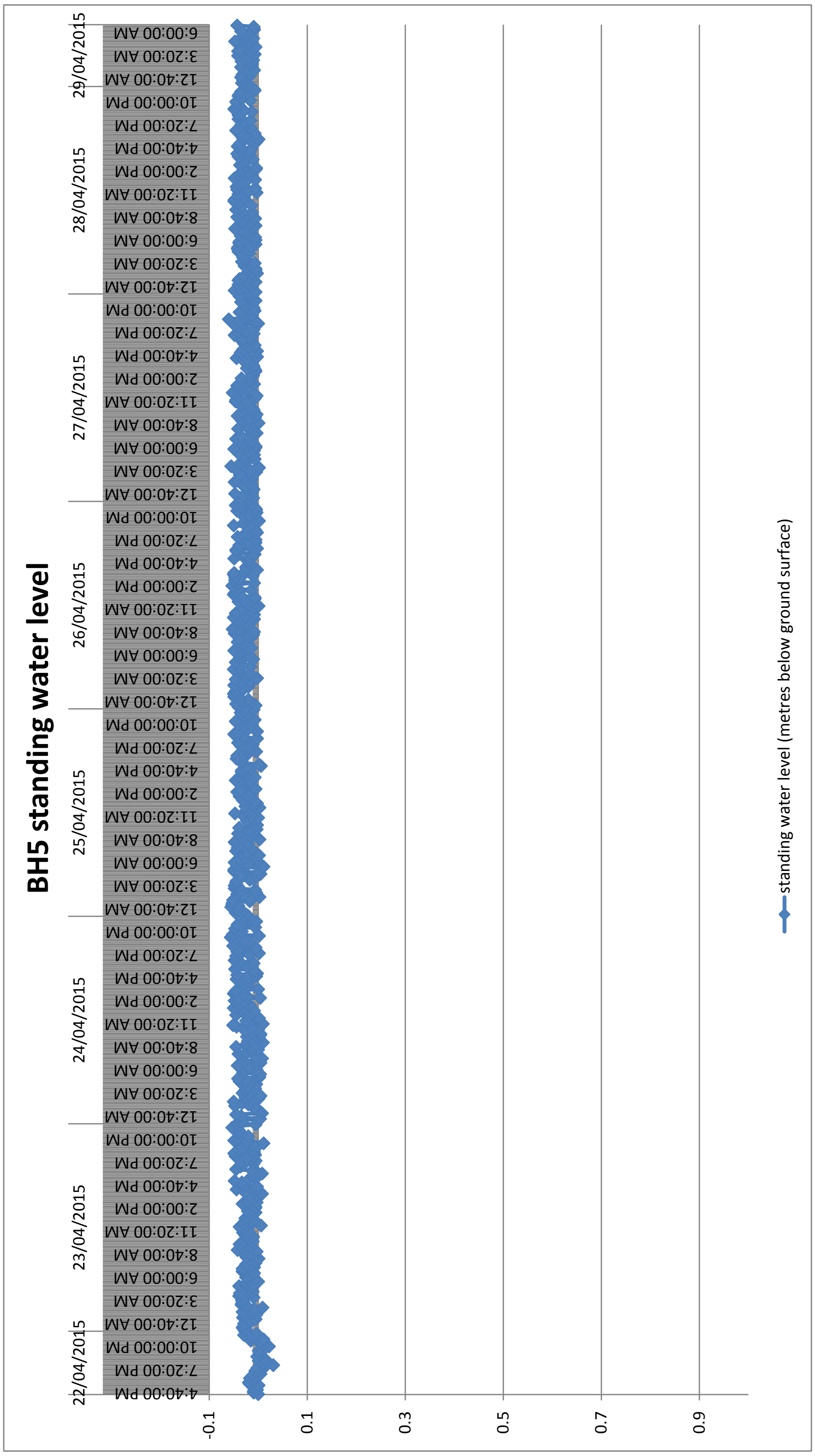
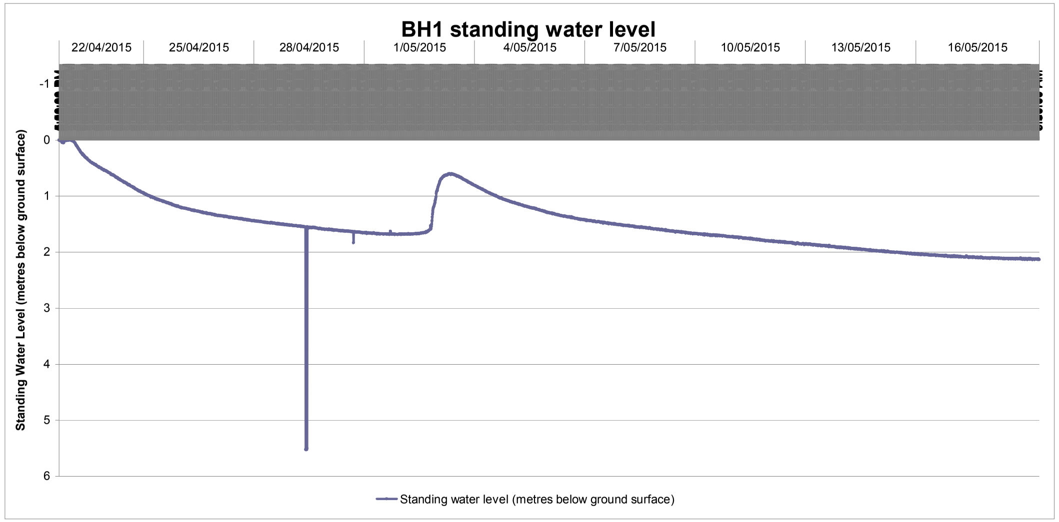
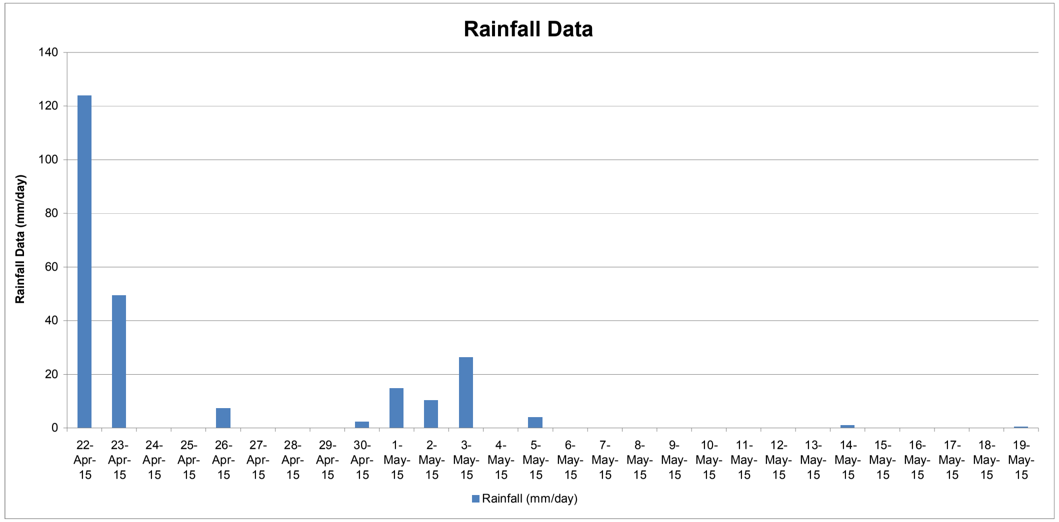
6:00:00 AM
8:40:00 AM
11:20:00 AM
2:00:00 PM
4:40:00 PM
7:20:00 PM
10:00:00 PM
12:40:00 AM
3:20:00 AM
6:00:00 AM
8:40:00 AM
11:20:00 AM
2:00:00 PM
4:40:00 PM
7:20:00 PM
10:00:00 PM
12:40:00 AM
3:20:00 AM
6:00:00 AM
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
standing water level (metres below ground surface)



BH5 standing water level


BH1 standing water level
22/04/2015
25/04/2015
28/04/2015
1/05/2015
4/05/2015
7/05/2015
10/05/2015
13/05/2015
16/05/2015
Standing Water Level (metres below ground surface)
-1
0
1
2
3
4
5
6
Standing water level (metres below ground surface)


Rainfall Data
Rainfall Data (mm/day)
140
120
100
80
60
40
20
0
22-Apr-15
23-Apr-15
24-Apr-15
25-Apr-15
26-Apr-15
27-Apr-15
28-Apr-15
29-Apr-15
30-Apr-15
1-May-15
2-May-15
3-May-15
4-May-15
5-May-15
6-May-15
7-May-15
8-May-15
9-May-15
10-May-15
11-May-15
12-May-15
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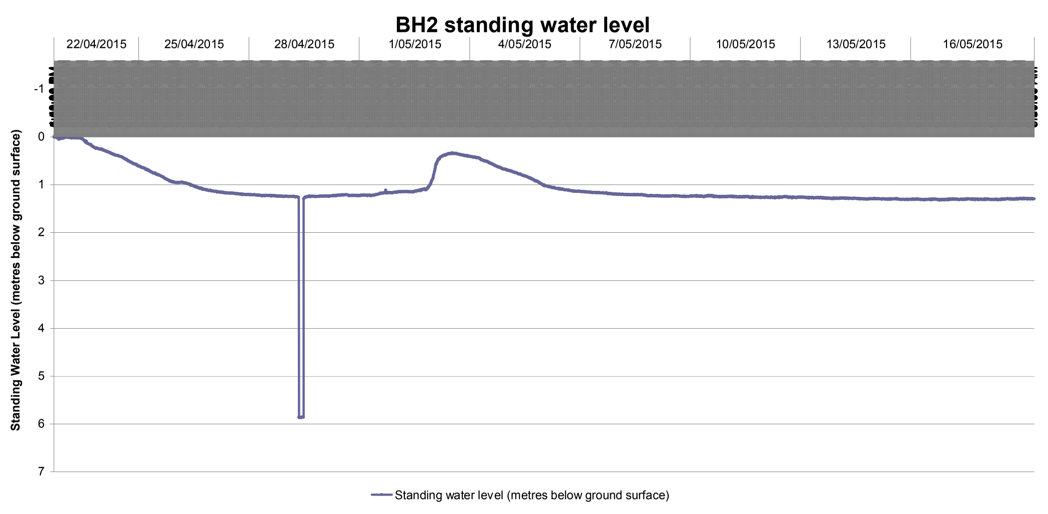
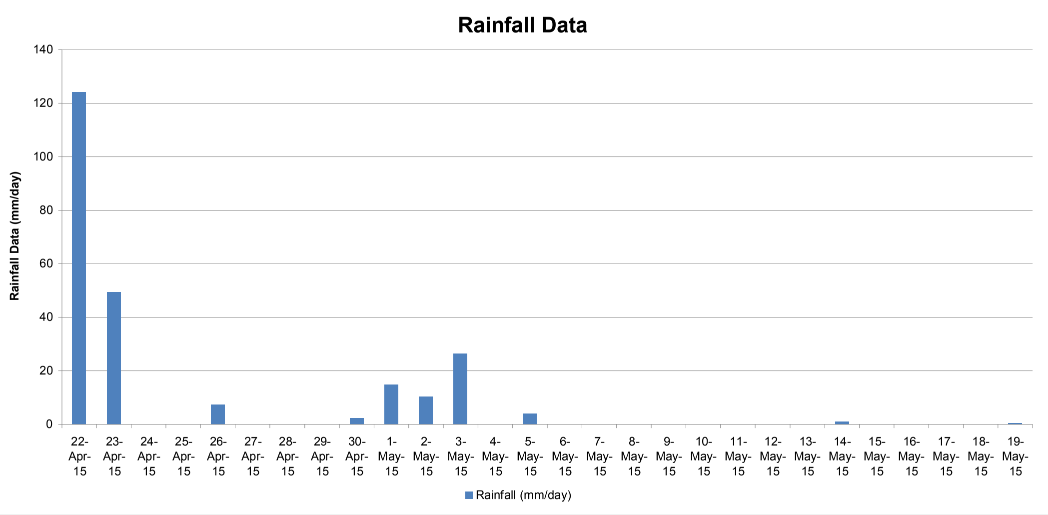
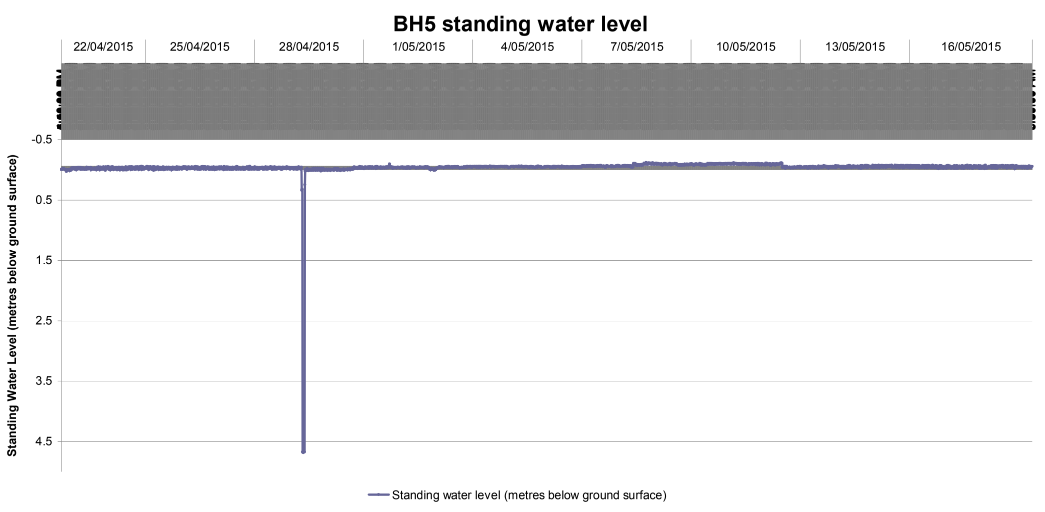
16-May-15
17-May-15
18-May-15
19-May-15
Rainfall (mm/day)

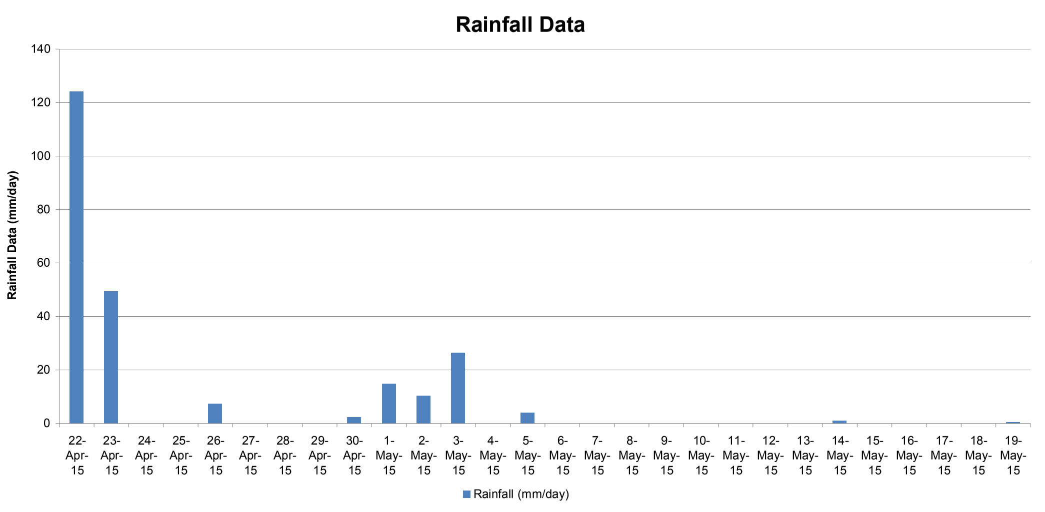


BH2 standing water level



Rainfall Data

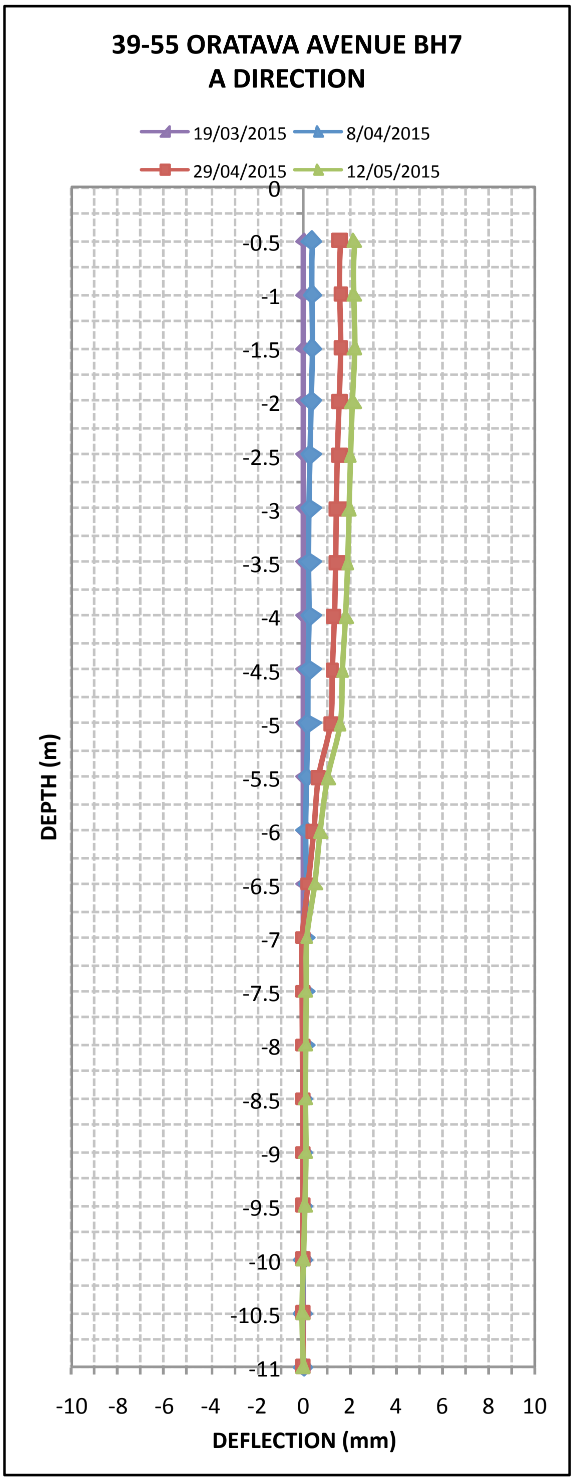

BH5 standing water level
22/04/2015
25/04/2015
28/04/2015
1/05/2015
4/05/2015
7/05/2015
10/05/2015
13/05/2015
16/05/2015
Standing Water Level (metres below ground surface)
-0.5
0.5
1.5
2.5
3.5
4.5
Standing water level (metres below ground surface)

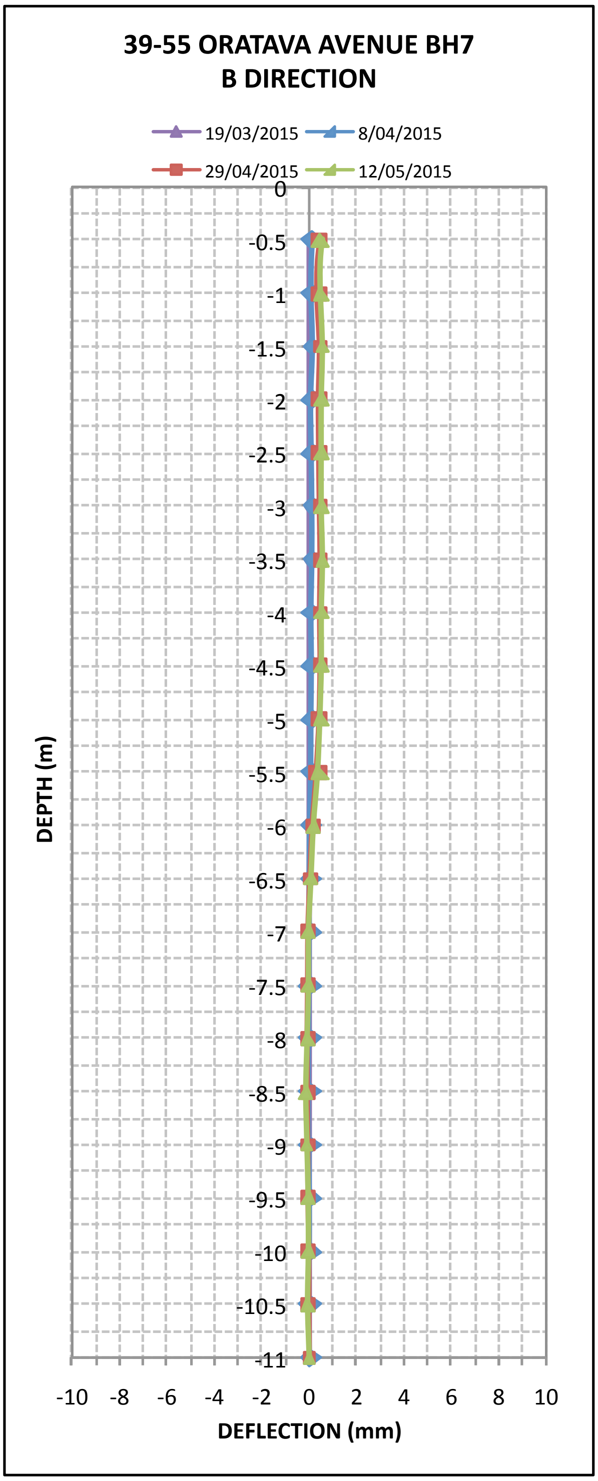

Rainfall Data
Rainfall Data (mm/day)
140
120
100
80
60
40
20
0
22-Apr-15
23-Apr-15
24-Apr-15
25-Apr-15
26-Apr-15
27-Apr-15
28-Apr-15
29-Apr-15
30-Apr-15
1-May-15
2-May-15
3-May-15
4-May-15
5-May-15
6-May-15
7-May-15
8-May-15
9-May-15
10-May-15
11-May-15
12-May-15
13-May-15
14-May-15
15-May-15
16-May-15
17-May-15
18-May-15
19-May-15
Rainfall (mm/day)

`

APPENDIX D

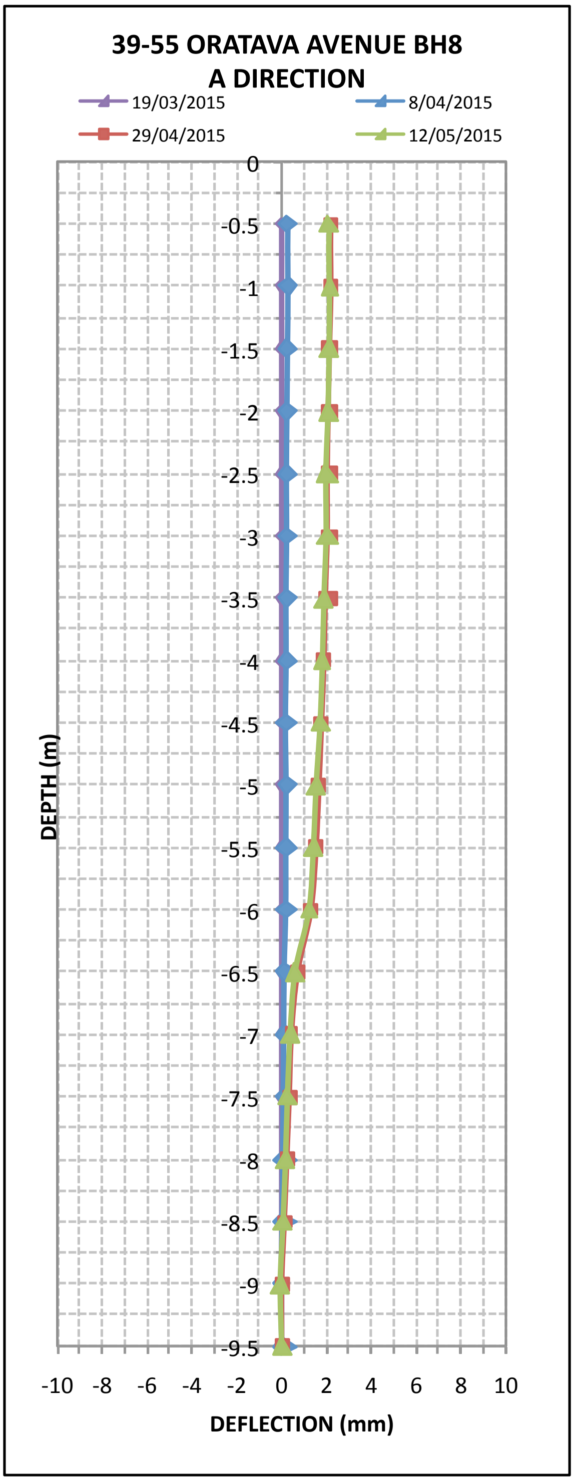
Inclinometer Monitoring Data

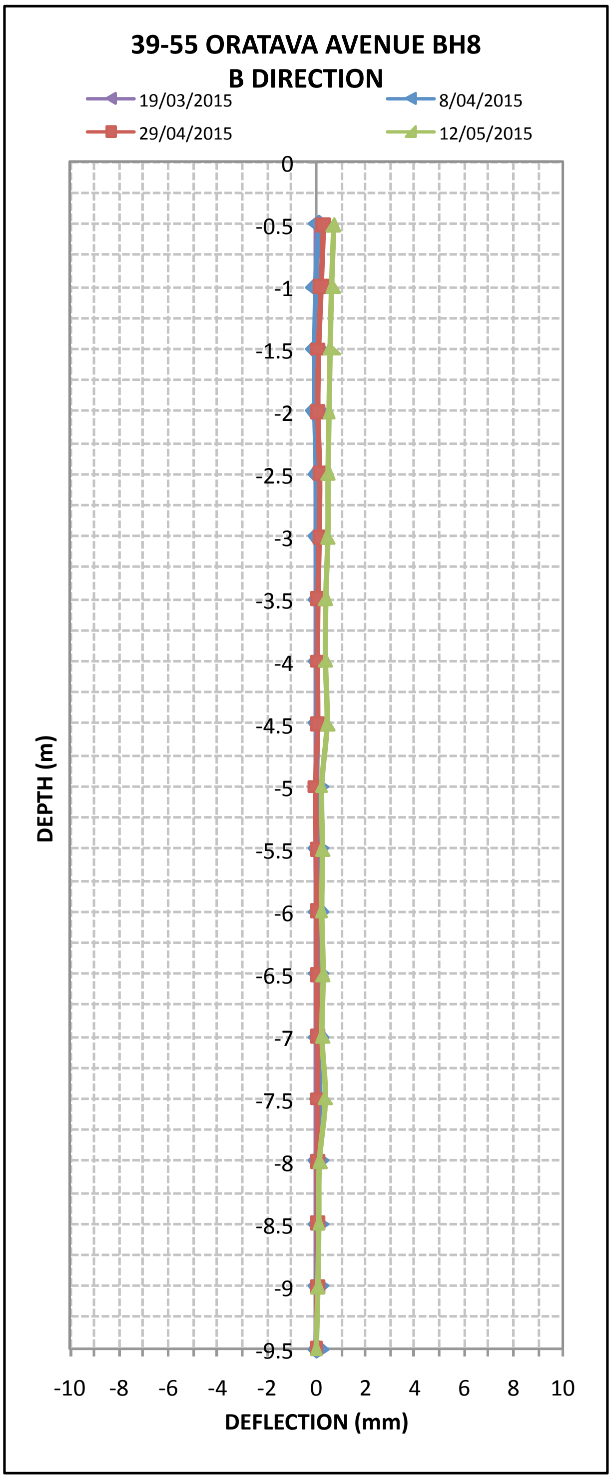




HMA Geotechnical Systems Australia

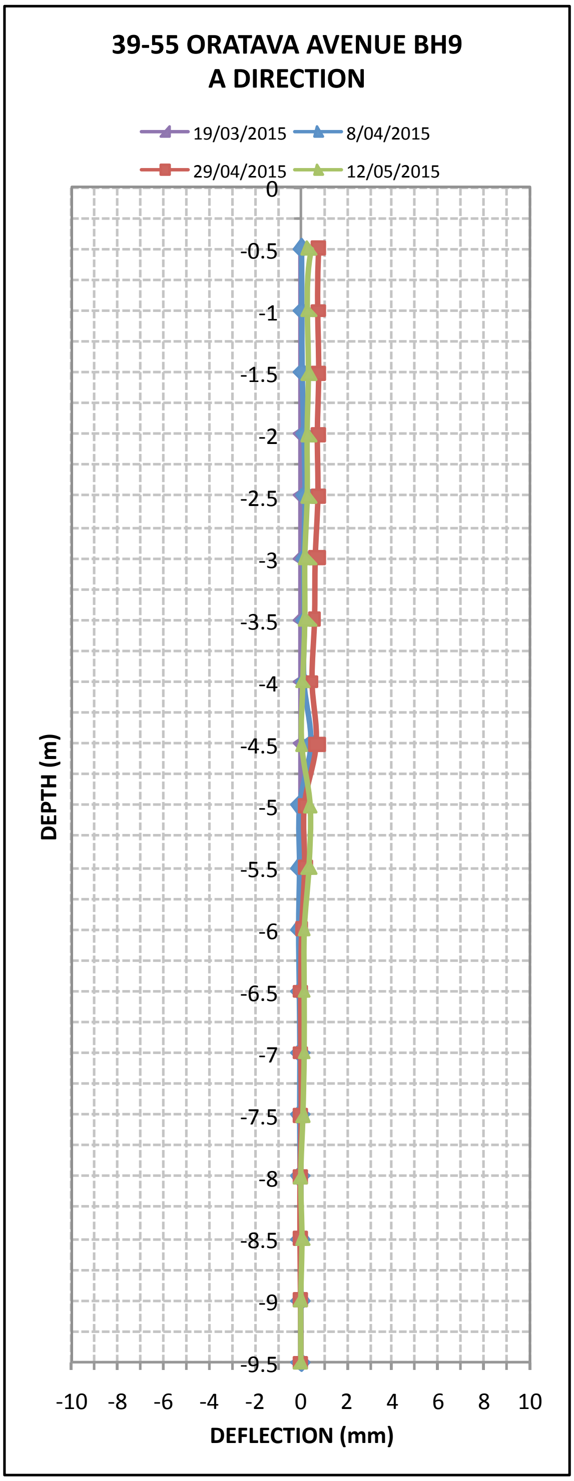
BH ID: BH7	INSTRUMENT: INCLINOMETER
JOB: HMA - 32071 39-55 ORATAVA AVE WEST PENNANT HILLS	
CLIENT: KAI LING (AUSTRALIA PTY LTD)	
DRAWN BY: NW	DATE: 12/05/2015 FIGURE: A - 1

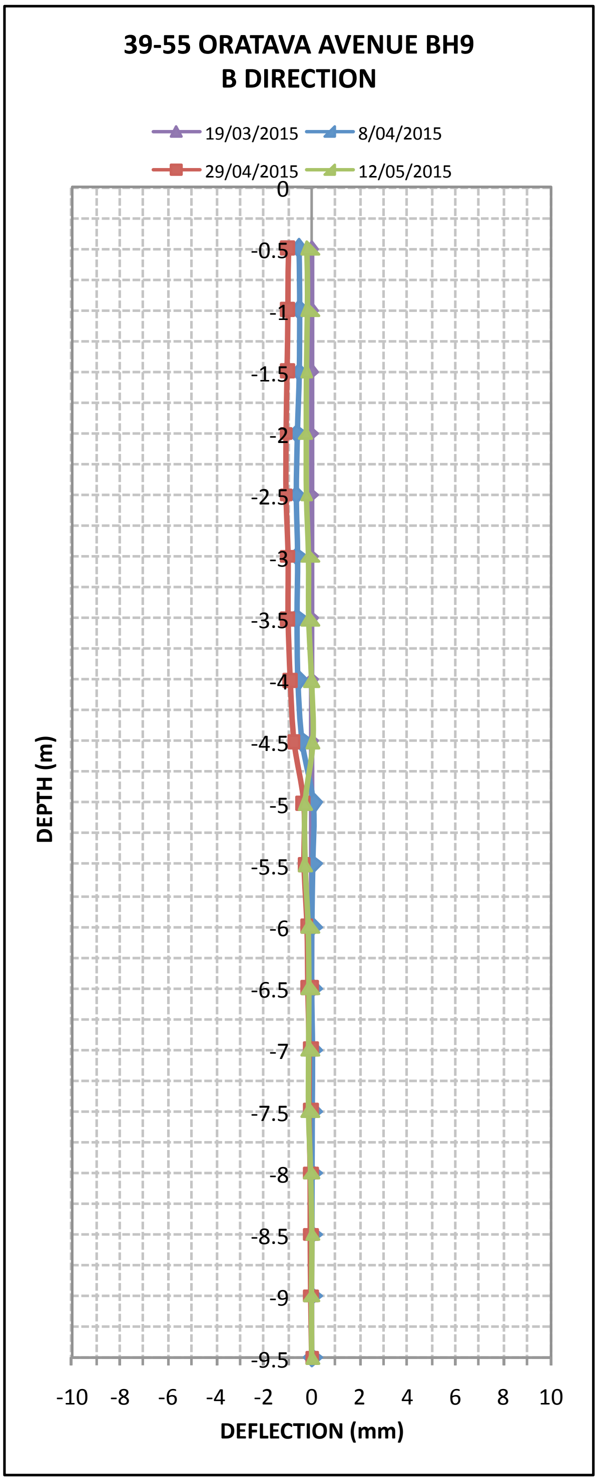




HMA Geotechnical Systems Australia

BH ID: BH8	INSTRUMENT: INCLINOMETER
JOB: HMA - 32071 39-55 ORATAVA AVE WEST PENNANT HILLS	
CLIENT: KAI LING (AUSTRALIA PTY LTD)	
DRAWN BY: NW	DATE: 12/05/2015
FIGURE: A - 2	





HMA Geotechnical Systems Australia

BH ID: BH9	INSTRUMENT: INCLINOMETER
JOB: HMA - 32071 39-55 ORATAVA AVE WEST PENNANT HILLS	
CLIENT: KAI LING (AUSTRALIA PTY LTD)	
DRAWN BY: NW	DATE: 12/05/2015 FIGURE: A - 3

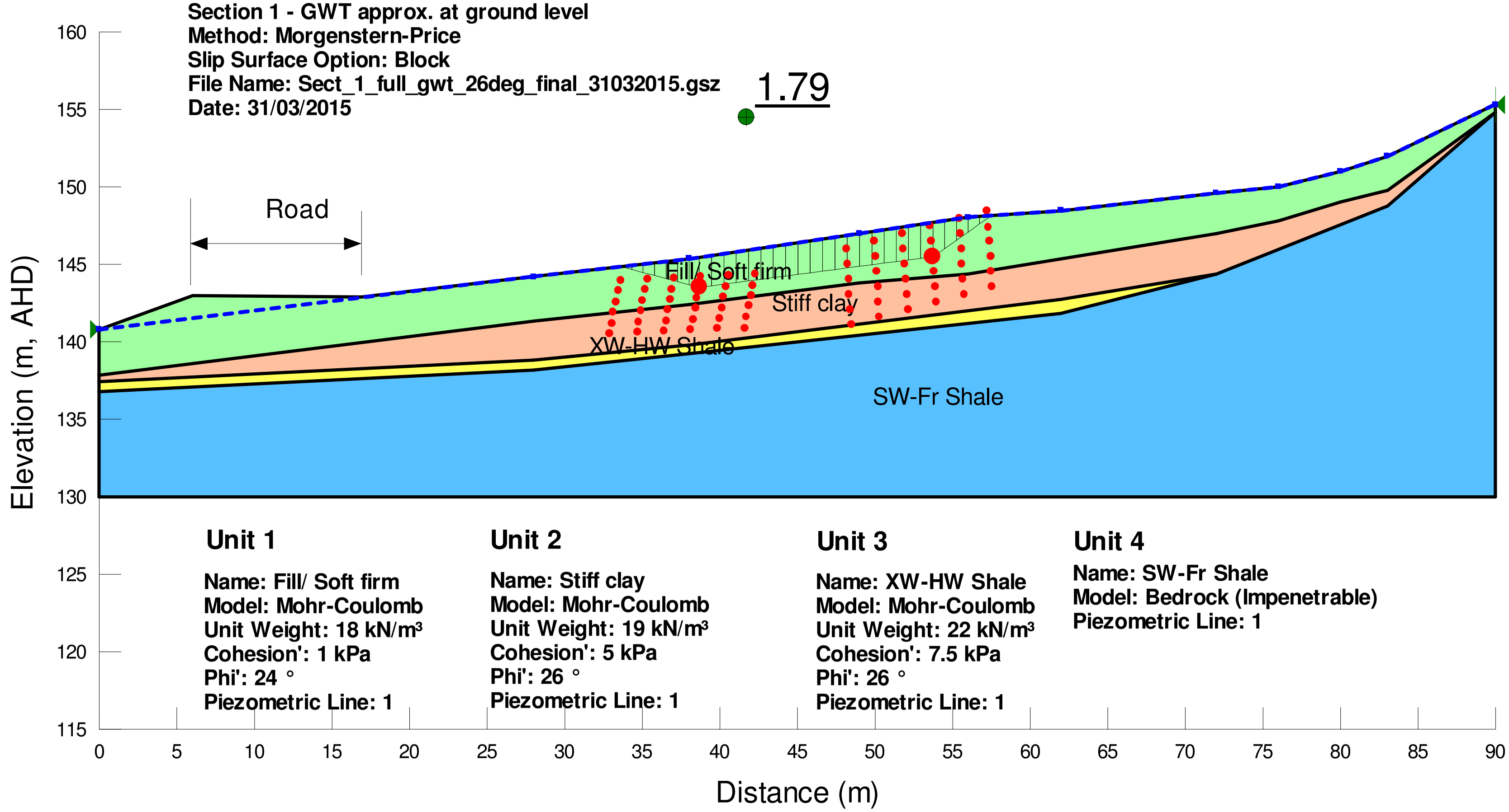
`

APPENDIX E

Slope/W Analyses
(Hyder Consulting)

55 Oratava Avenue West Pennant Hills

Section 1 - GWT approx. at ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_1_full_gwt_26deg_final_31032015.gsz
Date: 31/03/2015



Unit 1

Name: Fill/ Soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2

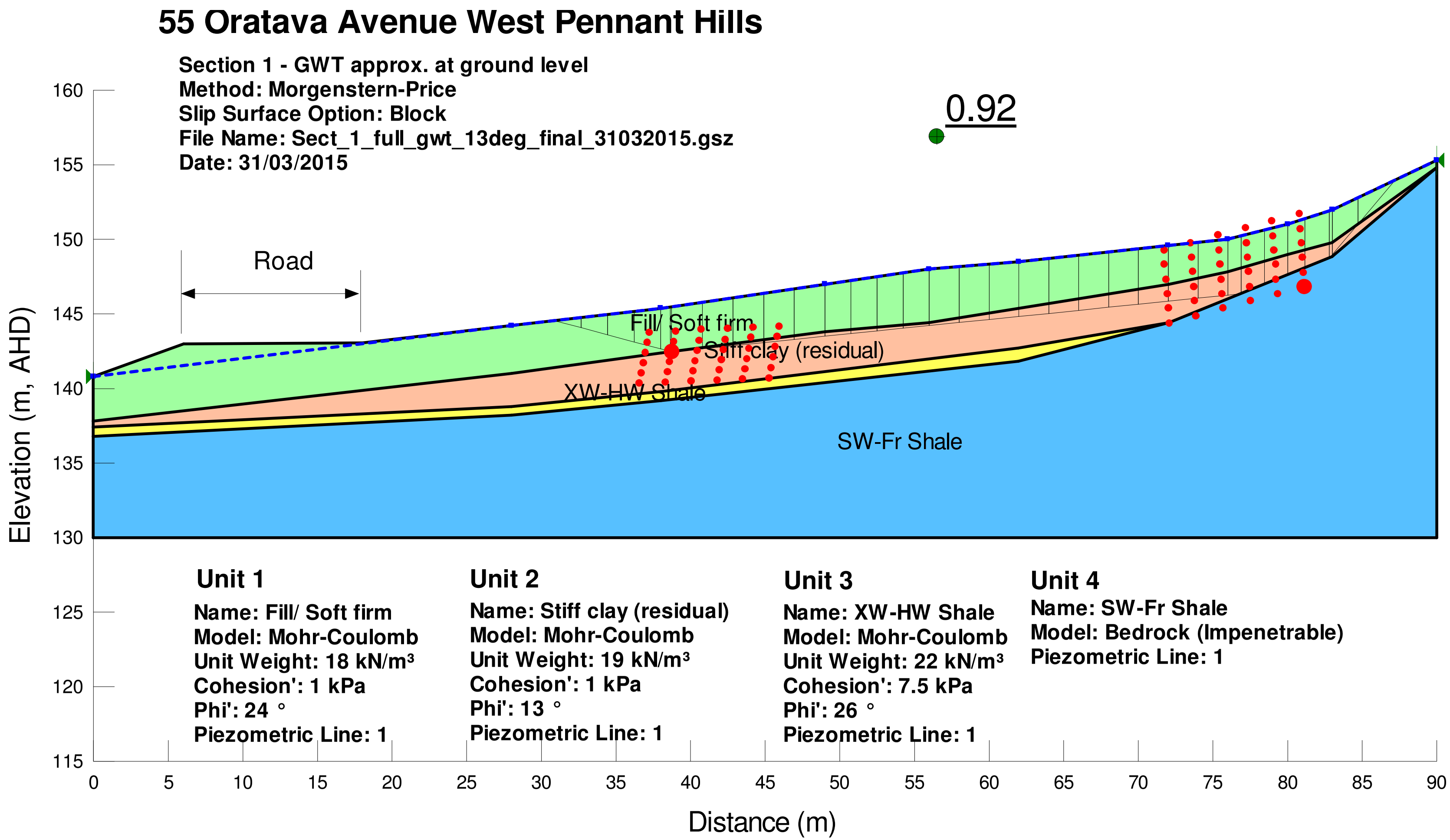
Name: Stiff clay
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 5 kPa
Phi': 26 °
Piezometric Line: 1

Unit 3

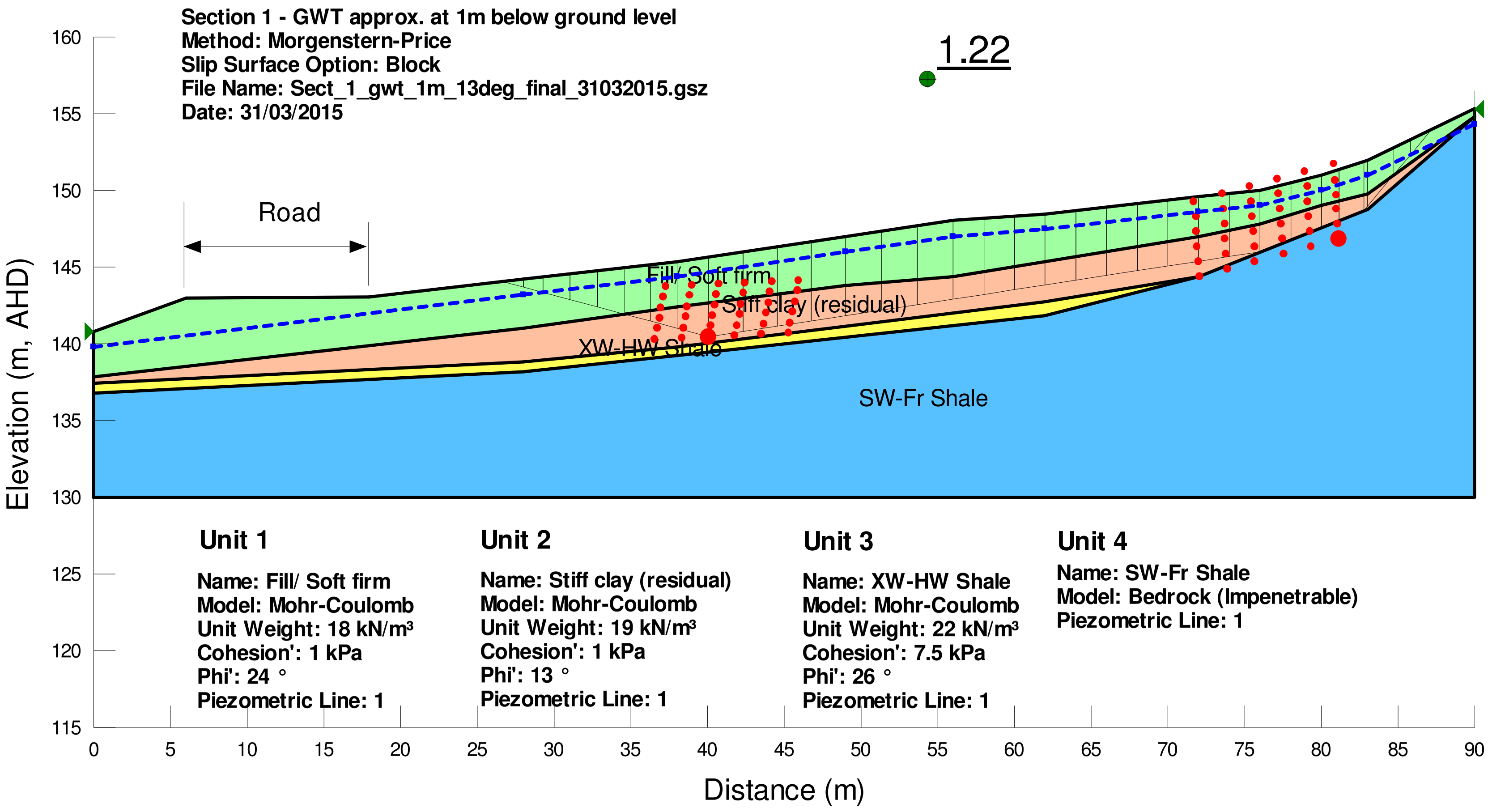
Name: XW-HW Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 26 °
Piezometric Line: 1

Unit 4

Name: SW-Fr Shale
Model: Bedrock (Impenetrable)
Piezometric Line: 1


55 Oratava Avenue West Pennant Hills
Section 1 - GWT approx. at ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_1_full_gwt_13deg_final_31032015.gsz
Date: 31/03/2015
0.92
Road
Fill/ Soft firm
Stiff clay (residual)
XW-HW Shale
SW-Fr Shale
Unit 1
Name: Fill/ Soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1
Unit 2
Name: Stiff clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 13 °
Piezometric Line: 1
Unit 3
Name: XW-HW Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 26 °
Piezometric Line: 1
Unit 4
Name: SW-Fr Shale
Model: Bedrock (Impenetrable)
Piezometric Line: 1
Elevation (m, AHD)
160
155
150
145
140
135
130
125
120
115
Distance (m)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90

55 Oratava Avenue West Pennant Hills



Section 1 - GWT approx. at 1m below ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_1_gwt_1m_13deg_final_31032015.gsz
Date: 31/03/2015

Unit 1

Name: Fill/ Soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2

Name: Stiff clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 13 °
Piezometric Line: 1

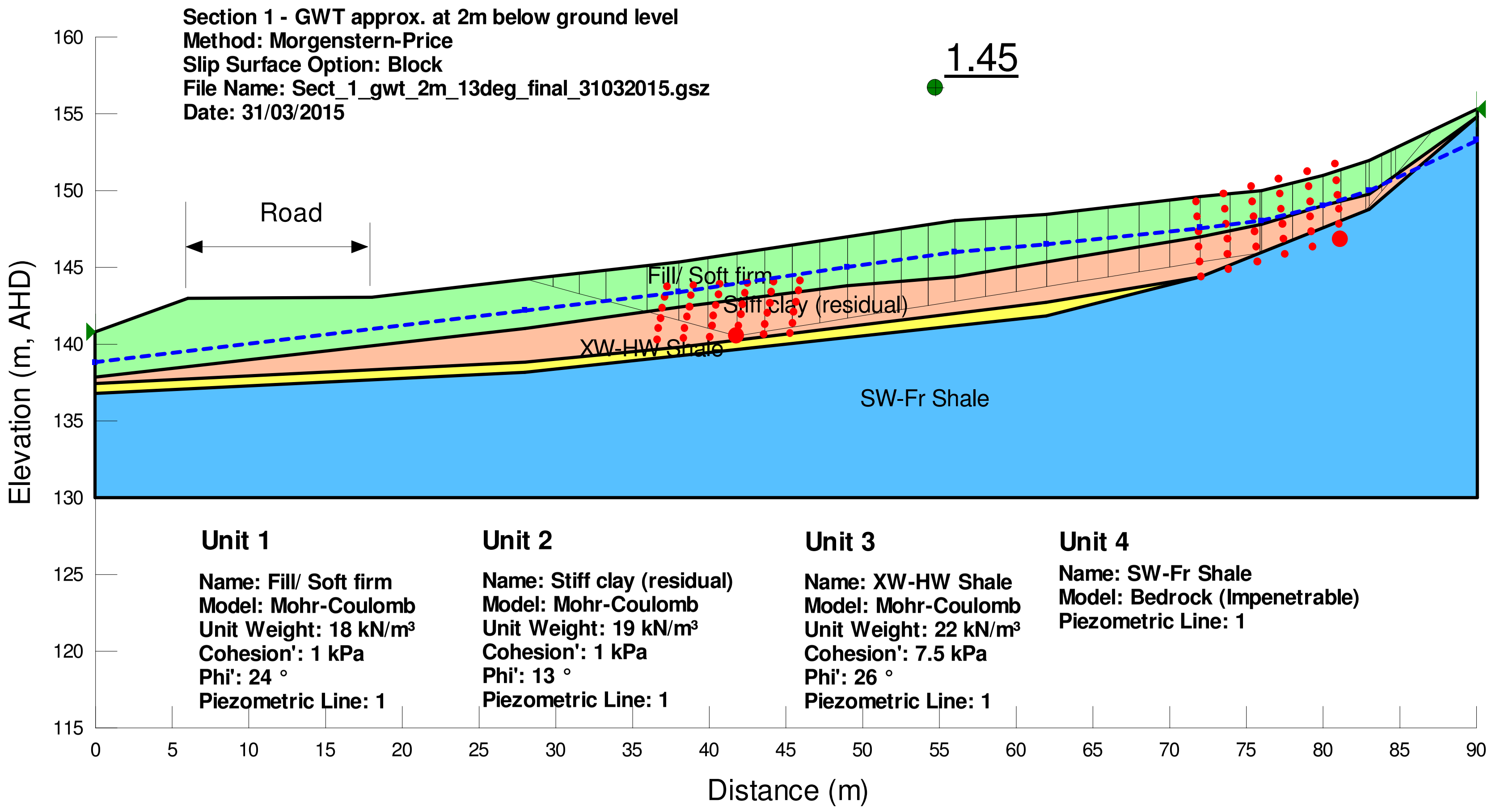
Unit 3

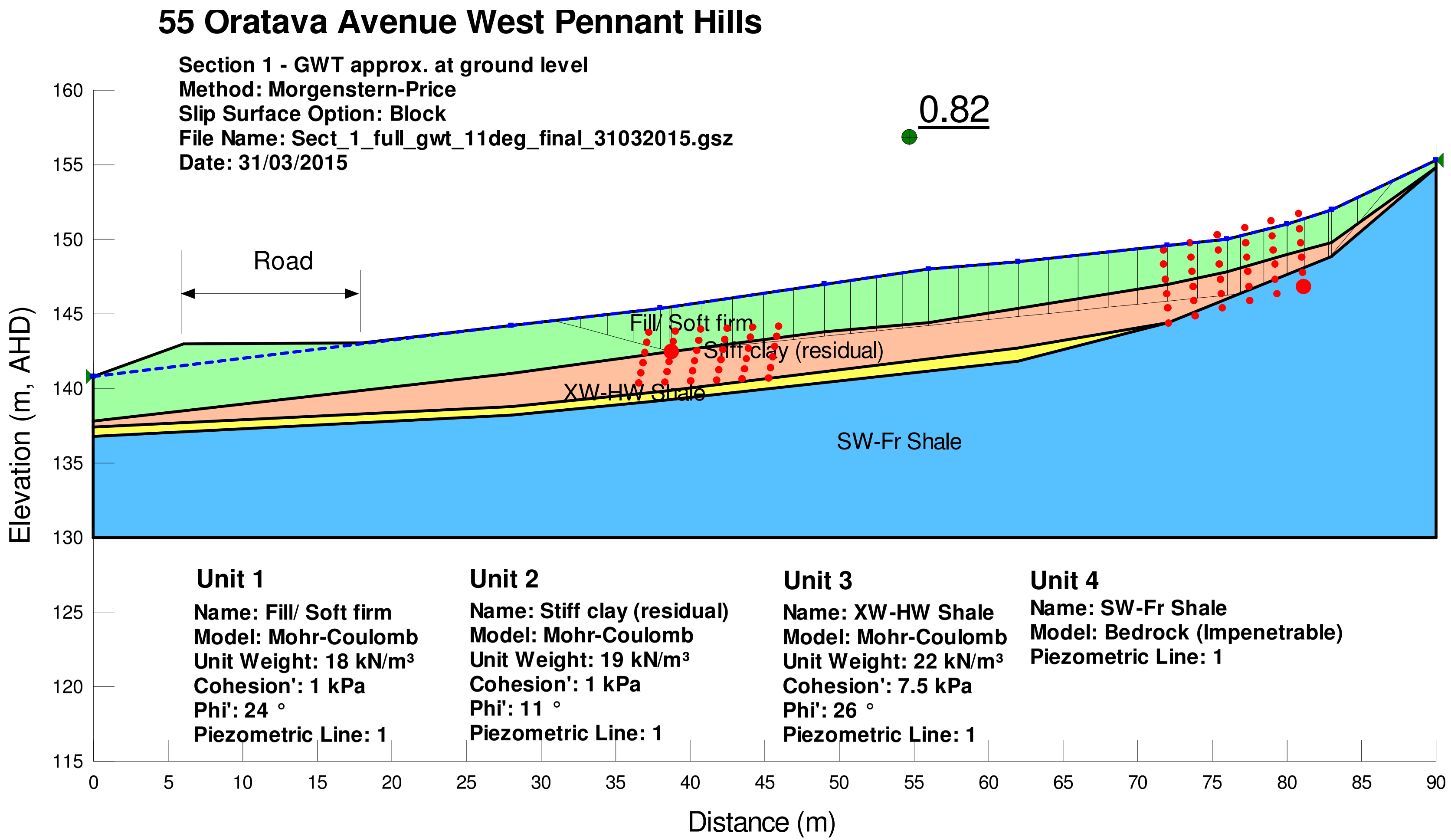
Name: XW-HW Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 26 °
Piezometric Line: 1

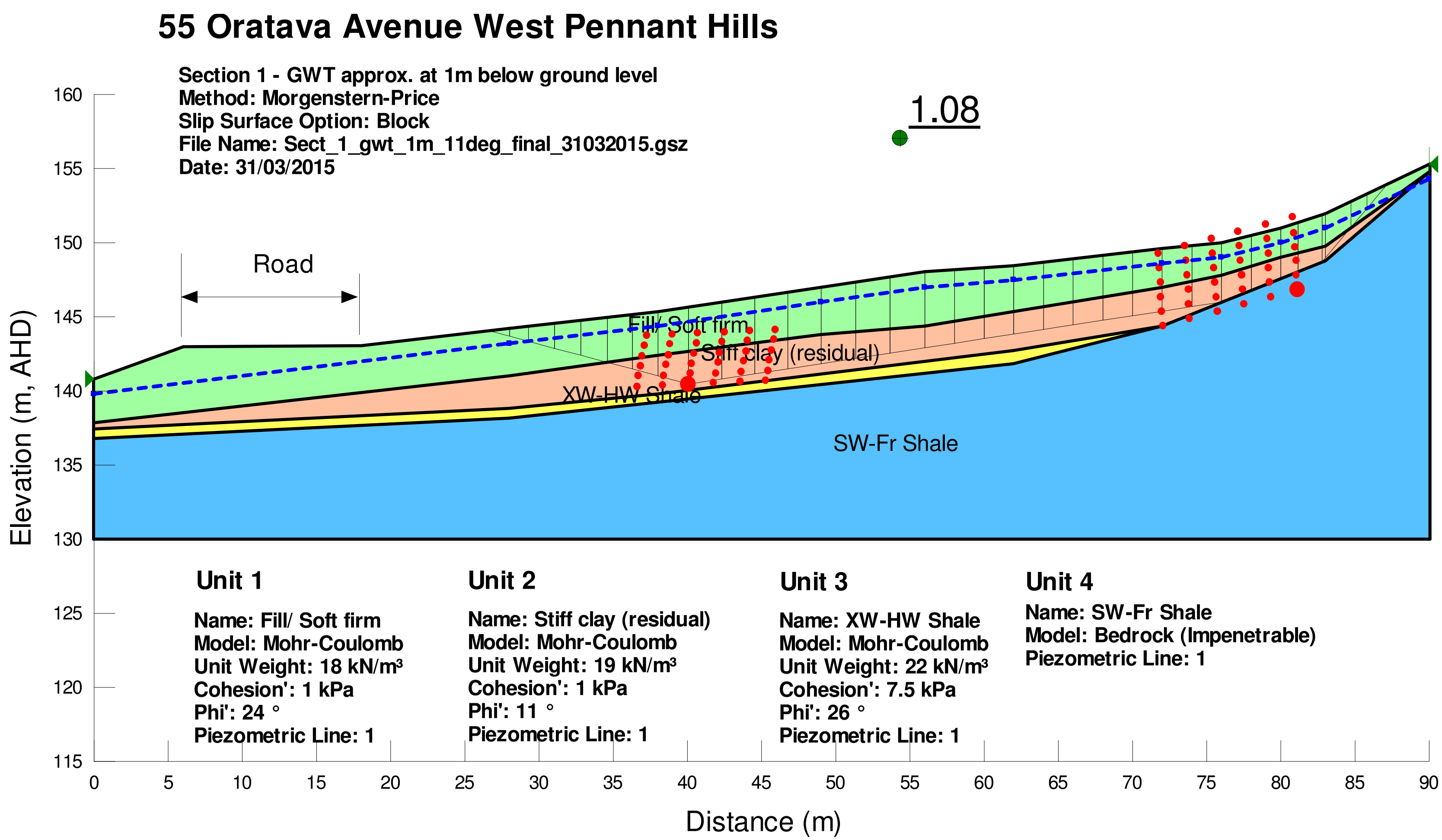
Unit 4

Name: SW-Fr Shale
Model: Bedrock (Impenetrable)
Piezometric Line: 1

55 Oratava Avenue West Pennant Hills




55 Oratava Avenue West Pennant Hills
Section 1 - GWT approx. at ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_1_full_gwt_11deg_final_31032015.gsz
Date: 31/03/2015
0.82
Road
Fill/ Soft firm
Stiff clay (residual)
XW-HW Shale
SW-Fr Shale
Unit 1
Name: Fill/ Soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1
Unit 2
Name: Stiff clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 11 °
Piezometric Line: 1
Unit 3
Name: XW-HW Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 26 °
Piezometric Line: 1
Unit 4
Name: SW-Fr Shale
Model: Bedrock (Impenetrable)
Piezometric Line: 1
Elevation (m, AHD)
160
155
150
145
140
135
130
125
120
115
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
Distance (m)



55 Oratava Avenue West Pennant Hills

Section 1 - GWT approx. at 1m below ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_1_gwt_1m_11deg_final_31032015.gsz
Date: 31/03/2015

Unit 1
Name: Fill/ Soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

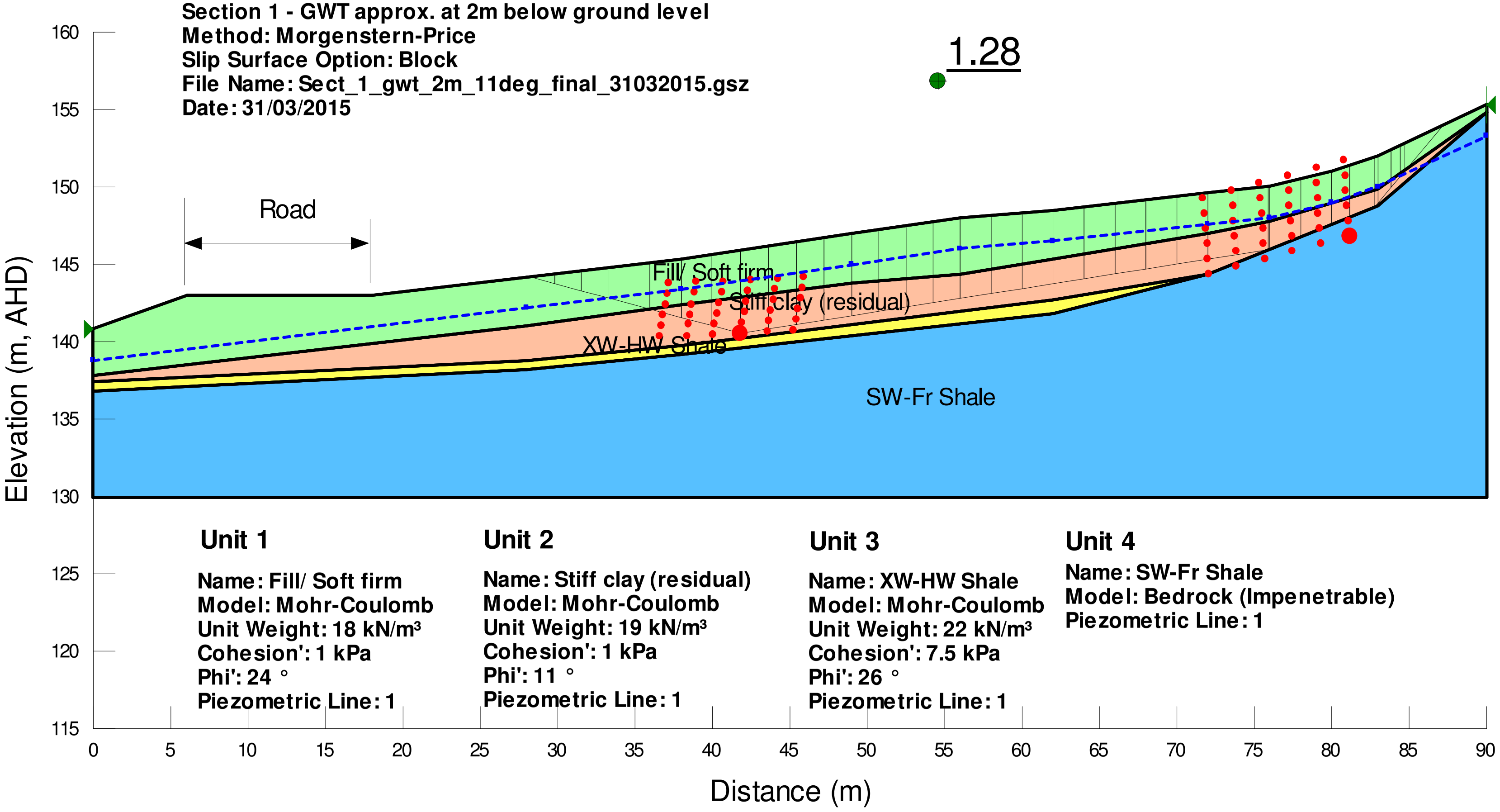
Unit 2
Name: Stiff clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 11 °
Piezometric Line: 1

Unit 3
Name: XW-HW Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 26 °
Piezometric Line: 1

Unit 4
Name: SW-Fr Shale
Model: Bedrock (Impenetrable)
Piezometric Line: 1

55 Oratava Avenue West Pennant Hills

Section 1 - GWT approx. at 2m below ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_1_gwt_2m_11deg_final_31032015.gsz
Date: 31/03/2015



Unit 1

Name: Fill/ Soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2

Name: Stiff clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 11 °
Piezometric Line: 1

Unit 3

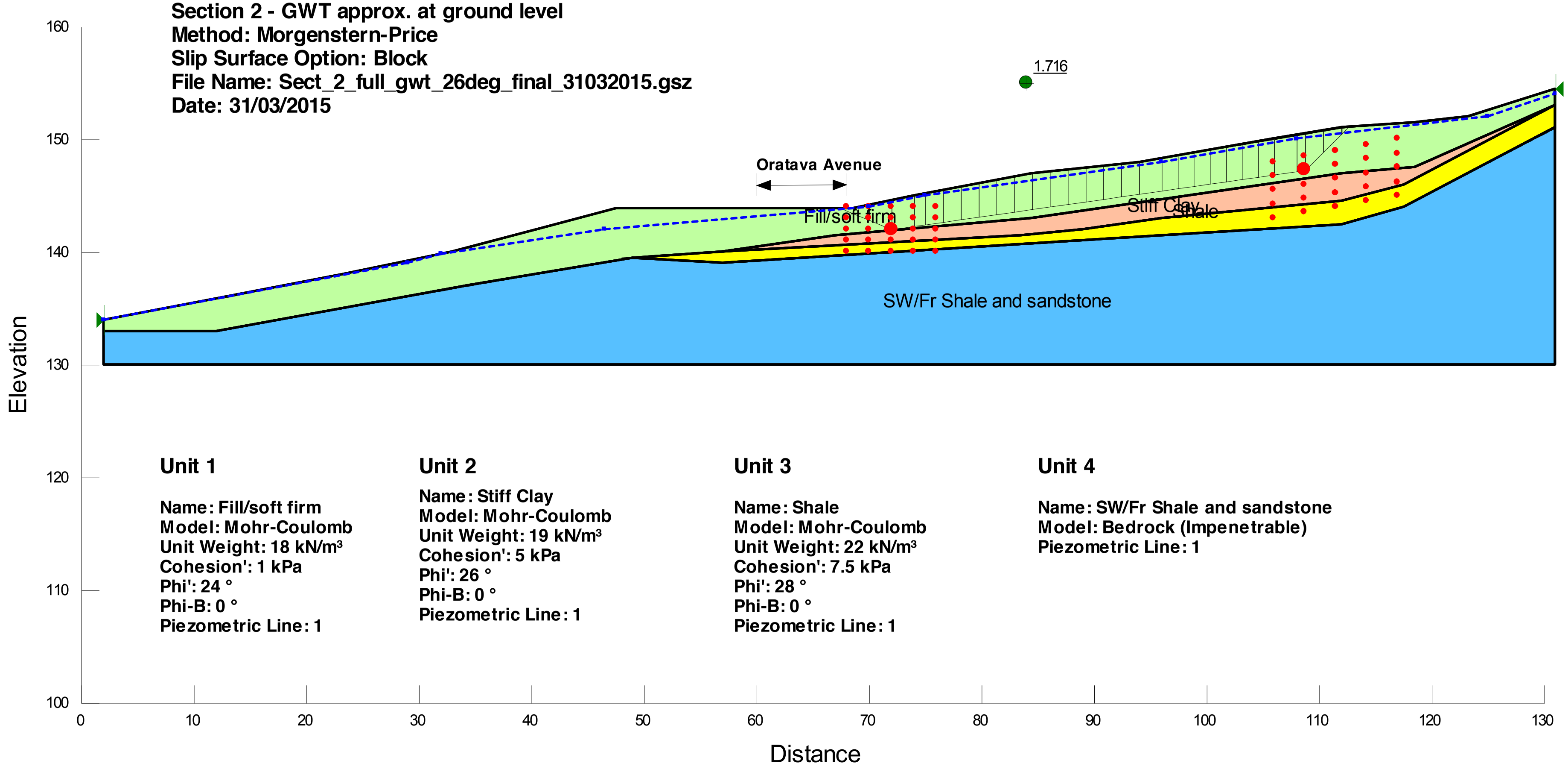
Name: XW-HW Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 26 °
Piezometric Line: 1

Unit 4

Name: SW-Fr Shale
Model: Bedrock (Impenetrable)
Piezometric Line: 1

55 Oratava Avenue West Pennant Hills

Section 2 - GWT approx. at ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_2_full_gwt_26deg_final_31032015.gsz
Date: 31/03/2015



Unit 1

Name: Fill/soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Phi-B: 0 °
Piezometric Line: 1

Unit 2

Name: Stiff Clay
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 5 kPa
Phi': 26 °
Phi-B: 0 °
Piezometric Line: 1

Unit 3

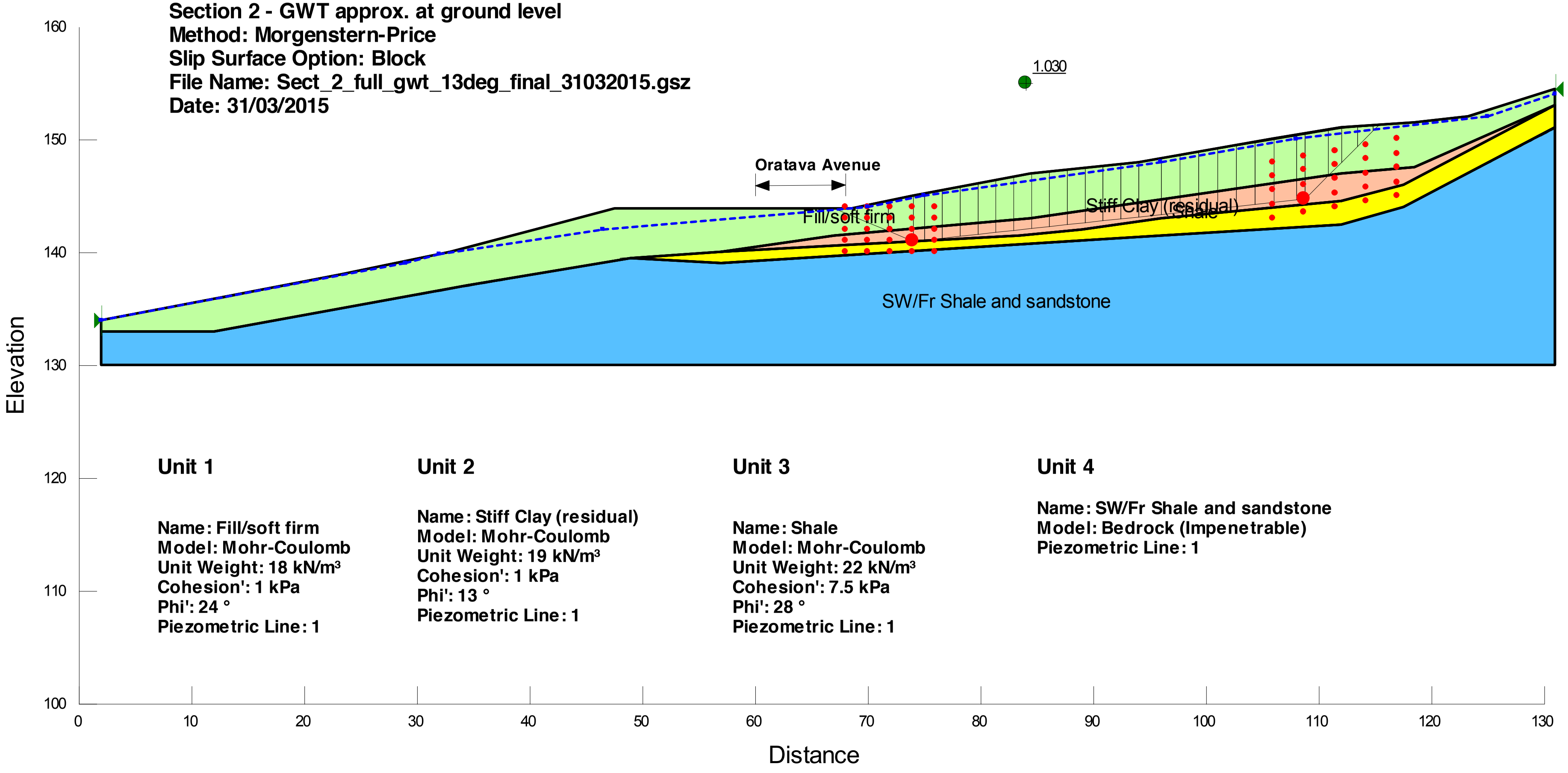
Name: Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 28 °
Phi-B: 0 °
Piezometric Line: 1

Unit 4

Name: SW/Fr Shale and sandstone
Model: Bedrock (Impenetrable)
Piezometric Line: 1

55 Oratava Avenue West Pennant Hills

Section 2 - GWT approx. at ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_2_full_gwt_13deg_final_31032015.gsz
Date: 31/03/2015



Unit 1

Name: Fill/soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2

Name: Stiff Clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 13 °
Piezometric Line: 1

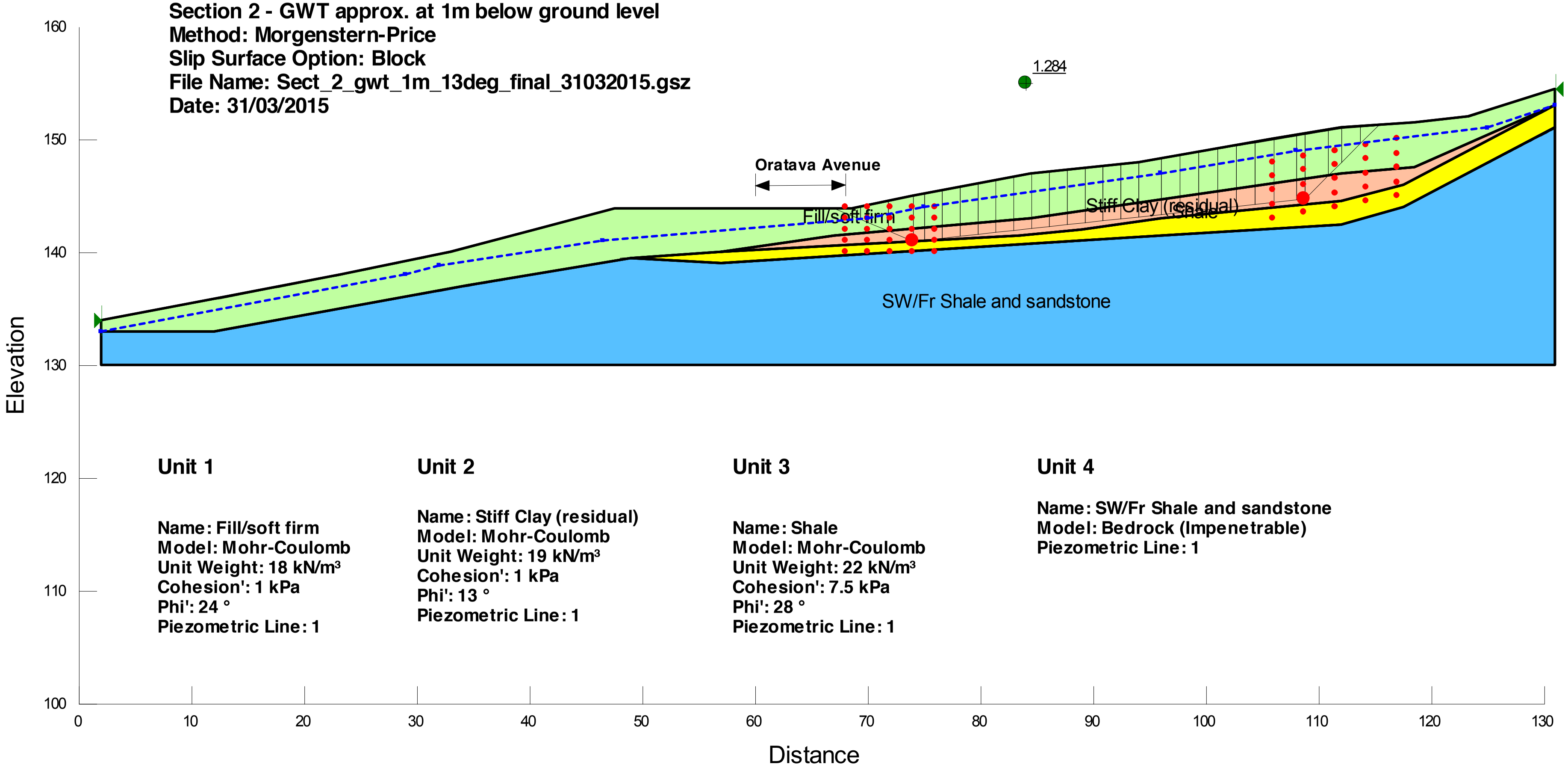
Unit 3

Name: Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 28 °
Piezometric Line: 1

Unit 4

Name: SW/Fr Shale and sandstone
Model: Bedrock (Impenetrable)
Piezometric Line: 1

55 Oratava Avenue West Pennant Hills



Section 2 - GWT approx. at 1m below ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_2_gwt_1m_13deg_final_31032015.gsz
Date: 31/03/2015

Unit 1

Name: Fill/soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2

Name: Stiff Clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 13 °
Piezometric Line: 1

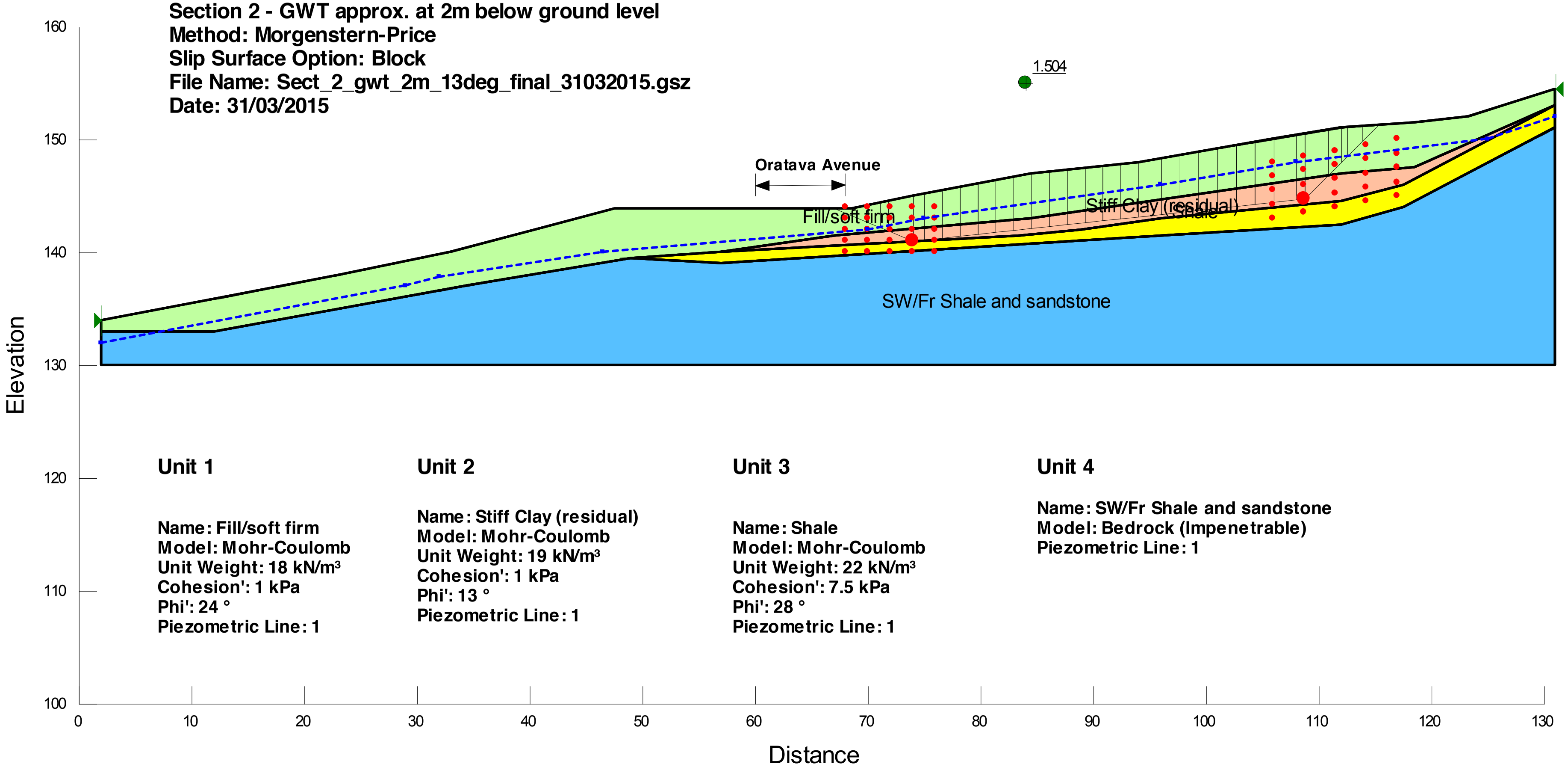
Unit 3

Name: Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 28 °
Piezometric Line: 1

Unit 4

Name: SW/Fr Shale and sandstone
Model: Bedrock (Impenetrable)
Piezometric Line: 1

55 Oratava Avenue West Pennant Hills



Section 2 - GWT approx. at 2m below ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_2_gwt_2m_13deg_final_31032015.gsz
Date: 31/03/2015

Unit 1

Name: Fill/soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2

Name: Stiff Clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 13 °
Piezometric Line: 1

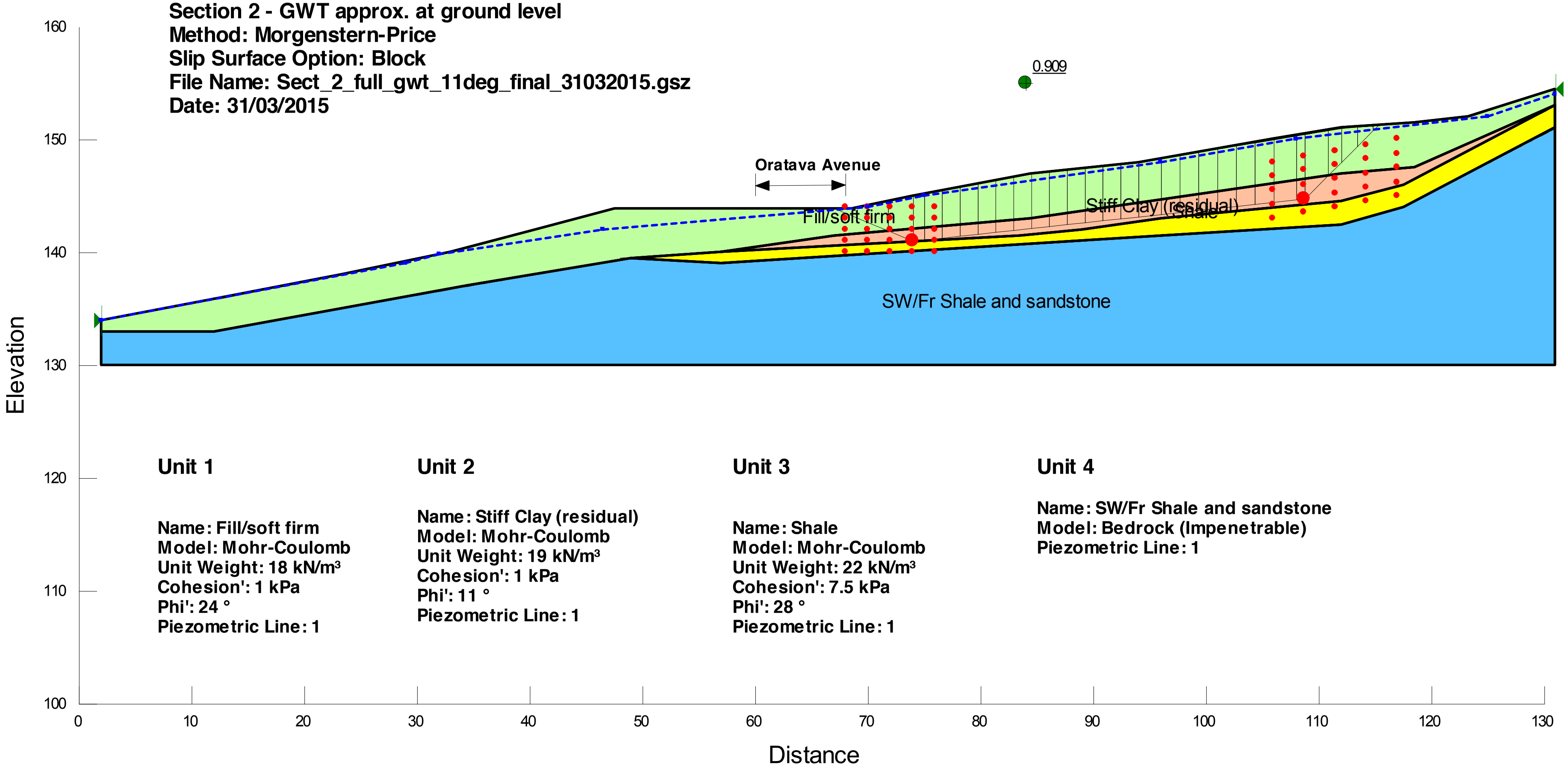
Unit 3

Name: Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 28 °
Piezometric Line: 1

Unit 4

Name: SW/Fr Shale and sandstone
Model: Bedrock (Impenetrable)
Piezometric Line: 1

55 Oratava Avenue West Pennant Hills



Section 2 - GWT approx. at ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_2_full_gwt_11deg_final_31032015.gsz
Date: 31/03/2015

Unit 1

Name: Fill/soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2

Name: Stiff Clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 11 °
Piezometric Line: 1

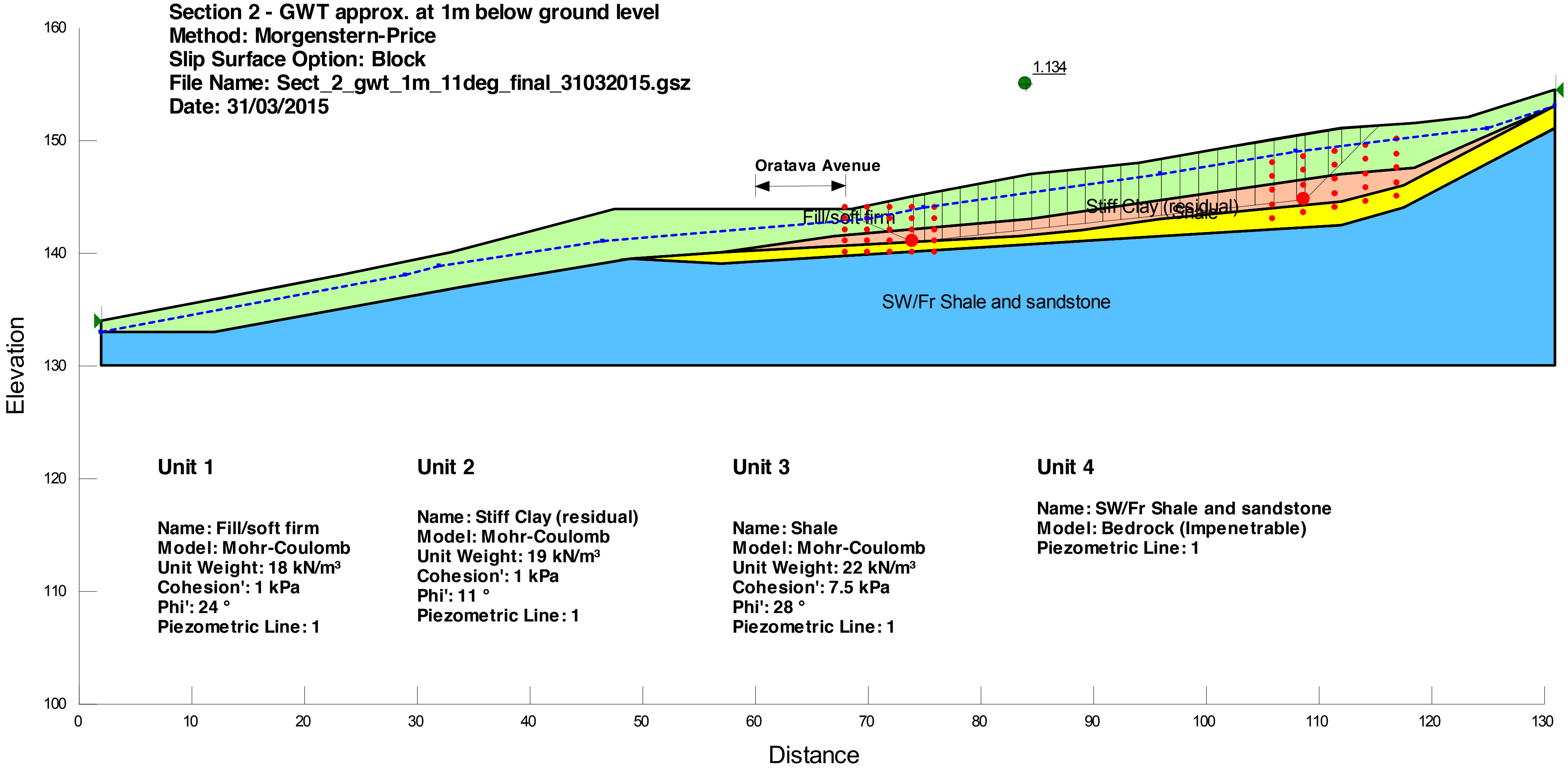
Unit 3

Name: Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 28 °
Piezometric Line: 1

Unit 4

Name: SW/Fr Shale and sandstone
Model: Bedrock (Impenetrable)
Piezometric Line: 1

55 Oratava Avenue West Pennant Hills



Section 2 - GWT approx. at 1m below ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_2_gwt_1m_11deg_final_31032015.gsz
Date: 31/03/2015

Unit 1

Name: Fill/soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2

Name: Stiff Clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 11 °
Piezometric Line: 1

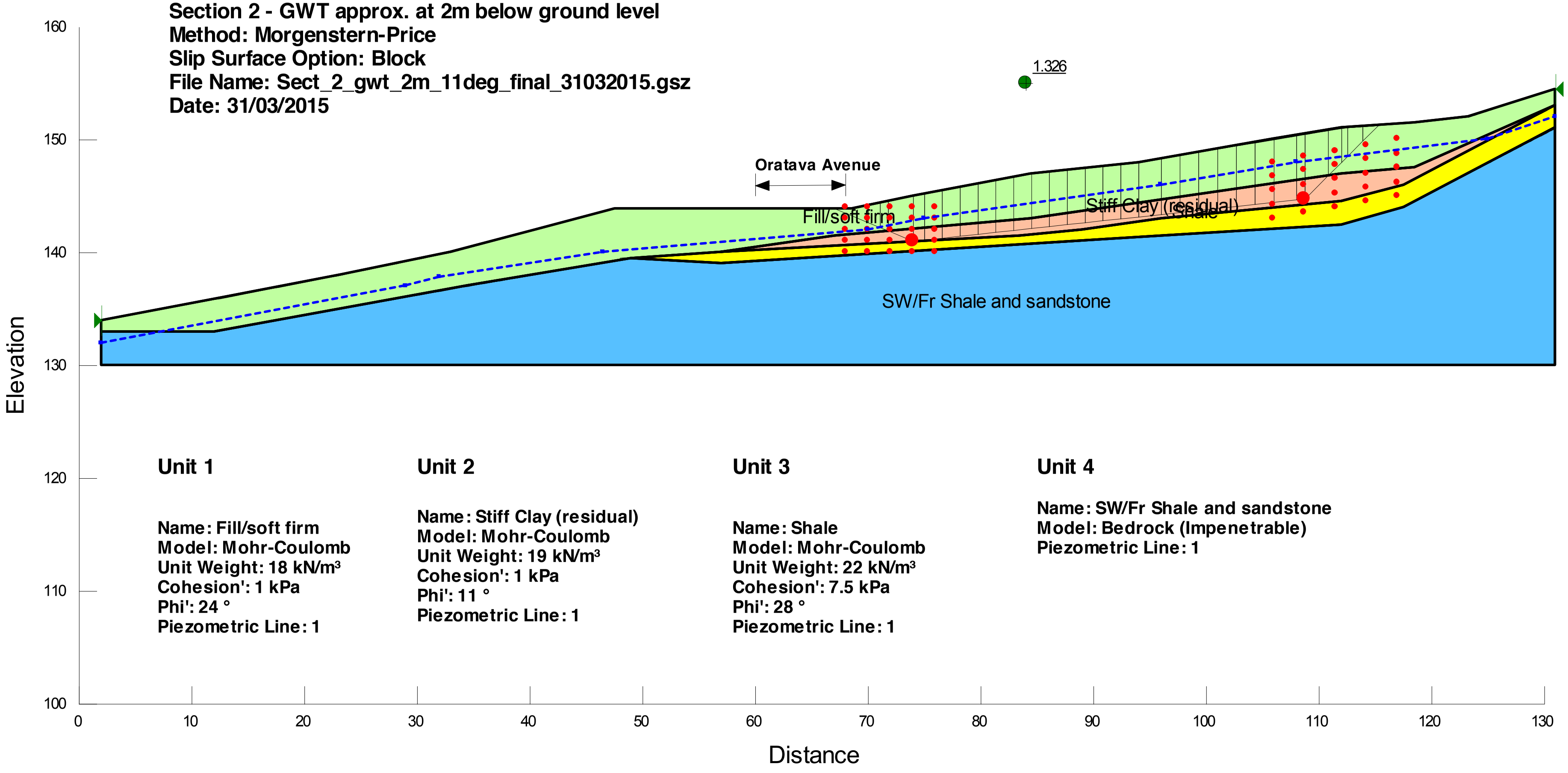
Unit 3

Name: Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 28 °
Piezometric Line: 1

Unit 4

Name: SW/Fr Shale and sandstone
Model: Bedrock (Impenetrable)
Piezometric Line: 1

55 Oratava Avenue West Pennant Hills



Section 2 - GWT approx. at 2m below ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_2_gwt_2m_11deg_final_31032015.gsz
Date: 31/03/2015

Unit 1

Name: Fill/soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2

Name: Stiff Clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 11 °
Piezometric Line: 1

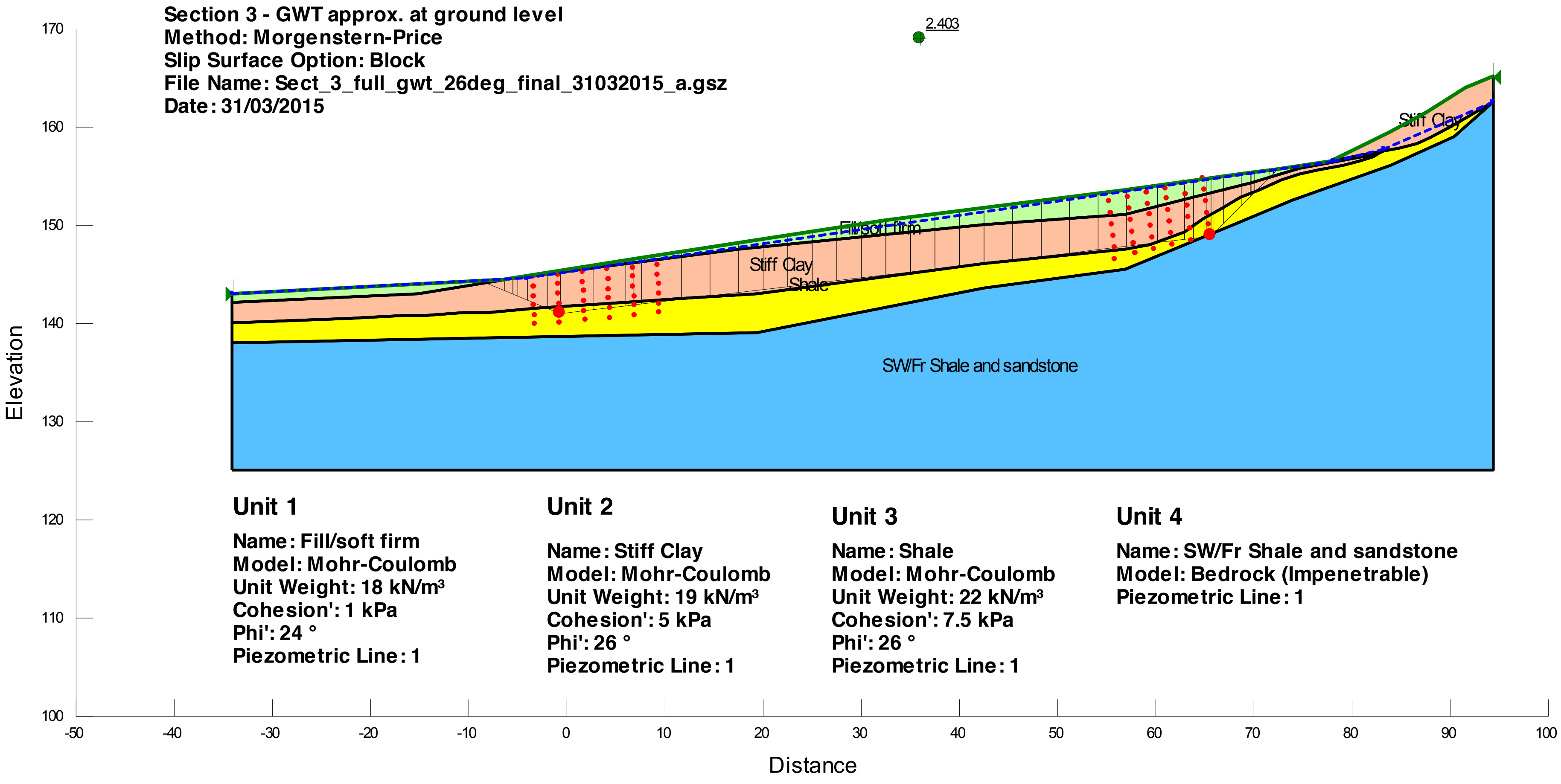
Unit 3

Name: Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 28 °
Piezometric Line: 1

Unit 4

Name: SW/Fr Shale and sandstone
Model: Bedrock (Impenetrable)
Piezometric Line: 1

55 Oratava Avenue West Pennant Hills



Section 3 - GWT approx. at ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_3_full_gwt_26deg_final_31032015_a.gsz
Date: 31/03/2015

Unit 1

Name: Fill/soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2

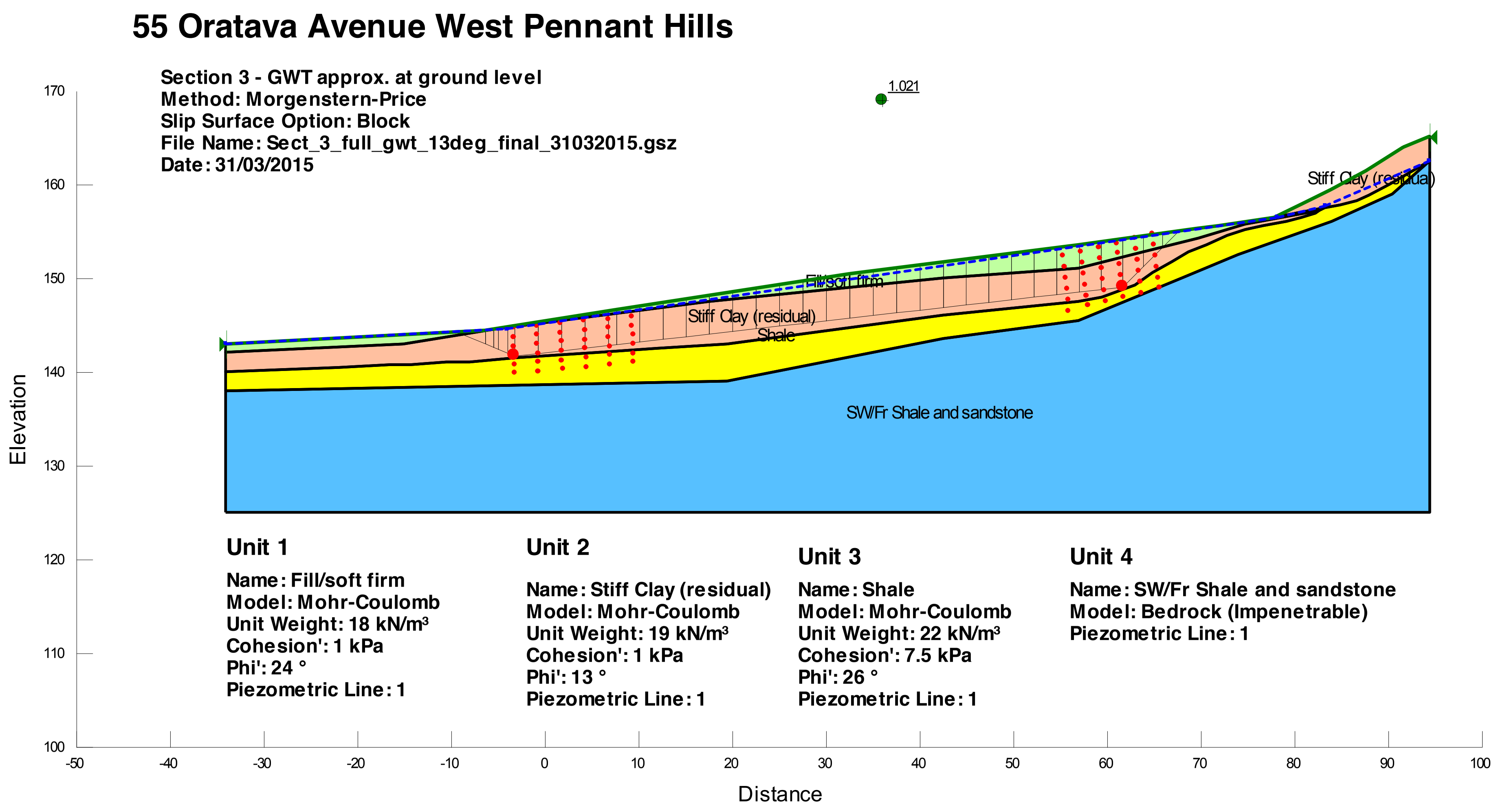
Name: Stiff Clay
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 5 kPa
Phi': 26 °
Piezometric Line: 1

Unit 3

Name: Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 26 °
Piezometric Line: 1

Unit 4

Name: SW/Fr Shale and sandstone
Model: Bedrock (Impenetrable)
Piezometric Line: 1



55 Oratava Avenue West Pennant Hills

Section 3 - GWT approx. at ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_3_full_gwt_13deg_final_31032015.gsz
Date: 31/03/2015

Unit 1

Name: Fill/soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2

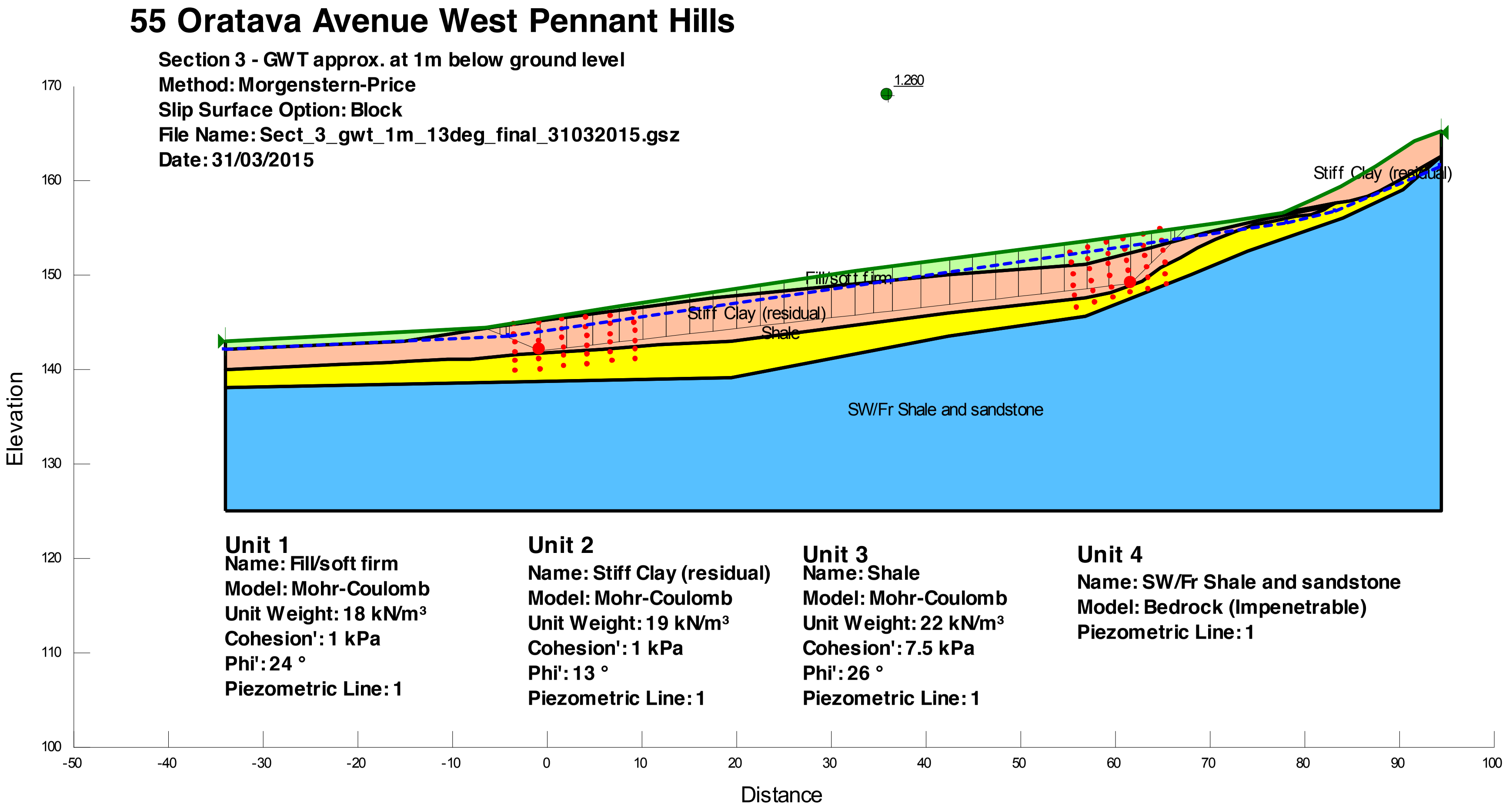
Name: Stiff Clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 13 °
Piezometric Line: 1

Unit 3

Name: Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 26 °
Piezometric Line: 1

Unit 4

Name: SW/Fr Shale and sandstone
Model: Bedrock (Impenetrable)
Piezometric Line: 1



55 Oratava Avenue West Pennant Hills

Section 3 - GWT approx. at 1m below ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_3_gwt_1m_13deg_final_31032015.gsz
Date: 31/03/2015

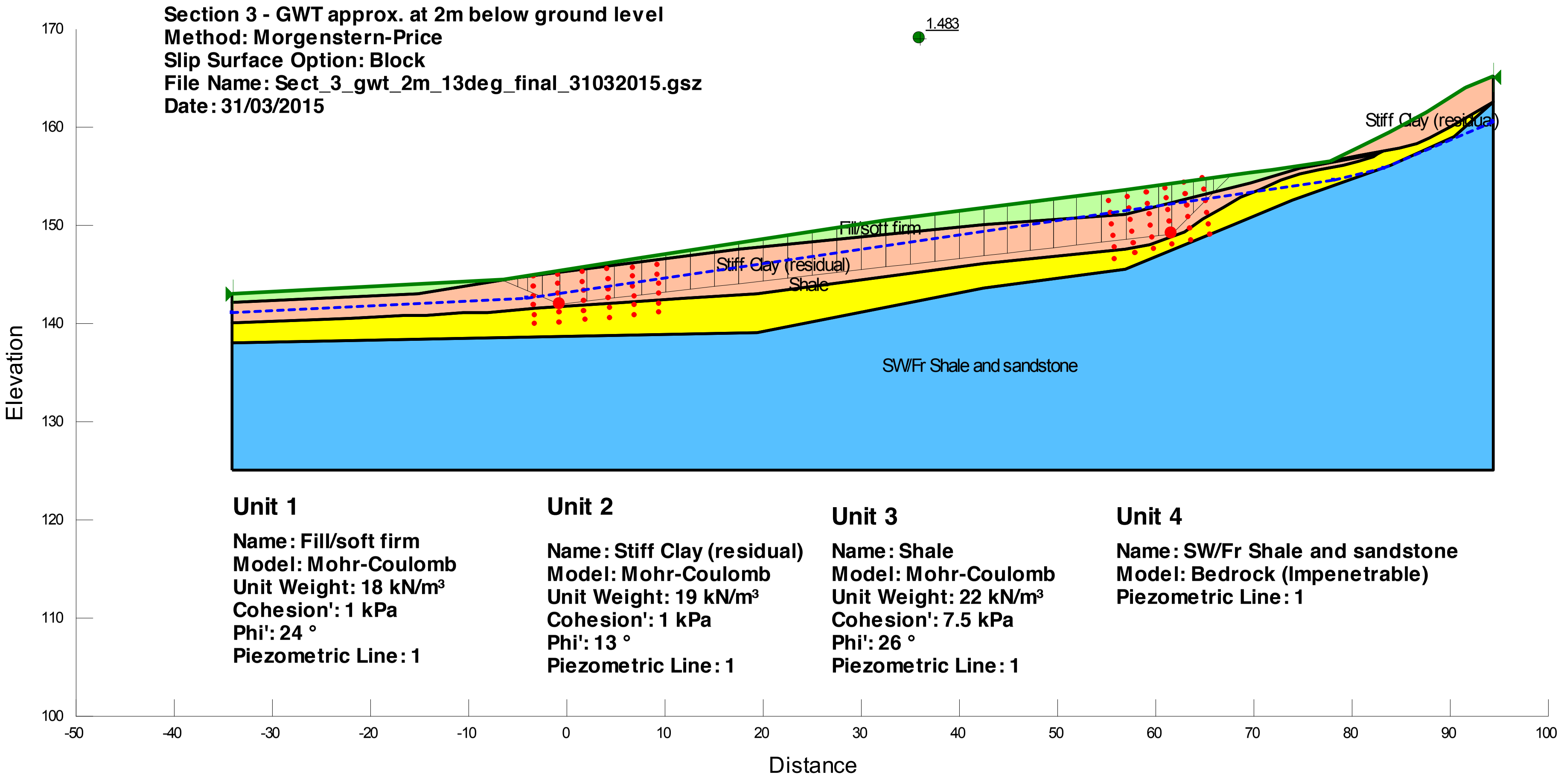
Unit 1
Name: Fill/soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2
Name: Stiff Clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 13 °
Piezometric Line: 1

Unit 3
Name: Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 26 °
Piezometric Line: 1

Unit 4
Name: SW/Fr Shale and sandstone
Model: Bedrock (Impenetrable)
Piezometric Line: 1

55 Oratava Avenue West Pennant Hills



Section 3 - GWT approx. at 2m below ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_3_gwt_2m_13deg_final_31032015.gsz
Date: 31/03/2015

Unit 1

Name: Fill/soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2

Name: Stiff Clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 13 °
Piezometric Line: 1

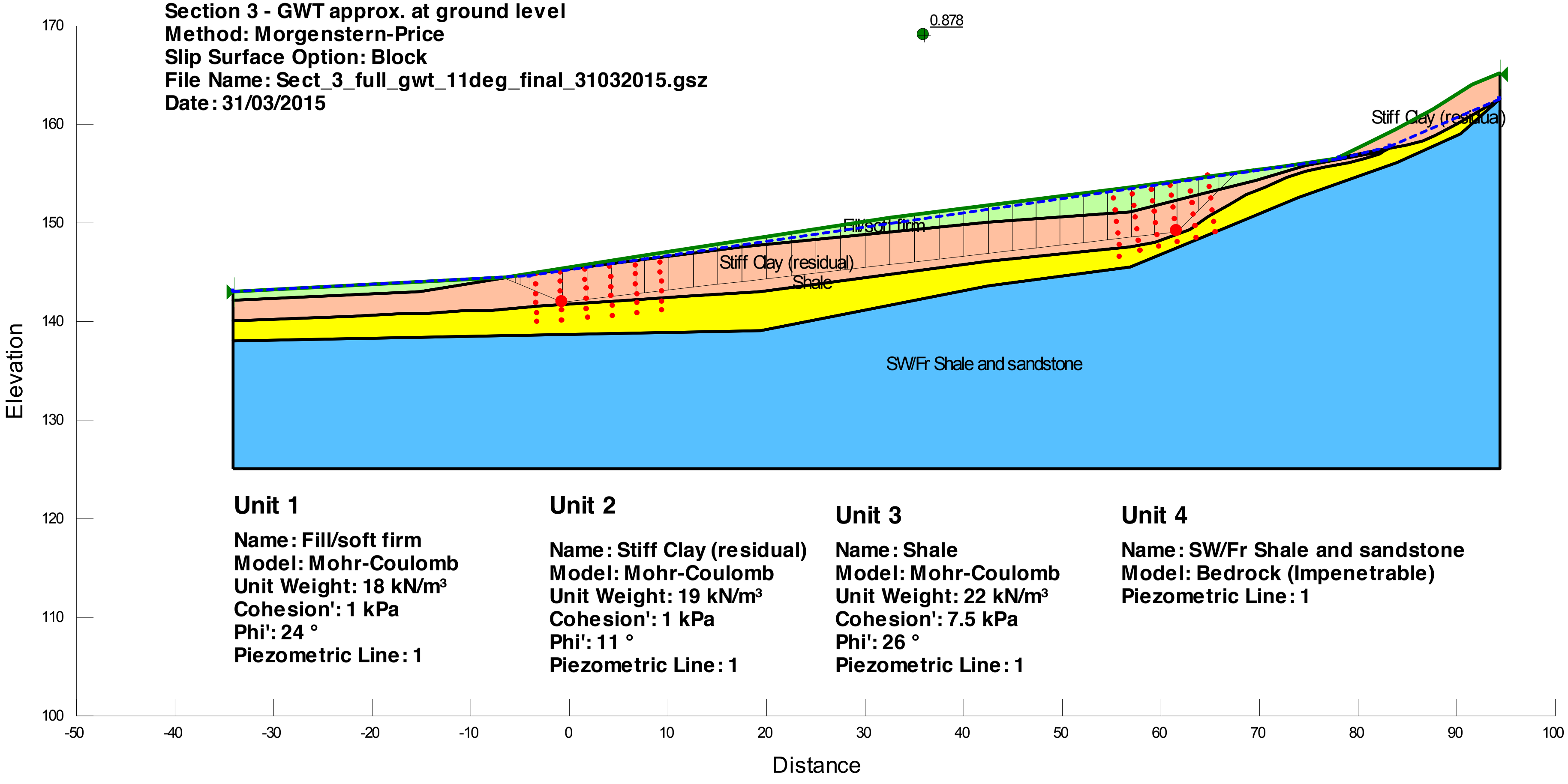
Unit 3

Name: Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 26 °
Piezometric Line: 1

Unit 4

Name: SW/Fr Shale and sandstone
Model: Bedrock (Impenetrable)
Piezometric Line: 1

55 Oratava Avenue West Pennant Hills



Section 3 - GWT approx. at ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_3_full_gwt_11deg_final_31032015.gsz
Date: 31/03/2015

Unit 1

Name: Fill/soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2

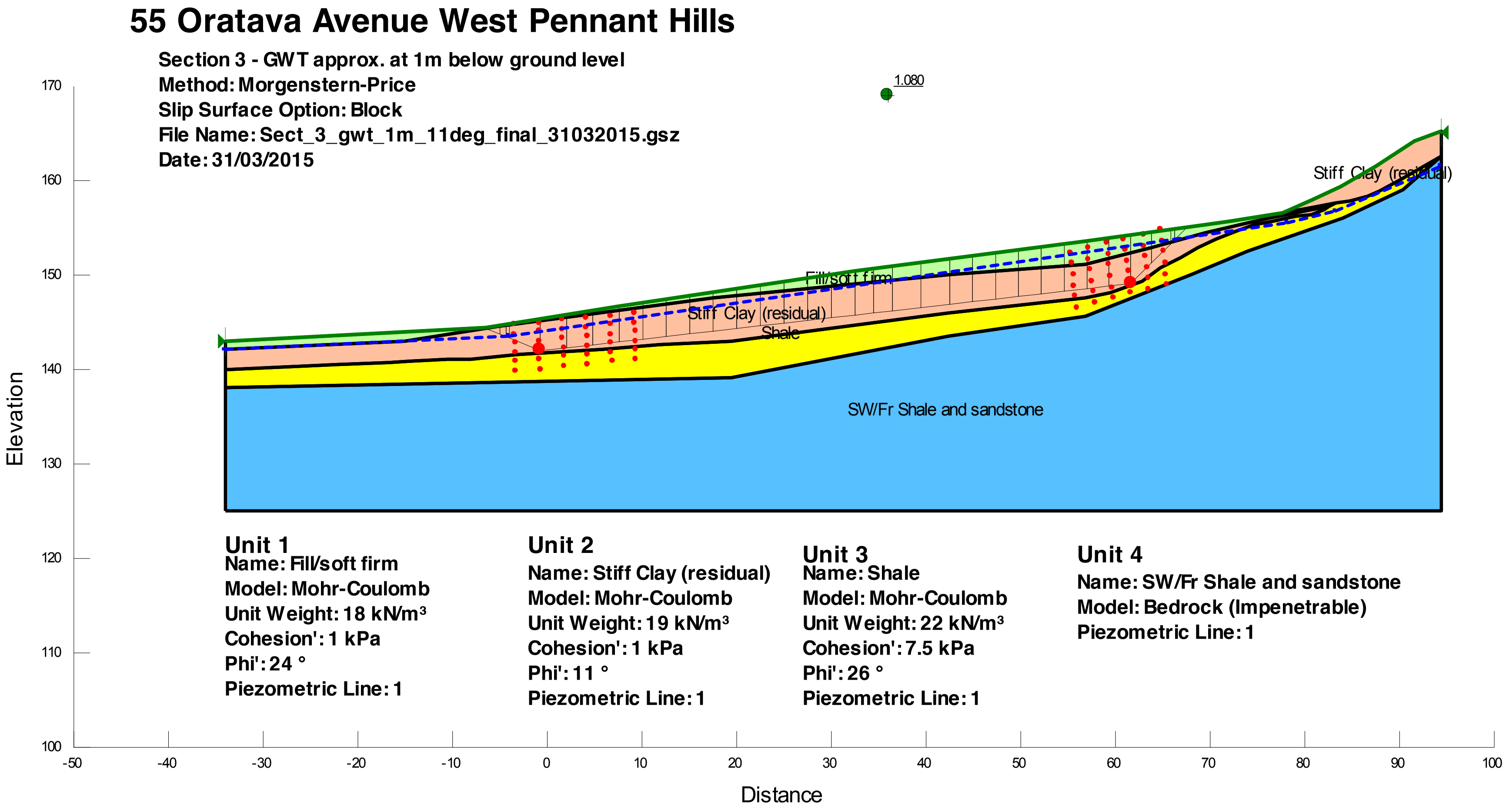
Name: Stiff Clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 11 °
Piezometric Line: 1

Unit 3

Name: Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 26 °
Piezometric Line: 1

Unit 4

Name: SW/Fr Shale and sandstone
Model: Bedrock (Impenetrable)
Piezometric Line: 1



55 Oratava Avenue West Pennant Hills

Section 3 - GWT approx. at 1m below ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_3_gwt_1m_11deg_final_31032015.gsz
Date: 31/03/2015

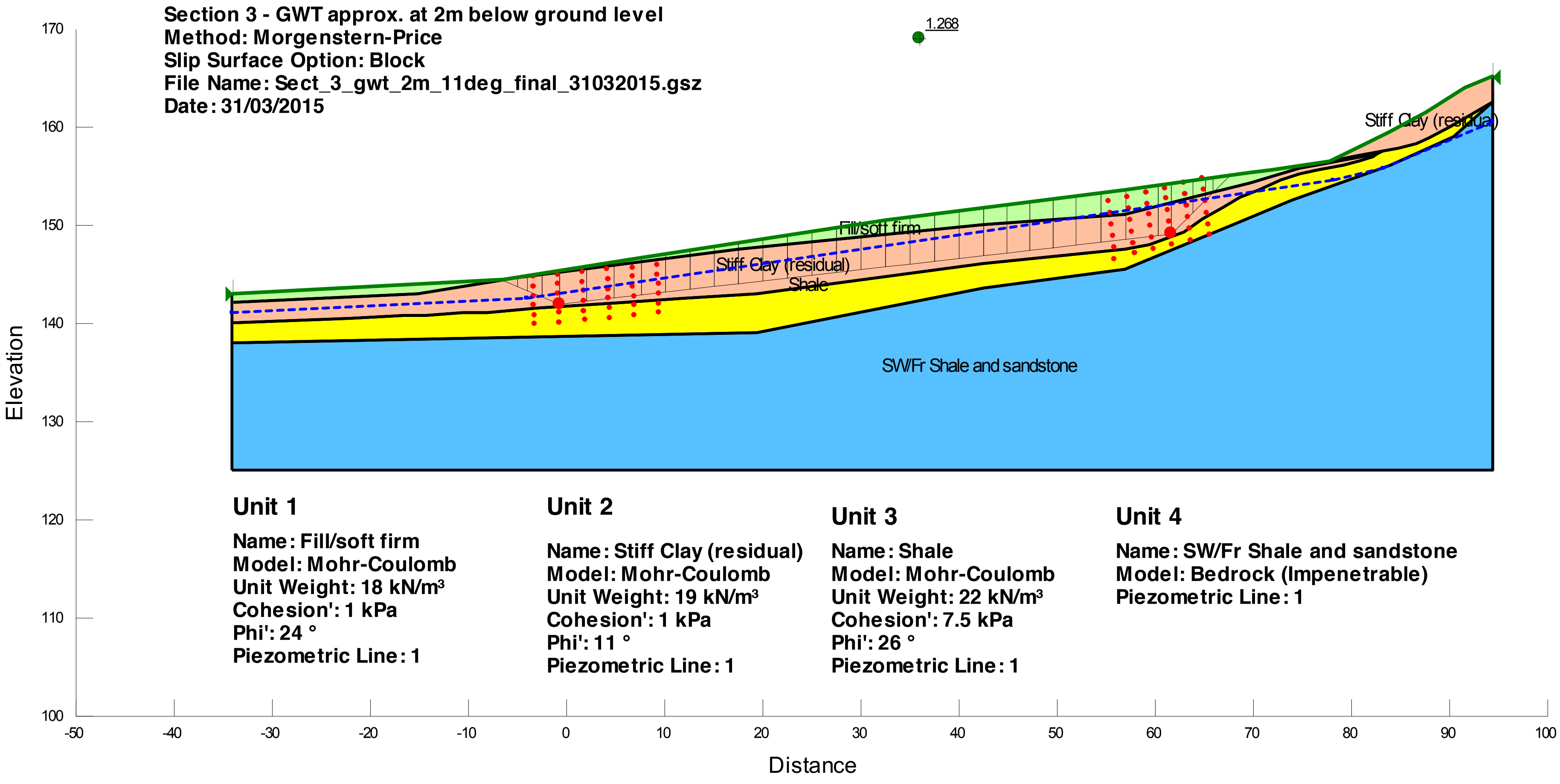
Unit 1
Name: Fill/soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2
Name: Stiff Clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 11 °
Piezometric Line: 1

Unit 3
Name: Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 26 °
Piezometric Line: 1

Unit 4
Name: SW/Fr Shale and sandstone
Model: Bedrock (Impenetrable)
Piezometric Line: 1

55 Oratava Avenue West Pennant Hills



Section 3 - GWT approx. at 2m below ground level
Method: Morgenstern-Price
Slip Surface Option: Block
File Name: Sect_3_gwt_2m_11deg_final_31032015.gsz
Date: 31/03/2015

Unit 1

Name: Fill/soft firm
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 24 °
Piezometric Line: 1

Unit 2

Name: Stiff Clay (residual)
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 1 kPa
Phi': 11 °
Piezometric Line: 1

Unit 3

Name: Shale
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion': 7.5 kPa
Phi': 26 °
Piezometric Line: 1

Unit 4

Name: SW/Fr Shale and sandstone
Model: Bedrock (Impenetrable)
Piezometric Line: 1

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APPENDIX F

Seep/W Analyses
(Hyder Consulting)

55 Oratava Ave WPH - Section 2 SEEP/W Analysis:

Introduction

- Section 2 was adopted for Seep/W analysis, about 130 m in length.
- Hydraulic head was assigned at both upstream and downstream boundaries to simulate observed groundwater monitored in relevant boreholes, ie. BH5 and BH2.
- Four units of material were considered in the model. The parameters are summarised in the table below.
- The saturated permeability for each unit was estimated from the field rising water head test data performed in 2002 and 2015.

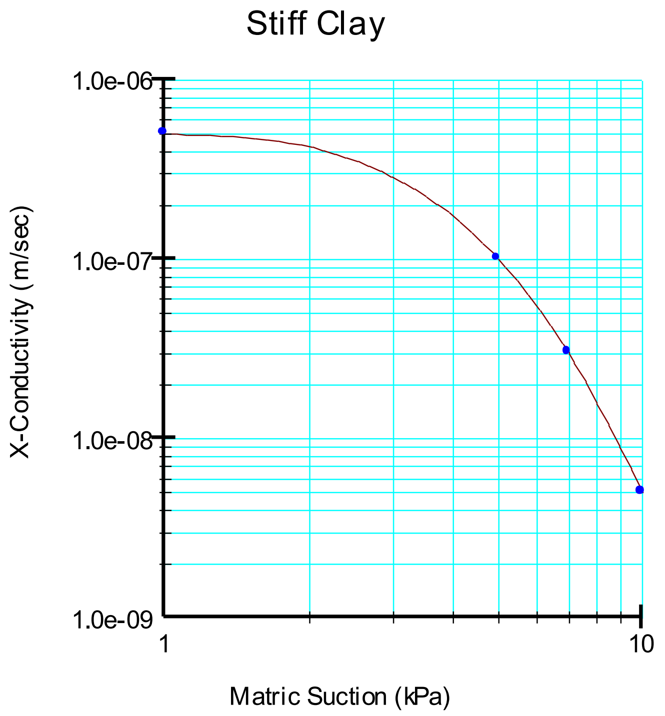
Modelling Assumptions

- Upstream boundary: RL 154.5 m so as to simulate spring at the toe of steep down. (Ref: Warwick Davis email of 15/5/2015)
- Downstream boundary: RL 133 m
- A water infiltration of about 25 mm/year due to rain storm event was included in the model based on past experience from previous project in this area.

Geotechnical model and parameters

Unit	Material	Saturation	Saturated permeability k (m/sec)	
			Base case	Lower bound case
1	Fill	Sat/Unsat	1e-05	1e-05
2	Stiff clay	Sat/Unsat	5e-07	1e-07
3	Shale	Saturated	1e-07	5e-08
3A	High permeable flow layer	Saturated	5e-05	5e-06
4	Shale	Saturated	1e-09	1e-09

In the Seep/W programme Unit 1 and Unit 2 was modelled with Sat/Unsat material where Permeability is allowed to vary with suction. A variable function chosen for Unit 1 and Unit 2 material where a metric suction of 10 kPa corresponds to a reduced permeability of two order of magnitude. The following plot shows the unsaturated permeability characteristics of unit 2 stiff clay.



A high permeable flow layer (unit 3A) of half a meter thick is assumed to exist at the interface with the underlying SW/Fr shale.

Trench Nos. 1, 2 and 3 were located at 10 m, 35 m and 60 m form the right boundary.

Results

- Plot 1 - Base model simulation (ie. no trench drains). It is noted that on 29 April 2105 BH2 and BH5, located in the vicinity of Section 2, recorded standing groundwater at 1.29 m and 0.0 m respectively below ground surface. From the Seep/W output, groundwater level was also analysed to be at or near ground surface.
- Plot2 - Base model simulation with inclusion of 3 m deep trench drains.
- Plot3 - Base model simulation with inclusion of chimney drains installed at the bottom of trench drains to intercept the permeable layer, ie. Unit 3A.
- Plot 4 - Base model with use of lower bound permeability for Unit 2, Unit 3 and Unit 3A. Groundwater level was analysed to be at or near the ground surface.
- Plot 5 –As Plot 4, but with inclusion of 3 m deep trench drains. Highest groundwater at about 2.0 m was analysed at the western end of the slope section, near Oratava Avenue.
- Plot 6 – As Plot 5, but with inclusion of chimney drains installed at the bottom trench drains to intercept the permeable layer, ie. Unit 3A.

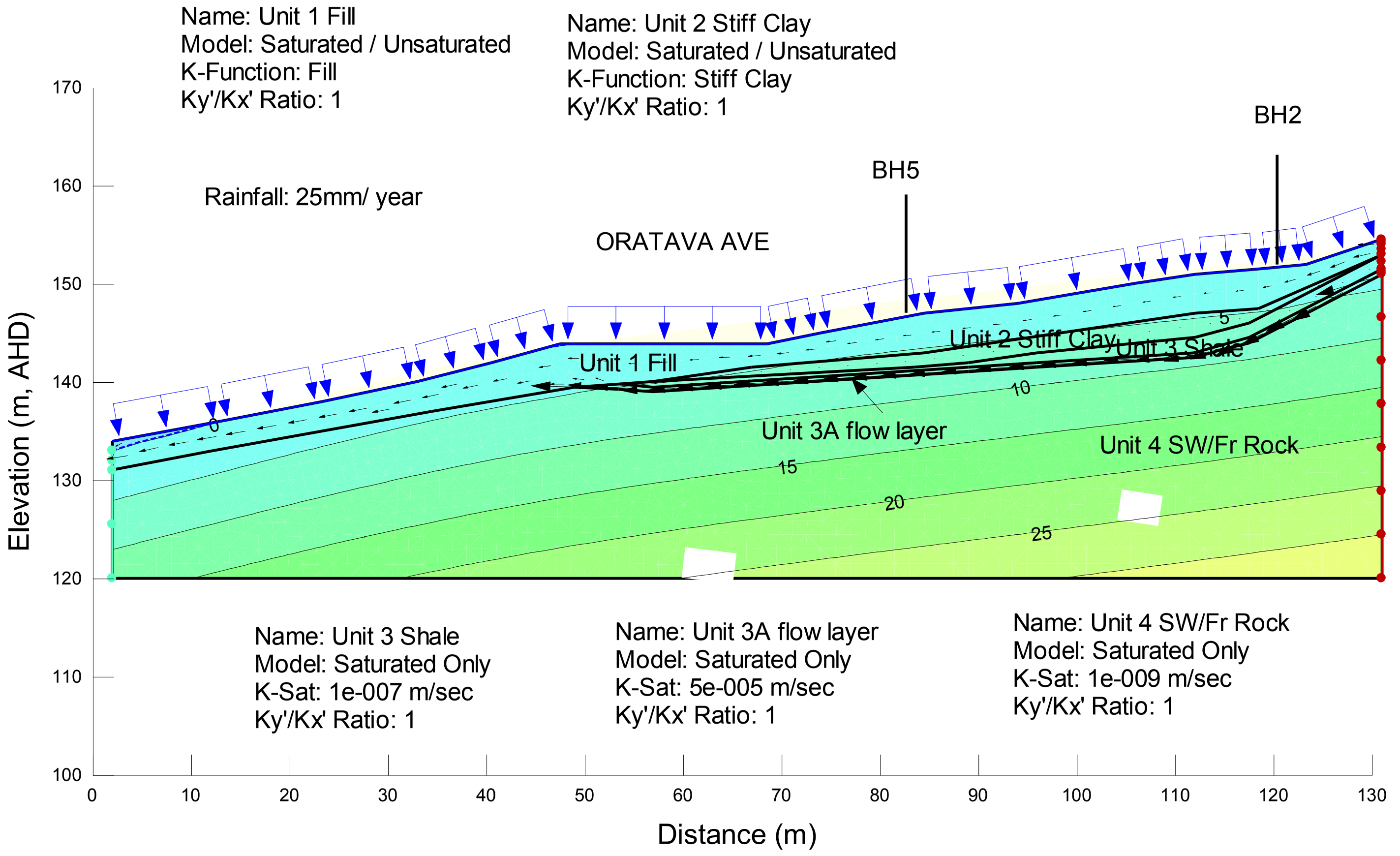
Observation

- For Section 2, subject to detailed design, trench drains + chimney drains may only be required at the western end of the slope section.

- Spacing and size of chimney drains to be determined and confirmed in detailed design phase. Currently it has been assumed that they have the same water carrying capacity as the trench drains.

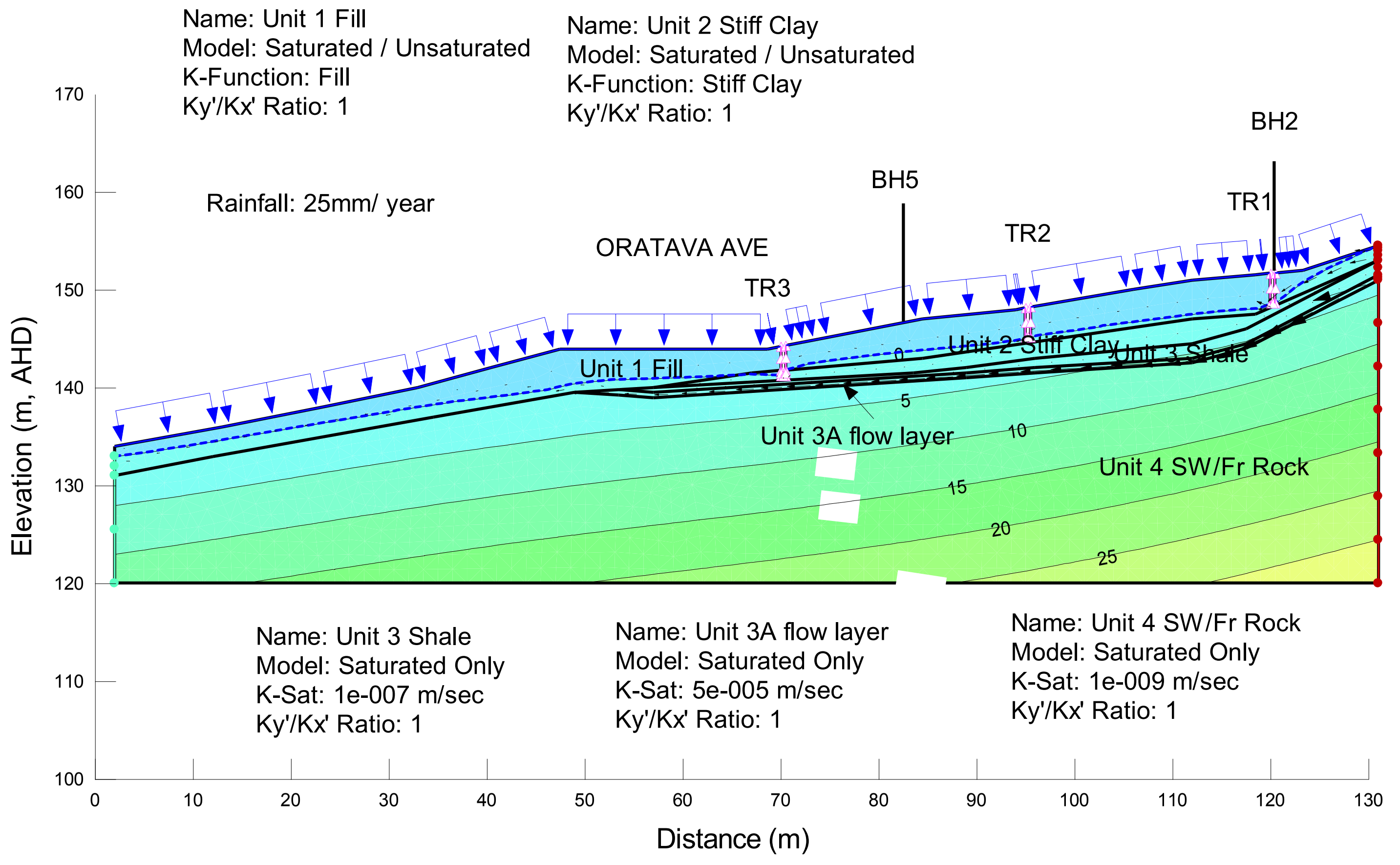
Plot 1

55 Oratava Avenue West Penant Hills
Section 2 seepw-R01 Base model.gsz
Steady-State Seepage



Plot 2

55 Oratava Avenue West Penant Hills
Section 2 seepw-R02 trench.gsz
Steady-State Seepage



Name: Unit 1 Fill
Model: Saturated / Unsaturated
K-Function: Fill
Ky'/Kx' Ratio: 1

Name: Unit 2 Stiff Clay
Model: Saturated / Unsaturated
K-Function: Stiff Clay
Ky'/Kx' Ratio: 1

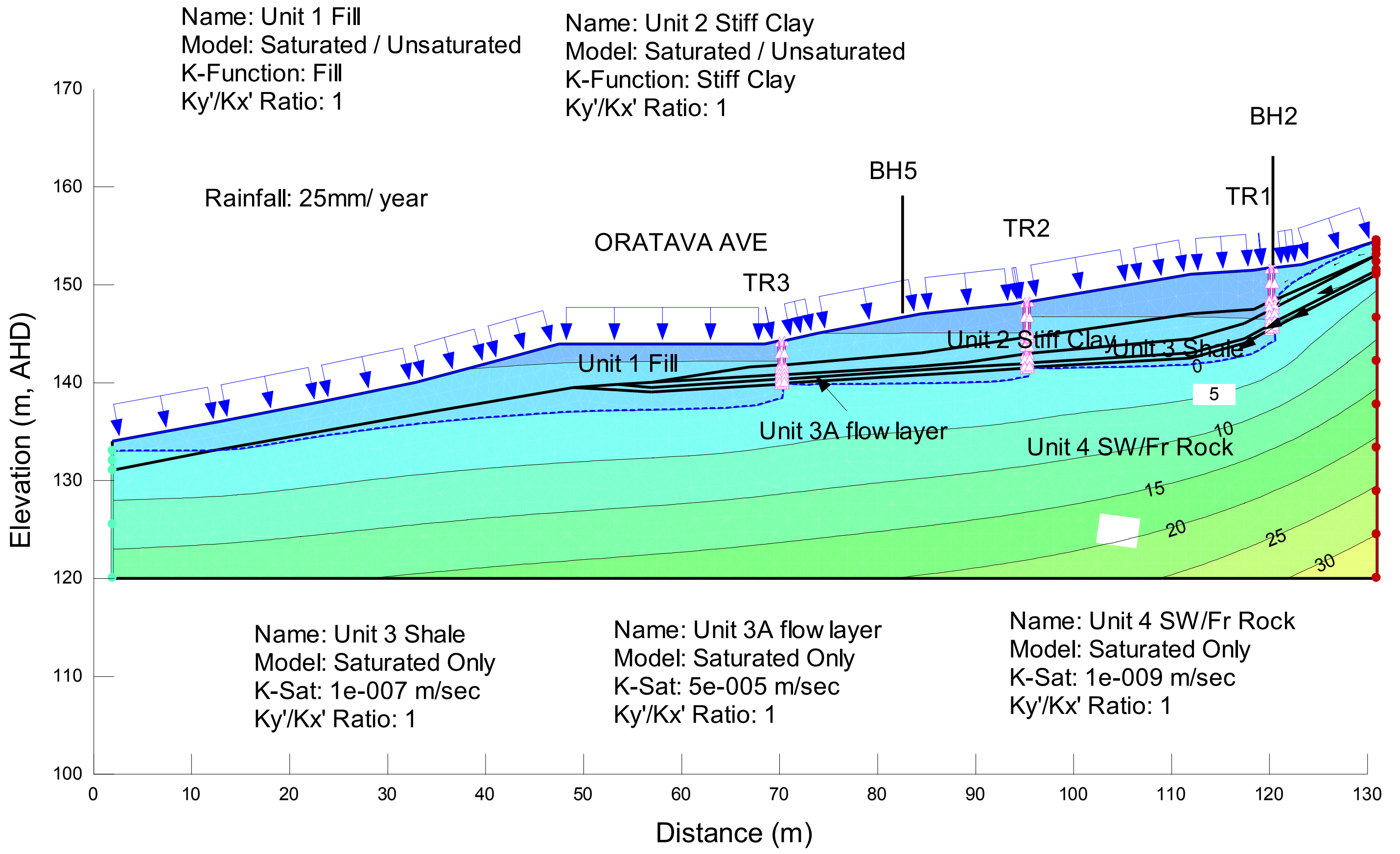
Name: Unit 3 Shale
Model: Saturated Only
K-Sat: 1e-007 m/sec
Ky'/Kx' Ratio: 1

Name: Unit 3A flow layer
Model: Saturated Only
K-Sat: 5e-005 m/sec
Ky'/Kx' Ratio: 1

Name: Unit 4 SW/Fr Rock
Model: Saturated Only
K-Sat: 1e-009 m/sec
Ky'/Kx' Ratio: 1

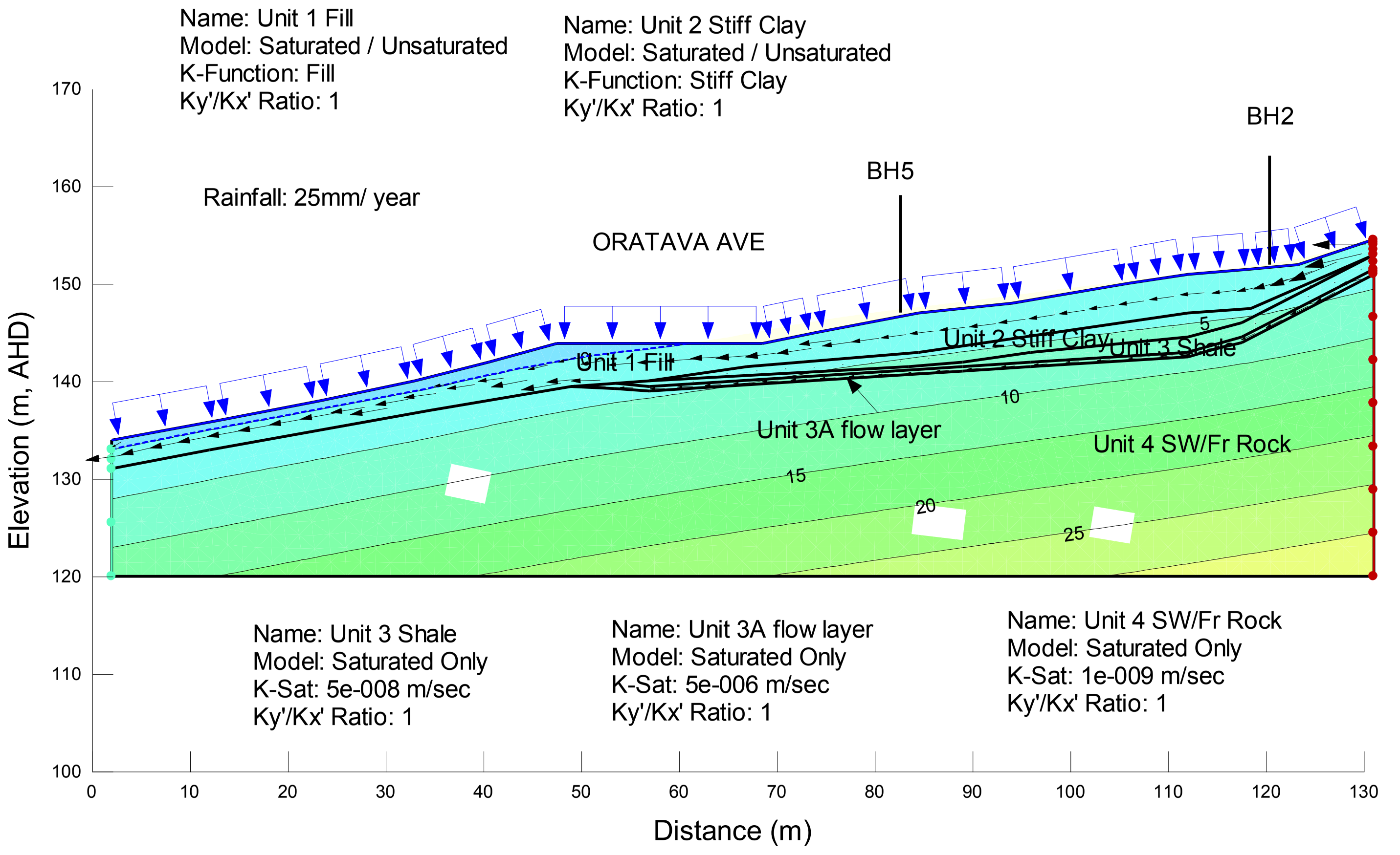
Plot 3

55 Oratava Avenue West Penant Hills
Section 2 seepw-R03 Chimney.gsz
Steady-State Seepage



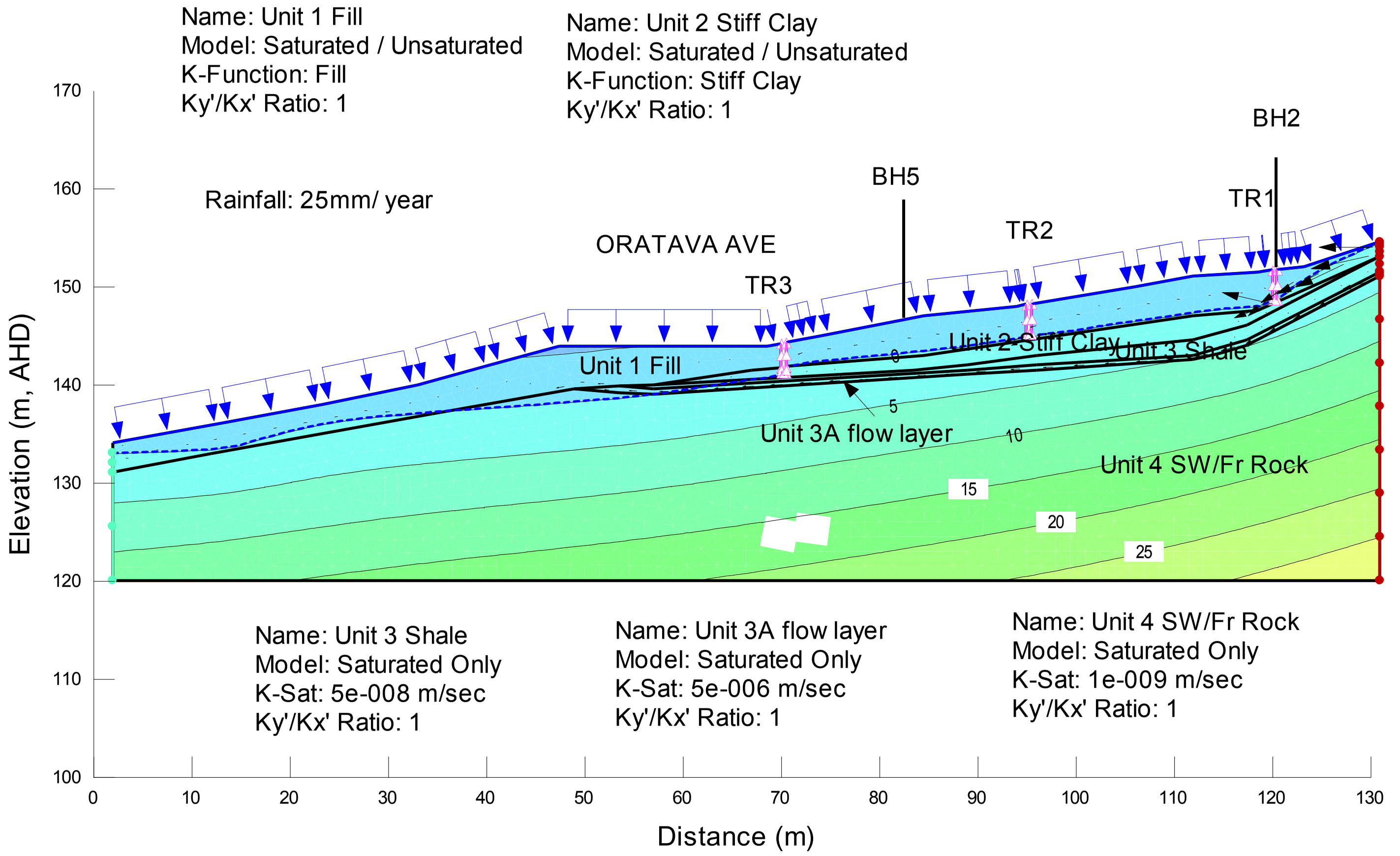
Plot 4

55 Oratava Avenue West Penant Hills
Section 2 seepw-R04 Base model LB.gsz
Steady-State Seepage



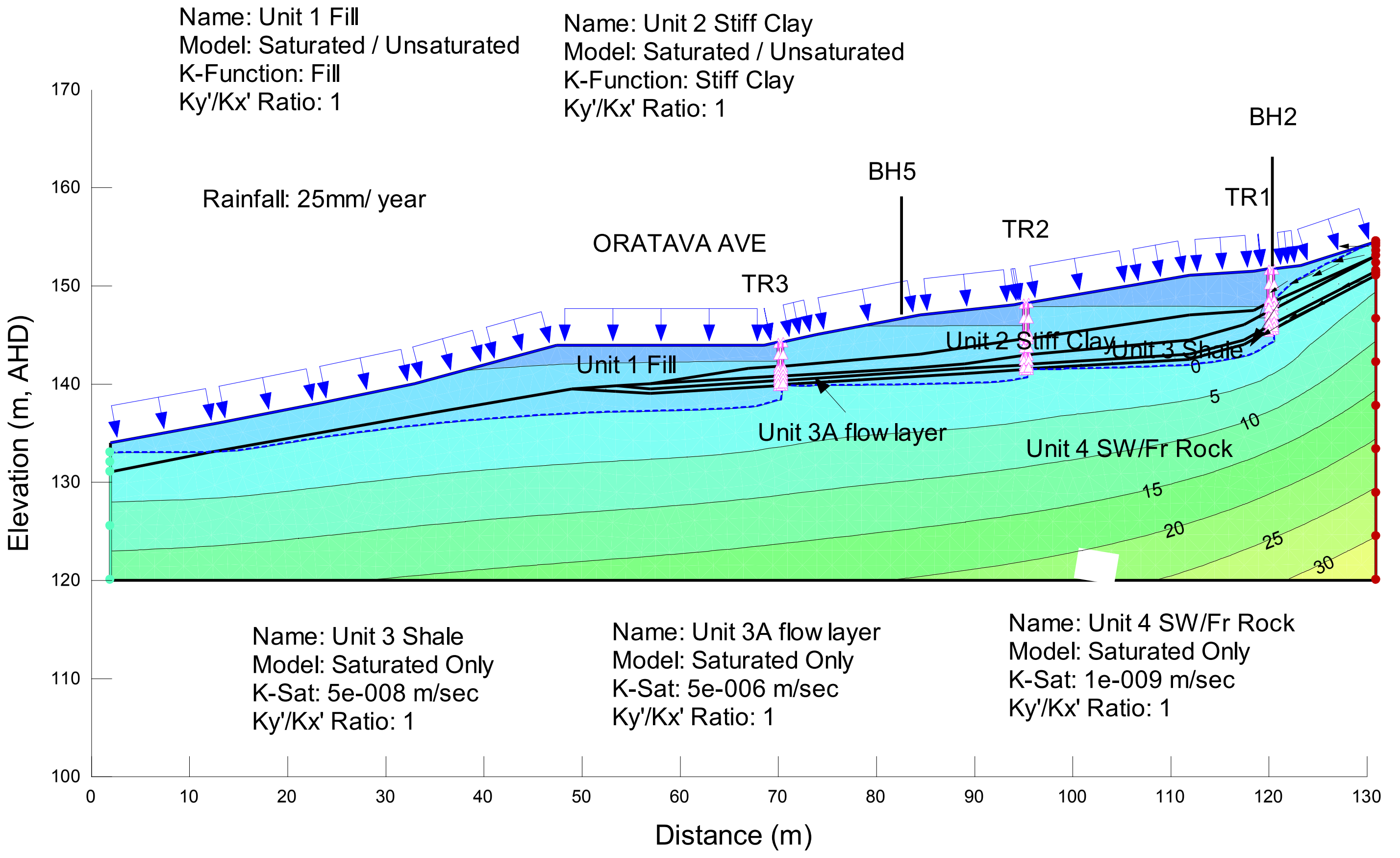
Plot 5

55 Oratava Avenue West Penant Hills
Section 2 seepw-R05 trench-LB.gsz
Steady-State Seepage



Plot 6

55 Oratava Avenue West Penant Hills
Section 2 seepw-R06 Chimney LB.gsz
Steady-State Seepage



Name: Unit 1 Fill
Model: Saturated / Unsaturated
K-Function: Fill
Ky'/Kx' Ratio: 1

Name: Unit 2 Stiff Clay
Model: Saturated / Unsaturated
K-Function: Stiff Clay
Ky'/Kx' Ratio: 1

Name: Unit 3 Shale
Model: Saturated Only
K-Sat: 5e-008 m/sec
Ky'/Kx' Ratio: 1

Name: Unit 3A flow layer
Model: Saturated Only
K-Sat: 5e-006 m/sec
Ky'/Kx' Ratio: 1

Name: Unit 4 SW/Fr Rock
Model: Saturated Only
K-Sat: 1e-009 m/sec
Ky'/Kx' Ratio: 1

55 Oratava Ave WPH - Section 3 SEEP/W Analysis:

Introduction

- Section 3 was adopted for Seep/W analysis, about 130 m in length.
- Hydraulic head was assigned at both upstream and downstream boundaries to coincide with the groundwater monitored in relevant boreholes.
- Four units of material were considered in the model. The parameters are summarised in the table below.
- The saturated permeability for each unit was estimated from the field rising water head test data performed in 2002 and 2015.

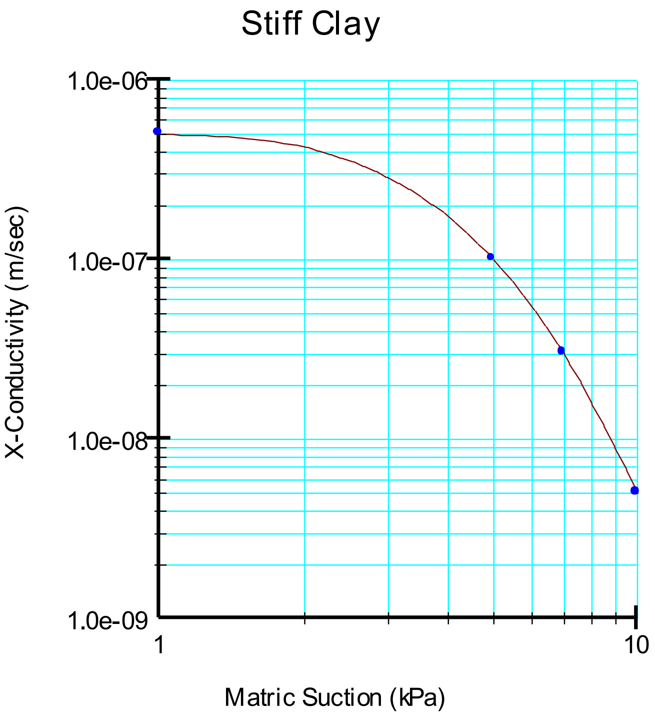
Modelling Assumptions

- Upstream boundary: RL 165 m
- Downstream boundary: RL 142 m
- A water infiltration of about 25 mm/year due to rain storm event was included in the model based on past experience from previous project in this area.

Geotechnical model and parameters

Unit	Material	Saturation	Saturated permeability k (m/sec)	
			Base case	Lower bound case
1	Fill	Sat/Unsat	1e-05	1e-05
2	Stiff clay	Sat/Unsat	5e-07	1e-07
3	Shale	Saturated	1e-07	5e-08
3A	High permeable flow layer	Saturated	5e-05	5e-06
4	Shale	Saturated	1e-09	1e-09

In the Seep/W programme Unit 1 and Unit 2 was modelled with Sat/Unsat material where Permeability is allowed to vary with suction. A variable function chosen for Unit 1 and Unit 2 material where a metric suction of 10 kPa corresponds to a reduced permeability of two order of magnitude. The following plot shows the unsaturated permeability characteristics of unit 2 stiff clay.



A half a metre thick high permeable flow layer (unit 3A) was assumed to exist at the interface with the underlying SW/Fr shale.

Results

- Plot 1 - Base model simulation (ie. no trench drains). It is noted that on 29 April 2105 BH10, located in the vicinity of Section 3, recorded a groundwater at about 1.9 m below ground surface. However groundwater level was analysed to be at about 4.1 m below ground surface in the BH10 area. Across and at BH1, which has an offset of about 15m from Section 3, the groundwater table was analysed to be at about 7 m below the surface as compared to the field measured 1.5 m below ground surface.
- Plot2 - Base model simulation with inclusion of 3 m deep trench drains.
- Plot3 - Base model simulation with inclusion of chimney drains installed at the bottom of trench drains to intercept the permeable layer, ie. Unit 3A.
- Plot 4 - Base model with use of lower bound permeability for Unit 2, Unit 3 and Unit 3A. Groundwater level at or near BH10 and BH1was analysed to be at about 2.4 m and 4.1 m below ground surface respectively.
- Plot 5 – As Plot 4, but with inclusion of 3 m deep trench drains. Highest groundwater at about 2.5 m was analysed at the western end of the slope section.
- Plot 6 – As Plot 5, but with inclusion of chimney drains installed at the bottom trench drains to intercept the permeable layer, ie. Unit 3A.

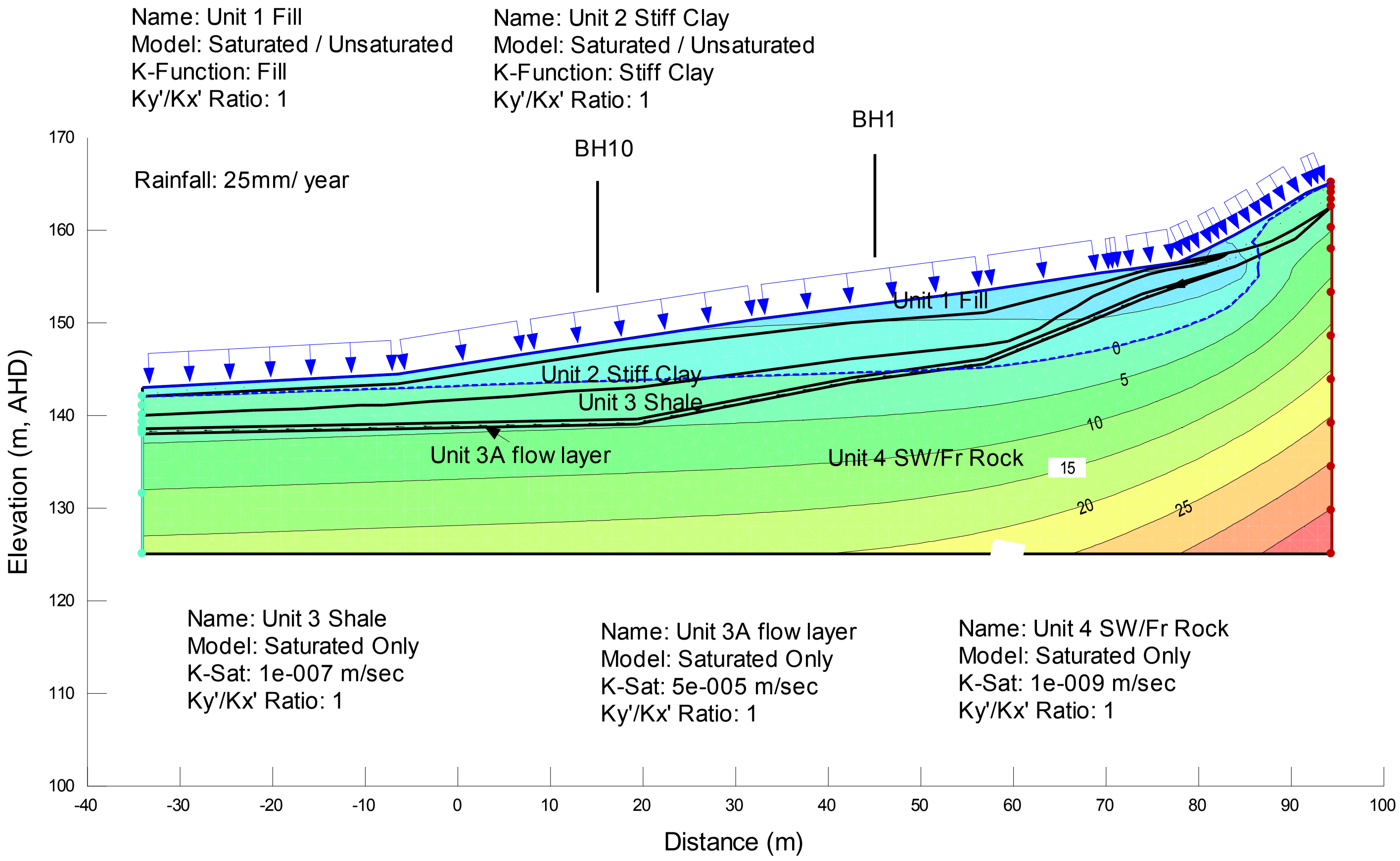
Observation

- For Section 3, subject to detailed design, trench drains + chimney drains may only be required at the western end of the slope section.

- Spacing and size of chimney drains to be determined and confirmed in detailed design phase. Currently it has been assumed that they have the same water carrying capacity as the trench drains.
- Section 2 appears more critical than Section 3, and needs to be analysed due to observed springs and measured high static groundwater

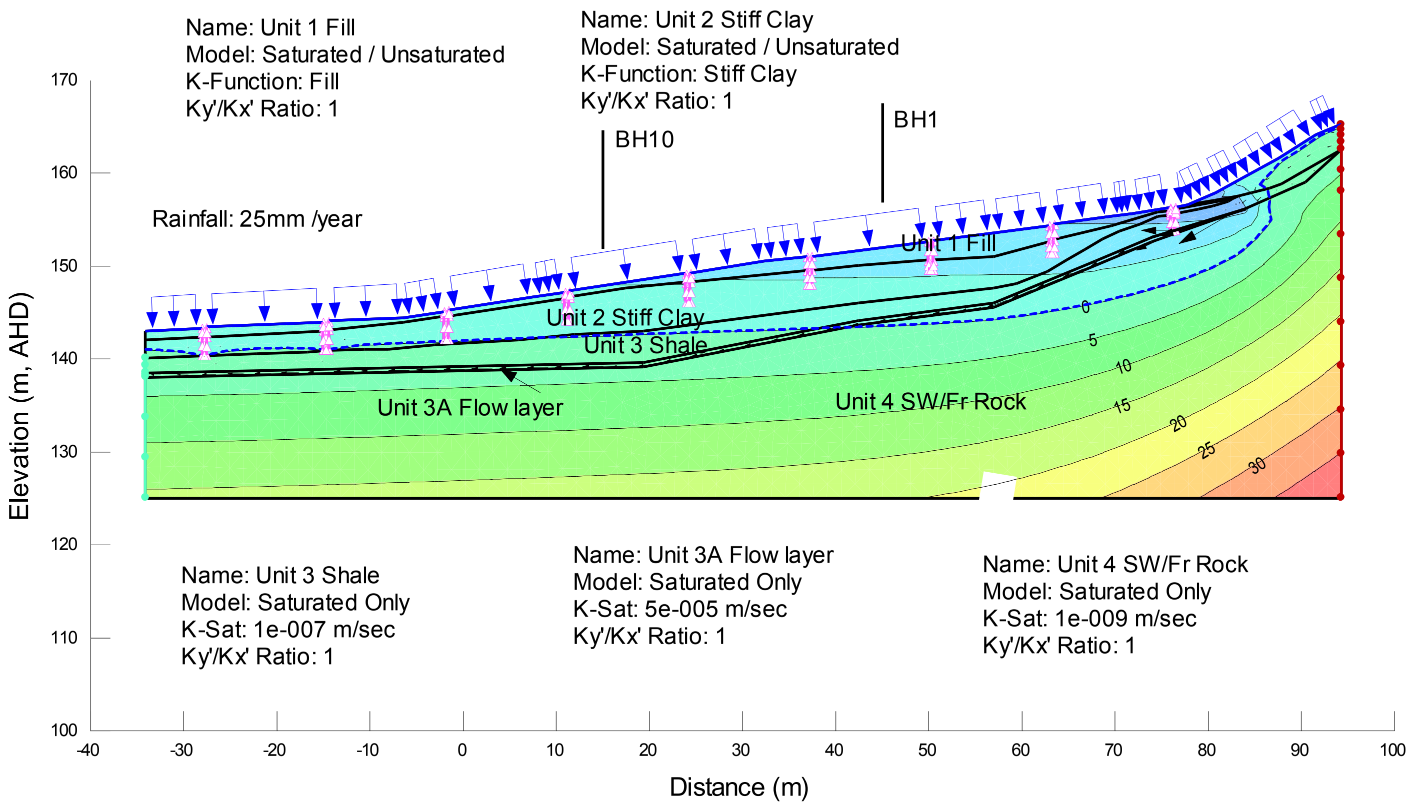
Plot 1

55 Oratava Avenue West Penant Hills
Section 3 seepw-Base model.gsz
Steady-State Seepage



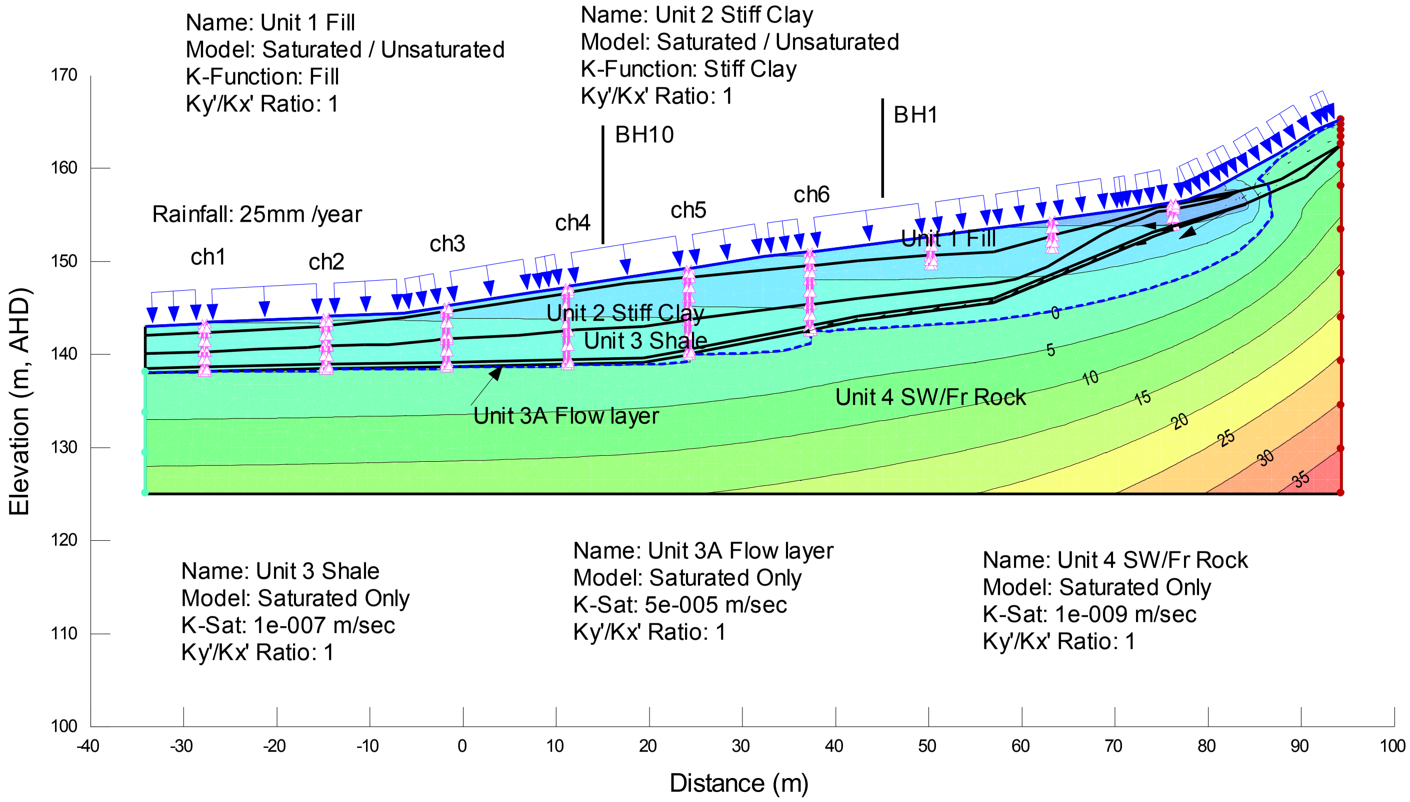
Plot 2

55 Oratava Avenue West Penant Hills
Section 3 seepw-R03 trench.gsz
Steady-State Seepage



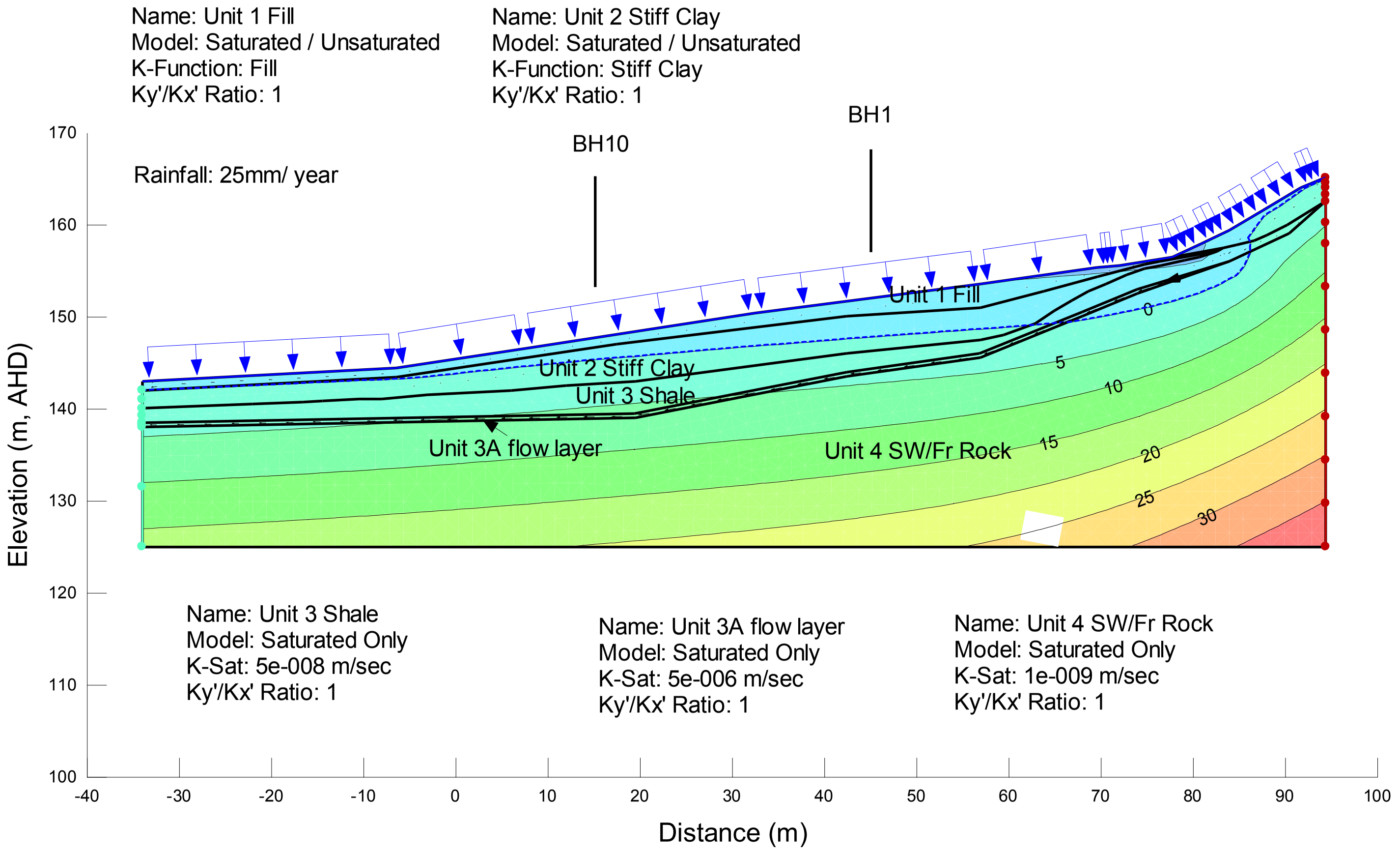
Plot 3

55 Oratava Avenue West Penant Hills
Section 3 seepw-R04 chimney.gsz
Steady-State Seepage



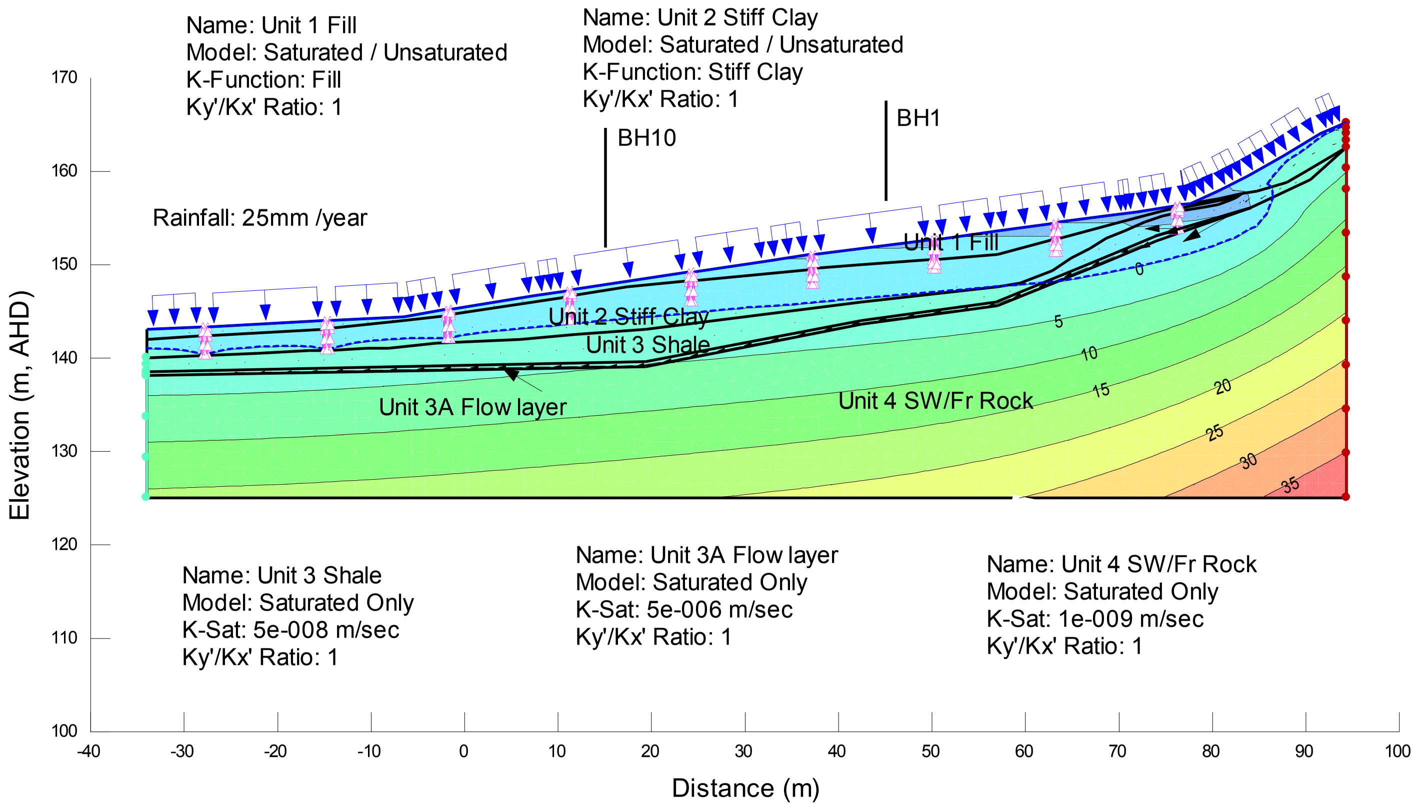
Plot 4

55 Oratava Avenue West Penant Hills
Section 3 seepw-R04 Base model-LB.gsz
Steady-State Seepage



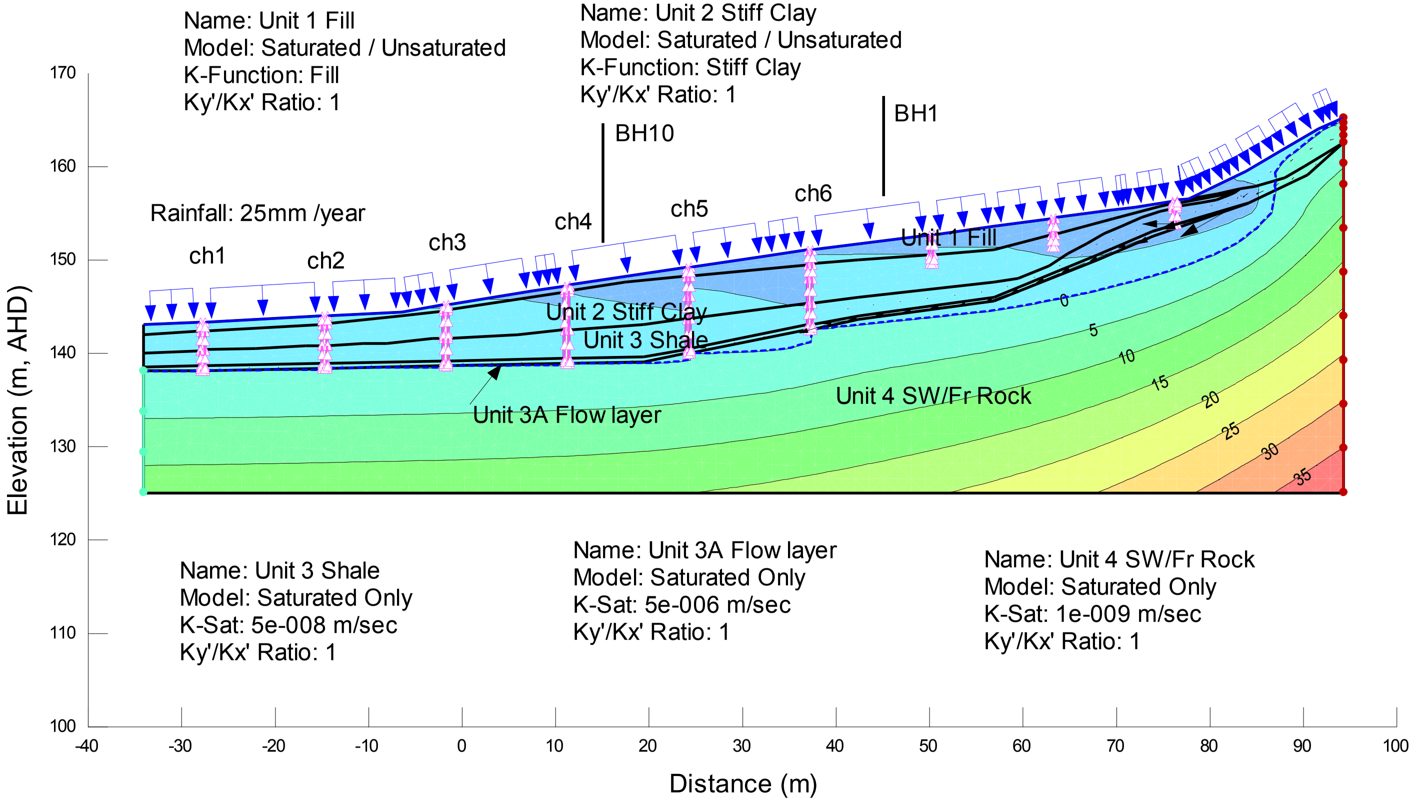
Plot 5

55 Oratava Avenue West Penant Hills
Section 3 seepw-R05 trench LB.gsz
Steady-State Seepage



Plot 6

55 Oratava Avenue West Penant Hills
Section 3 seepw-R06 chimney LB.gsz
Steady-State Seepage



APPENDIX G

Landslide Risk Assessment

Summary	6 pages
AGS 2007 Extracts	8 pages

APPENDIX G

LANDSLIDE RISK ASSESSMENT AND MANAGEMENT
NO.39 – 55 (LOT 8 DP1191647) ORATAVA AVE
AND PART OF NO.570 (LOT 3 DP1096405) PENNANT HILLS RD
WEST PENNANT HILLS NSW

G1 Geotechnical Constraints/Suitability of Development

The geotechnical constraints assessed for residential development on this site comprise hazards related to slope instability risk and foundation/footing conditions for building structures. These are discussed below.

G1.1 Risk Assessment Methodology

The risk of slope instability for this site has been assessed using the methods of the AGS March 2007 publication *Practice Note Guidelines for Landslide Risk Management 2007* (reference 1), as shown on the attached flow chart. Definitions of the terminology used are also provided in the attachments herewith.

Important factors relating to slope conditions and the impacts of development, which commonly influence the risks of slope instability, are discussed below.

The assessment has been carried out by:

- consideration of the likely slope failure mechanisms and likely initiating circumstances which could affect the elements at the site. The type or mode of landslide failure has also been classified.
- for each case, the potential consequences with respect to any existing or future development have been considered. The current assessed probability of occurrence of each event has been estimated on a qualitative basis. The consequences and probability of occurrence have been combined for each case to provide the risk assessment.

The terms used to describe the consequences, probability of occurrence and risk are defined in the attached Appendix C extract from AGS 2007 "Landslide Risk Assessment – Qualitative Terminology for Use in Assessing Risk to Property". Reference is also made to geotechnical risk assessment procedures and background presented by Walker (2002) (reference 4) and to background data contained in the publication by Fell 2006 (reference 8).

G1.2 Hazards/Failure Mechanisms

Potential hazards or slope/structure failure mechanisms are considered, namely:-

❑ **Type F1(a)** – *deep-seated translational slide, Zone G4 (intermittent “stick-slip” creep movements)*

Slope creep movements of this mechanism have been recorded in the inclinometer monitoring, although only over a short period of time. The movements appear directly related to rainfall exceeding a certain threshold intensity. The recurrence interval for the rainfall threshold appears to be of the order of 10 years.

The assessed likelihood of creep movements continuing intermittently is LIKELY to ALMOST CERTAIN (range 10^{-1} to 10^{-2} per annum probability). The consequences for property damage are assessed to be no worse than MINOR, and more likely to be INSIGNIFICANT.

- **Type F1(b)** – *deep-seated translational slide, Zone G4 (reactivation, no scarp development)*

  This is a more severe development of movement in the existing creep landslide behaviour. The required trigger is considered to be an extremely severe or prolonged rainfall event or change in rainfall patterns exceeding a 100year return period.

  The assessed likelihood of such a development/change in the landslide behaviour occurring is POSSIBLE (10^{-3} per annum). The consequences for property damage in this case are assessed to be up to MEDIUM.

- **Type F1(c)** – *deep-seated translational slide, Zone G4, reactivation with scarp development*

  Further development of the landslide behavior to this degree is considered to be UNLIKELY (10^{-4} per annum), if not lower in all likelihood.

  Should the event occur, more severe consequences for property damage would be anticipated, assessed as up to MEDIUM, but not worse than MAJOR.

- **Type F2** – *slide in shale bedrock on steep slope (Zone G3 or G4)*

  Excavations on the steeper sloping areas of the site associated with subdivision works or building development are anticipated. Locally adverse rock structure or insitu conditions (weathered zones) may combine to cause local small-scale failures. Notwithstanding the requirement for geotechnical and other normal engineering controls, a likelihood for this hazard type is estimated as POSSIBLE (10^{-3} per annum).

  The consequence for property damage associated with this hazard is assessed to be MINOR. Due to the nature of the risk matrix, MEDIUM consequence level is also covered by the resulting risk outcome, although this severity of damage would be anticipated to have a lower likelihood.

G1.3 Risk Analysis

For each identified hazard/event, the elements of the new development at that would be considered to be at risk are road structures, stormwater drainage lines and equipment, residential and associated structure(s), services, and landscaping improvements. Table G1 provides a summary of the risk analysis for the proposed development.

TABLE G1 – Preliminary Risk Assessment (Property)

Hazard Failure Mechanism	**Severity of Failure**	**Estimated Likelihood of Occurrence**	**Estimated Consequence Level**	**Measure of Consequence**	**Estimated Risk**	
					No Slope Improvements	**With Management** (Note 1)
F1	(a)	ALMOST CERTAIN (10^{-1})	A(-)	INSIGNIFICANT	M	L
		LIKELY (10^{-2})	A	MINOR	M	M (Note 2)
	(b)	POSSIBLE (10^{-3})	B	MEDIUM	M	L
	(c)	UNLIKELY (10^{-4})	C	MEDIUM to MAJOR	L – M	L
F2	--	POSSIBLE (10^{-3})	--	MINOR to MEDIUM	M	L (Note 3)

NOTES (Table G1):

1. Slope improvements in Zone G4 to be targeted at achieving at least 1 order of magnitude lowering of likelihood for Hazard F1 (all severity levels).

2. Prudent restrictions on development and inclusion of engineering controls for subdivision and residential building works are intended for further risk reduction to ensure low risk outcome. Refer to body of this report.

3. For Hazard F2, engineering controls are to be implemented for developments in Zones G3 and G5, and for adjacent areas of Zone G4, to achieve at least 1 order of magnitude lowering of likelihood. Refer to body of this report.

Consequence Descriptions

A(-)	"Little" damage, can "live with" the problems. Estimated cost range <$15,000.
A	"Limited" damage to part of structure(s), eg Category 0 – 1 cracking and/or slab distress; similar severity of distress to pool and surrounds but serviceability maintained; some ground movements affecting landscaping, paving etc, can be readily repaired; in-ground services can accommodate movements with suitable design and installation. Estimated cost range $20,000 – $50,000.
B	"Moderate" damage to residence, eg Category 2 – 3 cracking and/or slab distress; similar severity of distress to pool and surrounds but can be repaired; landscaping and paving distorted, but repairable. Estimated cost range $120,000 – $150,000.
C	"Extensive" damage to residential structure, substantial repairs, eg Category 4 cracking/damage and/or slab distress; structural distress to pool, probably requiring reconstruction. Estimated cost range $400,000 – $600,000.

[Market value of developed property assumed to be at least $1.5M, for purposes of assessing % cost of damage for AGS 2007 risk assessment procedures]

General Notes (Table G1)

a) The above risk assessment addresses the consequences to property from potential landslide events considered relevant to the subject site. The risk assessment is based on a visual appraisal and limited subsurface investigation only (where undertaken), as discussed in the attached report. Further assessment or quantification of the assessed geotechnical risks for the subject property would require additional data and/or investigation.

b) Refer above and elsewhere in this report for description and illustration of possible hazards/slope failure mechanisms.

c) The consequences assessed for the proposed development assume the structures and works are designed, constructed and maintained in accordance with all relevant recommendations of this report.

d) Refer to report and attachments for definition and explanation of terms used in the risk assessment.

The risk outcomes in Table G1 above are **"acceptable".** The assessed risks are subject to maintenance and/or improvement of the present site conditions as discussed in the attached report, and to further geotechnical review should these conditions alter significantly in the future.

Examples of recommended hillside development and construction practice are provided in the attachments to this report. Where relevant, the examples provide guidance for future development on this site, and should be incorporated in the development.

For risk to life, it is assessed that the low likelihood of damage to a dwelling within Zone G4 for the dominant geotechnical hazard F1 at this site, together with the low vulnerability (given the nature and severity levels for the hazard) and taking into account the probability of evacuation from the dwelling in the event of the hazard occurring, would yield a very low risk level for persons. The risk level is estimated to be approximately 2 orders of magnitude lower than the acceptable value of 10^{-6} per annum for the person most at risk.

If required, specific risk assessments can be verified when building designs and other elements of the future developments are known. At the present stage of the subdivision assessment, it is concluded that the geotechnical risk associated with future development on the site is readily capable of achieving an ***acceptable risk level*** in accordance with normal standards.

G1.4 Engineering Requirements

The engineering recommendations elsewhere in this report are to be implemented and followed for the subdivision design and construction works, and for all residential building.

It is assumed that the conditions of approval for the subdivision will be supported and strengthened by suitable 88B or equivalent Conditions on the titles of the future building allotments embracing the recommendations herein.

G2 Ongoing Site Management / General Slope Maintenance / Risk Reduction

1. Drainage structures, retaining walls and general slope conditions within the property are to be inspected and maintained by the owner/proprietor. Unless required otherwise by recommendations elsewhere in this report, the minimum maintenance regime should be in accordance with the table below.

Recommended Maintenance and Inspection Programme

Structure/Feature	Maintenance/Inspection Task	Frequency
Drainage Lines	Inspect to ensure line is flowing and not blocked	Every year or during and following each significant rainfall event
Drainage Pits	Inspect to ensure that pits are free of debris and sediment build-up. Clear surface grates of vegetation and litter	During normal grounds maintenance and during and following each significant rainfall event, but not less frequently than every year
Retaining Walls	Inspect walls for deviation from as-constructed condition (tilting, rotation, lateral movement), and for signs of structural distress	Every 5 years or following each significant rainfall event
	Inspect and flush drainage lines behind wall	
	Maintain collector drain along top of wall	Every year or during and following each significant rainfall event
	Maintain sealed ground surface at top of wall to prevent infiltration of surface water into drainage behind wall	
General slope areas	Inspect for possible erosion, tension cracks, fretting of rock faces or block rotation on ledges or cliff lines	Every 5 years or following each significant rainfall event

2. Maintain the functional performance of all retaining walls, and their associated drainage components, in general in accordance with the design requirements and maintenance specified on the structural drawings or other supplied details.

3. In the case of (a) retaining walls or their essential components, (b) drainage essential to slope stabilisation, or (c) other components of the development that determine the geotechnical hazards, where the structural or civil engineer responsible for design has indicated a design life of less than 100 years, the structure and/or its structural elements must be inspected by a structural or civil engineer (as appropriate) at the end of the design life. The engineer shall issue a written report identifying the required remedial measures to extend the design life of the structure and its essential components over the remaining portion of the 100 year period.

4. A Geotechnical Engineer should be engaged to undertake an assessment relating to slope instability risk, should changes occur to the natural site features or to the development on this or adjoining property that adversely affect the risk of slope instability of the land or the development thereon.

IMPORTANT FACTORS INFLUENCING ASSESSMENT OF STABILITY OF SLOPES FOR URBAN/RESIDENTIAL DEVELOPMENT

1. Limitations of the Assessment Procedure

The assessment procedures carried out for this appraisal are in accordance with the recommendations of the AGS Risk Classification System described in Appendix H, and with accepted local practice. The following limitations must be acknowledged:-

- ◊ the assessment of the stability of natural slopes requires a great degree of judgment and personal experience, even for experienced practitioners with good local knowledge;
- ◊ the assessment must be based on development of a sound geological model; slope processes and process rates influencing landsliding or landslide potential will vary according to geomorphological influences;
- ◊ the likelihood that landsliding may occur on a given slope is generally hard to predict and is associated with significant uncertainties;
- ◊ different practitioners may produce different assessments of risk;
- ◊ actual risk of landsliding cannot be determined; risk changes with time;
- ◊ consequences of landsliding need to be considered in a rational framework of risk acceptance;
- ◊ acceptable risk in relation to damage to property from landslide activity is subjective; it remains the responsibility of the owner and/or local authority to decide whether the risk is acceptable; the geotechnical practitioner can assist with this judgement;
- ◊ the extent and methods of investigation for assessment of landslide risk will be governed by experience, by the perceived risk level, and by the degree to which the risk or consequences of landsliding are accepted for a specific project.
- ◊ the assessment may be required at a number of stages of the project or development; frequently (due to time or budget constraints imposed by the client) there will be no opportunity for long-term monitoring of the slope behaviour or groundwater conditions, or for on-going opportunity for the slope processes and performance of structures to be reviewed during and after development; such limitations should be recognised as relevant to the assessment.

2. Slope Instability

In the Sydney Basin region, natural slope instability is mostly confined to the talus or colluvial material, but in some cases occurs in the residual clay soil overburden. The underlying bedrock on natural slopes, even in highly weathered form, is generally stable. Exceptions can occur and are known, particularly in the Illawarra and Newcastle regions.

In most of the reported slope failures in the Sydney Basin region, the cause of failure may be traced to one of the following factors:

(i) interference with natural drainage features,

(ii) introduction of additional water to the area,

(iii) excavation or removal of soil or rock from the toe (bottom) of the slope,

(iv) addition of soil or rock to the top of the slope.

There have been some slope failures with no immediately apparent cause and it is our opinion that these failures resulted from natural changes in the groundwater conditions in the slope during or some time after very heavy or prolonged periods of rainfall.

Continuing or intermittent downslope soil movement is an on-going natural geological process. It may be modified (accelerated or slowed) by the activities of man. Such movements become of concern when their magnitudes or rates have the potential to threaten the integrity of man-made improvements or threaten life or safety. A broad assessment of slope stability risk is presented in this report and it should be recognised that there is always a possibility that unpredicted slope movements can occur.

Developments can be designed to tolerate, or be isolated from, the effects of minor slope movements. Geotechnical assessment and design input, and monitoring will usually be required for such purposes.

In the case of creeping hillslopes, design that isolates the structure from the effects of slope creep is preferable. For example, retaining walls should be separated from the house structure so that if they move as a result of soil creep or other slope influences, the movements are not transmitted to the house. Where this cannot be achieved for the design, significant strengthening of the structure and/or its foundations, or other measures to modify the potential for slope movements, or the capacity of the structure to accommodate slope movements, will be required.

3 Development on Slopes

3.1 General

Some risk of slope instability is always attached to the development of land on slopes formed on talus and colluvium, and on residual soils. Appendix G explains the various levels of risk normally expected for development of land on such slopes and gives some guidelines for hillside construction.

3.2 Effects of Construction on Slope Stability

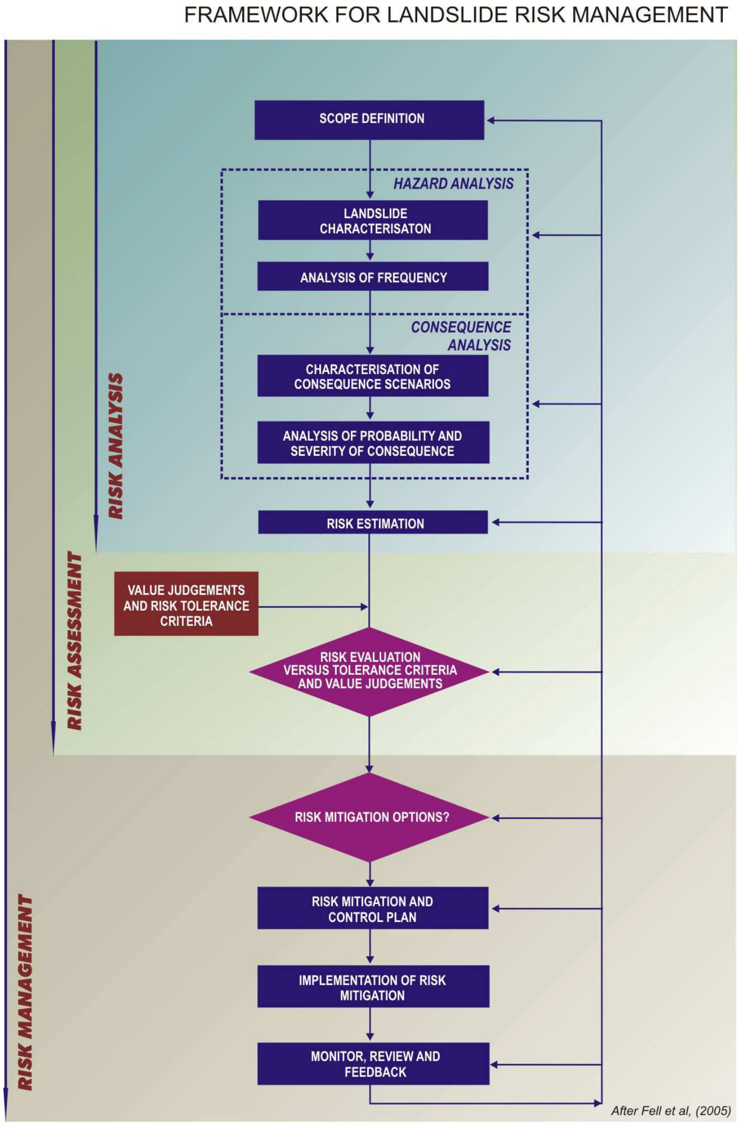
The stability of apparently stable land may be adversely affected by various activities on the land or in the vicinity, as follows:

- the diversion of surface water onto the land by new roads, houses, landscaping, or other construction activities,
- the placing of filling either above or beside the land,
- the excavation or removal of soil or rock from the area below (downhill) of the land,
- the construction of absorption areas for stormwater or effluent, or other systems whereby liquids are introduced into the soil and rock.

3.3 Effects of Drainage on Slope Stability

Good surface and subsurface drainage will almost always improve the stability of a slope. Where a new structure, modifications to an existing structure or landscaping is proposed on a slope, it is highly likely that some form of surface or subsurface drainage will be required to maintain or improve the stability of the slope.

A geotechnical engineer should review all proposed construction, developments or alterations on slopes, to assess the effect on slope stability and any required drainage.


FRAMEWORK FOR LANDSLIDE RISK MANAGEMENT

After Fell et al, (2005)

Figure 1.

The Framework for LRM presented in Figure 1 is similar to the flow chart in AGS (2000). However, it has been simplified in presentation and has been amended slightly from AGS (2000) to reflect the inclusion of Frequency Analysis as part of Hazard Analysis (in accordance with the abovementioned definition of hazard and as defined in AGS 2000).

Definitions for associated terminology have also been included in Appendix A together with an explanation of Landslide Risk as presented in AGS Australian GeoGuide LR7.

PART B GUIDELINES FOR REGULATORS

3 GUIDELINES FOR REGULATORS

3.1 BACKGROUND

The term landslide denotes *“the movement of a mass of rock, debris or earth down a slope”*. The phenomena described as landslides are not limited to either “land” or to “sliding” and usage of the word has implied a much more extensive meaning than its component parts suggest. The rates of movement cover the full range from very rapid to extremely

Picarellei, L., Oboni, F., Evans, S.G., Mostyn, G. and Fell, R., (2005) *"Hazard characterization and quantification"* Proc Int Conf on Landslide Risk Management, Vancouver, 31 May-3 June 2005, AA Balkema Publ, O. Hungr, R. Fell, R. Couture and E. Eberhardt eds., pp681

Varnes, D.J. and The International Association of Engineering Geology Commission on Landslides and other Mass Movements (1984). Landslide Hazard Zonation: A review of principles and practice. Natural Hazards, Vol 3, Paris,France. UNESCO, 63p.

Standards Australia (1996) *"Residential Slabs and Footings"* Australian Standard AS2870

Standards Australia (2001) *"Concrete Structures"* Australian Standard AS3600

Standards Australia (2001) *"Steel Structures"* Australian Standard AS4100

Standards Australia (2002) *"Earth Retaining Structures"* Australian Standard AS4678.

APPENDIX A - DEFINITION OF TERMS AND LANDSLIDE RISK

RISK TERMINOLOGY

Acceptable Risk – A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.

Annual Exceedance Probability (AEP) – The estimated probability that an event of specified magnitude will be exceeded in any year.

Consequence – The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.

Elements at Risk – The population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.

Frequency – A measure of likelihood expressed as the number of occurrences of an event in a given time. See also Likelihood and Probability.

Hazard – A condition with the potential for causing an undesirable consequence (the landslide). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the likelihood of their occurrence within a given period of time.

Individual Risk to Life – The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.

Landslide Activity – The stage of development of a landslide; pre failure when the slope is strained throughout but is essentially intact; failure characterised by the formation of a continuous surface of rupture; post failure which includes movement from just after failure to when it essentially stops; and reactivation when the slope slides along one or several pre-existing surfaces of rupture. Reactivation may be occasional (eg seasonal) or continuous (in which case the slide is "active").

Landslide Intensity – A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, kinetic energy per unit area.

Landslide Risk - The AGS Australian GeoGuide LR7 (AGS, 2007e) should be referred to for an explanation of Landslide Risk.

Landslide Susceptibility – The classification, and volume (or area) of landslides which exist or potentially may occur in an area or may travel or retrogress onto it. Susceptibility may also include a description of the velocity and intensity of the existing or potential landsliding.

Likelihood – Used as a qualitative description of probability or frequency.

Probability – A measure of the degree of certainty. This measure has a value between zero (impossibility) and 1.0 (certainty). It is an estimate of the likelihood of the magnitude of the uncertain quantity, or the likelihood of the occurrence of the uncertain future event.

There are two main interpretations:

(i) Statistical – frequency or fraction – The outcome of a repetitive experiment of some kind like flipping coins. It includes also the idea of population variability. Such a number is called an "objective" or relative frequentist probability because it exists in the real world and is in principle measurable by doing the experiment.

(ii) Subjective probability (degree of belief) – Quantified measure of belief, judgment, or confidence in the likelihood of an outcome, obtained by considering all available information honestly, fairly, and with a minimum of bias. Subjective probability is affected by the state of understanding of a process, judgment regarding an evaluation, or the quality and quantity of information. It may change over time as the state of knowledge changes.

Qualitative Risk Analysis – An analysis which uses word form, descriptive or numeric rating scales to describe the magnitude of potential consequences and the likelihood that those consequences will occur.

Quantitative Risk Analysis – An analysis based on numerical values of the probability, vulnerability and consequences and resulting in a numerical value of the risk.

Risk – A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability x consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.

Risk Analysis – The use of available information to estimate the risk to individual, population, property, or the environment, from hazards. Risk analyses generally contain the following steps: Scope definition, hazard identification and risk estimation.

Risk Assessment – The process of risk analysis and risk evaluation.

Risk Control or **Risk Treatment** – The process of decision making for managing risk and the implementation or enforcement of risk mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.

Risk Estimation – The process used to produce a measure of the level of health, property or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis and their integration.

Risk Evaluation – The stage at which values and judgments enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental and economic consequences, in order to identify a range of alternatives for managing the risks.

Risk Management – The complete process of risk assessment and risk control (or risk treatment).

Societal Risk – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental and other losses.

Susceptibility – see Landslide Susceptibility

Temporal Spatial Probability – The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.

Tolerable Risk – A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible.

Vulnerability – The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.

ASSOCIATED TERMINOLOGY

Importance Level – of a building or structure is directly related to the societal requirements for its use, particularly during or following extreme events. The consequences with respect to life safety of the occupants of buildings are indirectly related to the Importance Level, being a result of the societal requirement for the structure rather than the reason *per se* of the Importance Level.

Authority or **Council** having statutory responsibility for community activities, community safety and development approval or management of development within its defined area/region.

The **Regulator** will be the responsible body/authority for setting Acceptable/Tolerable Risk Criteria to be adopted for the community/region/activity, which will be the basis for setting levels for Acceptable and Tolerable Risk in the application of the risk assessment guidelines.

Importance Level of Structure	Explanation	Examples (Regulatory authorities may designate any structure to any classification type when local conditions make such desirable)
1	Buildings or structures generally presenting a low risk to life and property (including other property).	Farm buildings. Isolated minor storage facilities. Minor temporary facilities. Towers in rural situations.
2	Buildings and structures not covered by Importance Levels 1, 3 or 4.	Low-rise residential construction. Buildings and facilities below the limits set for Importance Level 3.
3	Buildings or structures that as a whole may contain people in crowds, or contents of high value to the community, or that pose hazards to people in crowds.	Buildings and facilities where more than 300 people can congregate in one area. Buildings and facilities with primary school, secondary school or day-care facilities with capacity greater than 250. Buildings and facilities for colleges or adult education facilities with a capacity greater than 500. Health care facilities with a capacity of 50 or more residents but no having surgery or emergency treatment facilities. Jails and detention facilities. Any occupancy with an occupant load greater than 5,000. Power generating facilities, water treatment and waste water treatment facilities, any other public utilities not included in Importance Level 4. Buildings and facilities not included in Importance Level 4 containing hazardous materials capable of causing hazardous conditions that do not extend beyond property boundaries.
4	Buildings or structures that are essential to post-disaster recovery, or with significant post-disaster functions, or that contain hazardous materials.	Buildings and facilities designated as essential facilities. Buildings and facilities with special post-disaster functions. Medical emergency or surgery facilities. Emergency service facilities: fire, rescue, police station and emergency vehicle garages. Utilities required as back-up for buildings and facilities of Importance Level 4. Designated emergency shelters. Designated emergency centres and ancillary facilities. Buildings and facilities containing hazardous (toxic or explosive) materials in sufficient quantities capable of causing hazardous conditions that extend beyond property boundaries.

(from BCA Guidelines)

Practitioner – A specialist Geotechnical Engineer or Engineering Geologist who is degree qualified, is a member of a professional institute and who has achieved chartered professional status – being either Chartered Professional Engineer (CPEng) within the Institution of Engineers Australia, Chartered Professional Geologist (CPGeo) within the Australasian Institute of Mining & Metallurgy, or Registered Professional Geoscientist (RPGeo) within the Australian Institute of Geoscientists – specifically with Landslide Risk Management as a core competency.

A Practitioner will include persons qualified under the Institution of Engineers Australia NPER – LRM register.

It would normally be required that the Practitioner can demonstrate an appropriate minimum period of experience in the practice of landslide risk assessment and management in the geographic region, or can demonstrate relevant experience in similar geological settings.

Regulator – The regulatory authority [Federal Government/ State Government/ Instrumentality/ Regional/Local.

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	Notional Boundary					
10^{-1}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-6}$	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		Description	Descriptor	Level
Indicative Value	Notional Boundary			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		**CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)**				
	Indicative Value of Approximate Annual Probability	**1: CATASTROPHIC 200%**	**2: MAJOR 60%**	**3: MEDIUM 20%**	**4: MINOR 5%**	**5: INSIGNIFICANT 0.5%**
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.

(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

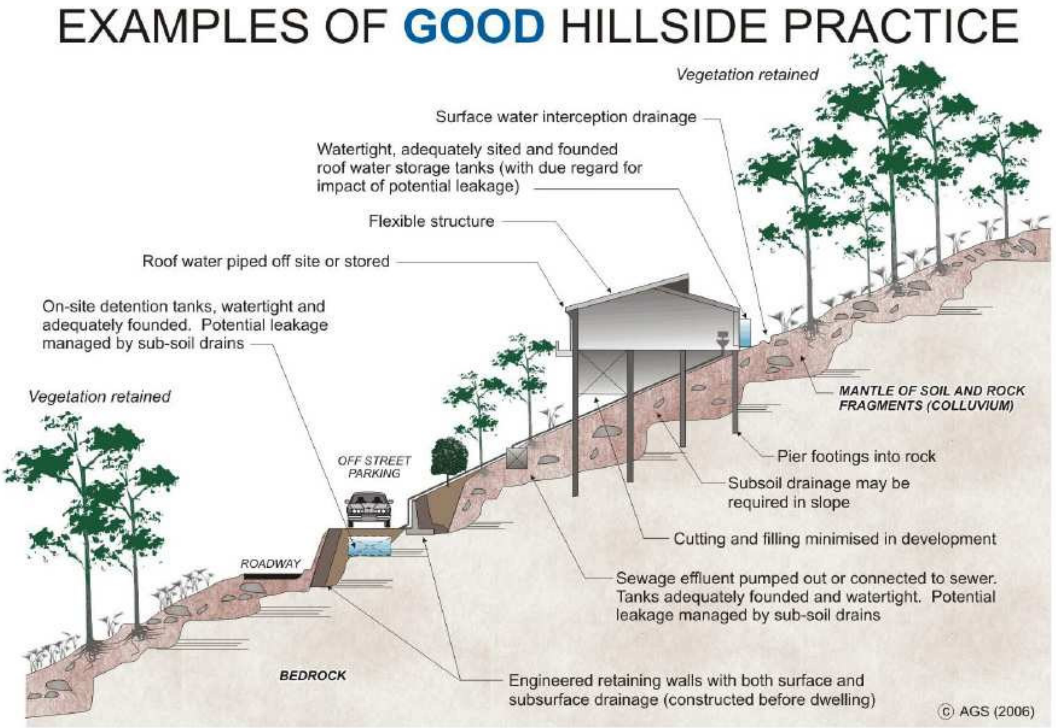
Risk Level		**Example Implications** (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

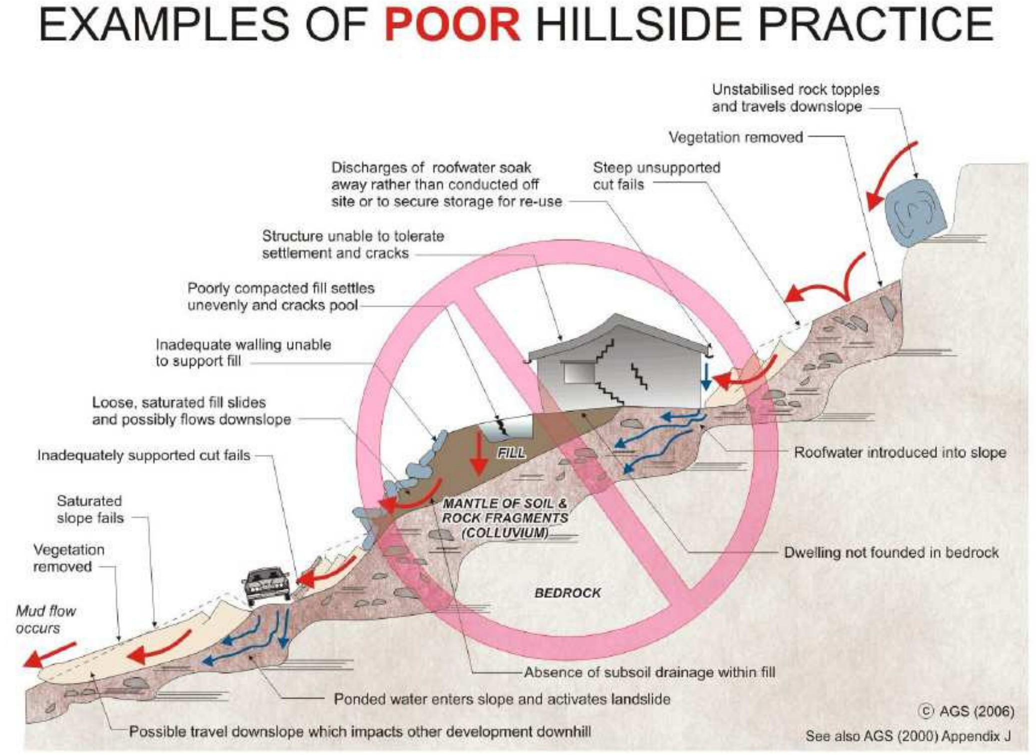
Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	


EXAMPLES OF GOOD HILLSIDE PRACTICE
Vegetation retained
Surface water interception drainage
Watertight, adequately sited and founded roof water storage tanks (with due regard for impact of potential leakage)
Flexible structure
Roof water piped off site or stored
On-site detention tanks, watertight and adequately founded. Potential leakage managed by sub-soil drains
Vegetation retained
MANTLE OF SOIL AND ROCK FRAGMENTS (COLLUVIUM)
OFF STREET PARKING
Pier footings into rock
Subsoil drainage may be required in slope
Cutting and filling minimised in development
ROADWAY
Sewage effluent pumped out or connected to sewer. Tanks adequately founded and watertight. Potential leakage managed by sub-soil drains
BEDROCK
Engineered retaining walls with both surface and subsurface drainage (constructed before dwelling)
© AGS (2006)


EXAMPLES OF POOR HILLSIDE PRACTICE
Unstabilised rock topples and travels downslope
Vegetation removed
Discharges of roofwater soak away rather than conducted off site or to secure storage for re-use
Steep unsupported cut fails
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles unevenly and cracks pool
Inadequate walling unable to support fill
Loose, saturated fill slides and possibly flows downslope
FILL
Roofwater introduced into slope
Inadequately supported cut fails
Saturated slope fails
MANTLE OF SOIL & ROCK FRAGMENTS (COLLUVIUM)
Vegetation removed
Dwelling not founded in bedrock
Mud flow occurs
BEDROCK
Absence of subsoil drainage within fill
Ponded water enters slope and activates landslide
Possible travel downslope which impacts other development downhill
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See also AGS (2000) Appendix J

APPENDIX H

Limitations of This Report

APPENDIX H

LIMITATIONS OF THIS REPORT

Soil and rock formations are variable. The logs presented as part of this report indicate the approximate subsurface conditions only at the specific test locations. Boundaries between zones on the logs or stratigraphic sections are often not distinct, but rather are transitional and have been interpreted.

The precision with which subsurface conditions are indicated depends largely on the frequency and method of sampling, and on the uniformity of subsurface conditions. The spacing of test sites also usually reflects budget and schedule constraints.

Groundwater conditions described in this report refer only to those observed at the place and under circumstances noted in the report. The conditions may vary seasonally or as a consequence of construction activities on the site or adjacent sites.

Where ground conditions encountered at the site differ significantly from those anticipated in the report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Davies Geotechnical Pty Ltd be notified of any variations and be provided with an opportunity to review the recommendations of this report. Recognition of changed soil and rock conditions requires experience and it is recommended that a suitably experienced geotechnical engineer be engaged to visit the site with sufficient frequency to detect if conditions have changed significantly.

The comments given in this report are intended only for the guidance of the design engineer, or for other purposes specifically noted in the report. The number of boreholes or test excavations necessary to determine all relevant underground conditions which may affect construction costs, techniques and equipment choice, scheduling, and sequence of operations would normally be greater than has been carried out for design purposes. Contractors should therefore rely on their own additional investigations, as well as their own interpretations of the borehole data in this report, as to how subsurface conditions may affect their work.