ORANGE
Australia's Colour City
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Completion of the North Orange By-pass from Astill Drive (North) to Chinaman's Bend, Orange

Soils Assessment

Prepared by

SEEC Morse McVey

March 2009

Specialist Consultant Studies Compendium: Part 5

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Completion of the North Orange By-pass from Astill Drive (North) to Chinaman's Bend, Orange

Soils Assessment

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March 2009

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EXECUTIVE SUMMARY

This report details the results of an assessment of the soils along the proposed route of the North Orange By-Pass from Astill Drive to Mitchell Highway, Orange. It includes a review of existing soil information and a detailed assessment of the soil conditions along that route.

The soils along the route are delineated into five distinct units, A to E. A summary of the constraints and opportunities of each unit is included in Section 5 of this report. Recommendations for erosion and sediment control during construction and for road design to address various soil-related issues are included in Section 6.

While most of the proposed route has minor soil constraints for road construction, certain areas have constraints that will need to be addressed, either through specific construction or timing techniques, or through enhanced design to mitigate potential problems.

Salinity was identified as an issue along a small area of the proposed road corridor, with existing saline discharge at the ground surface in one location. This will necessitate specialised design measures to minimise the risk that saline groundwaters cause ongoing safety and maintenance problems for the proposed road.

Mitigation measures will also be required to minimise the risk that the road causes or exacerbates subsoil salinity in areas where the route traverses footslope areas.

The majority of the construction area has a low erosion hazard, apart from steeper areas in the south and two significant watercourse crossings. These areas are classified as high erosion hazard and will require special erosion and sediment control measures as per the requirements in Landcom, 2004.

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1 INTRODUCTION

1.1 Background

SEEC Morse McVey have been commissioned by R.W. Corkery & Co. Pty. Limited on behalf of Orange City Council to conduct a soils assessment along the route of the proposed North Orange By-Pass from Astill Drive to Mitchell Highway, Orange (the "proposed road") (**Figure 1**).

This report serves to identify specific soils-related constraints and opportunities that might affect the proposed road's design and construction. In conducting this assessment we have:

- conducted a review of existing soil landscape information;
- conducted an extensive field survey of the landforms and soils;
- collected representative soil samples for laboratory testing;
- obtained relevant laboratory test results for specific soil characteristics; and
- analysed the laboratory data to provide recommendations for design and construction.

A field survey was conducted by SEEC Morse McVey staff from 25 to 27 March 2008, in conjunction with staff from Envirowest Consulting, who were addressing geotechnical issues for the project. Soil investigations involved the use of either an auger drill rig or a backhoe.

1.2 Study Area

The Study Area follows the intended route of the proposed road and is presented in **Figure 1**.

The topography of the Study Area varies from moderately inclined (8 to 25%) sideslopes and hills in the south, to very gently inclined (near-level to 10%) footslopes and sideslopes in the north. Much of the Study Area lies on footslopes or near the toe of the surrounding hillslopes. As such, much of the corridor is subject to high run-on from upslope.

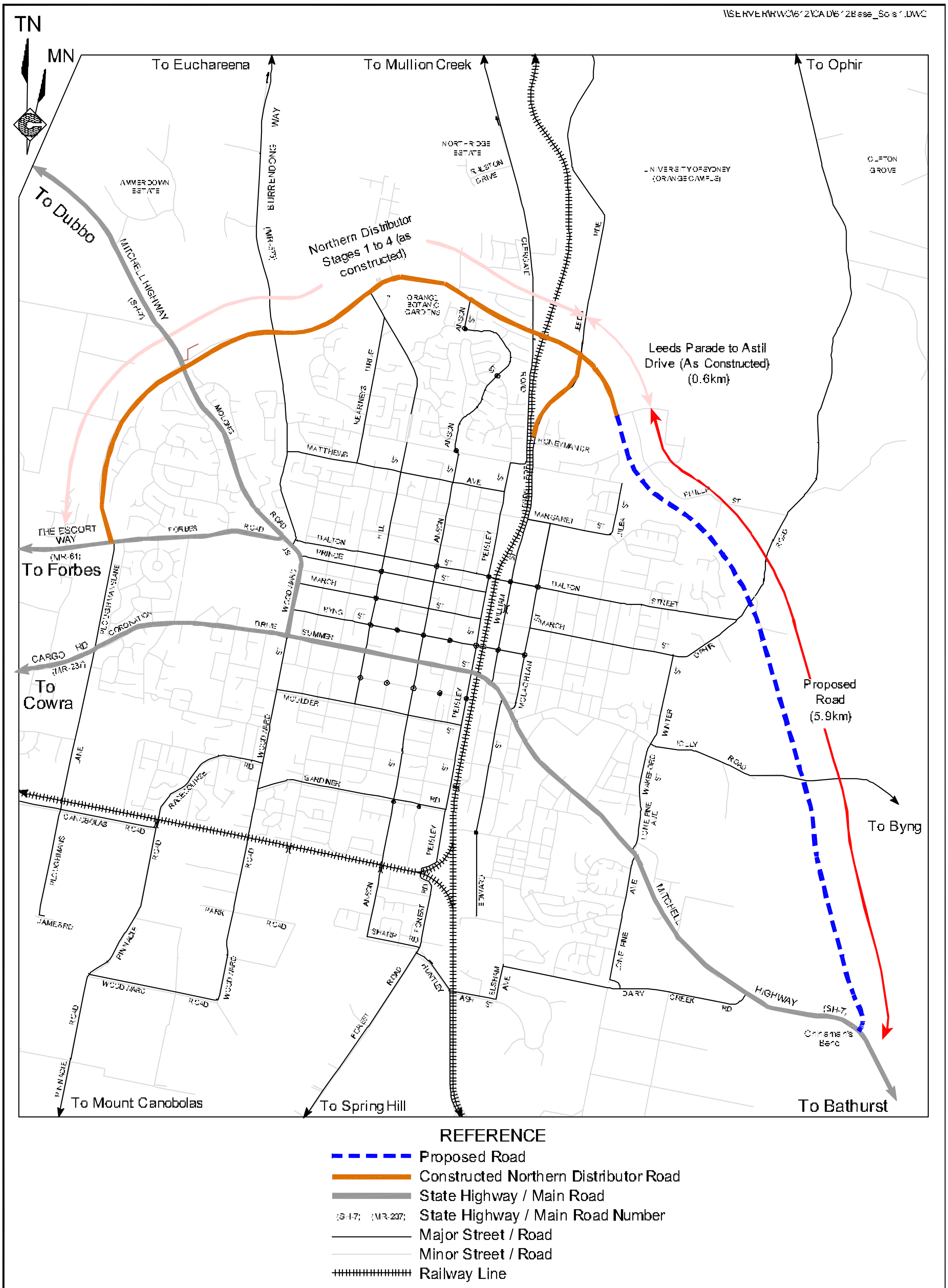
The majority of the Study Area has been cleared and is under a cover of native and exotic pasture grasses. At the time of inspection, most of it was used for grazing purposes or is open space on the urban fringe.

The Study Area crosses a number of drainage depressions and creeks including Blackman's Swamp Creek and Dairy Creek.

2 LITERATURE REVIEW

2.1 Soil Landscape Mapping

Soil landscape mapping for this area was conducted by Kovac *et al.* (1989 and 1990). **Figure 2** shows the soil landscape mapping. This shows that the proposed roadway lies on either the North Orange or Byng Soil Landscapes.



SCALE

0.5 0 0.5 1.0 1.5 2.0 2.5 km

Base Map Source: Orange City Council

Figure 1

NORTH ORANGE BY-PASS LOCATION

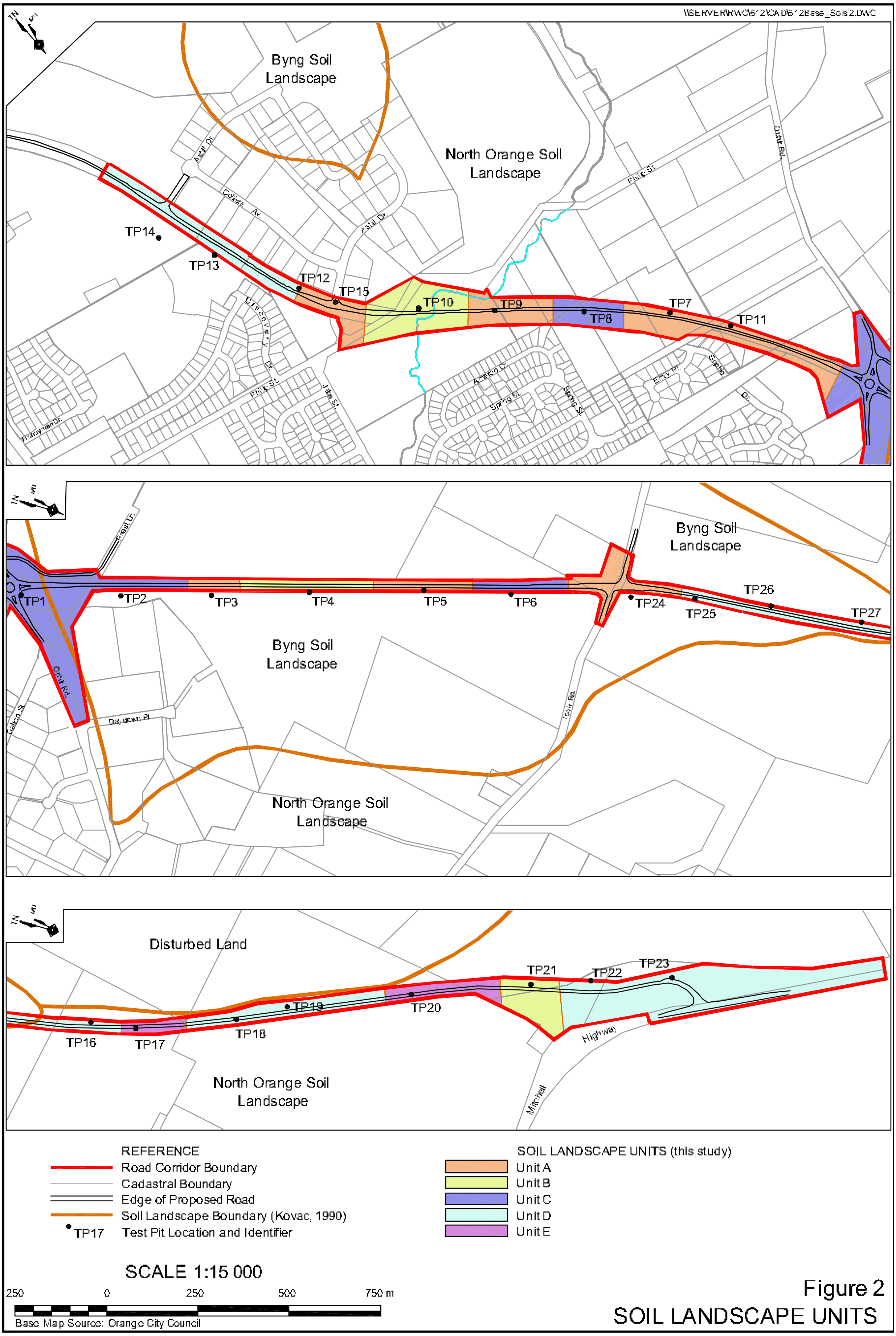


Figure 2
SOIL LANDSCAPE UNITS

2.1.1 North Orange Soil Landscape

Kovac *et al.* (1990) identified the North Orange Soil Landscape as undulating to rolling low hills north of Orange. Soils are mainly red to yellow earths (on upper slope areas) and yellow or brown solodic/solonetzic soils (on lower slope positions), formed from *in situ* weathering of the underlying parent material (mainly tuff and andesite).

Slopes generally range from 6 to 10%, but can be up to 30%. Long hillslopes are sometimes broken by rock outcrop or small benches.

Some of the identified soil and landscape limitations of the North Orange Soil Landscape include (Kovac *et al.,* 1990)

- Shrink/swell hazard – low for earthy soils in well-drained positions (ridges, crests and upper slopes), moderate to high on lower slope areas where subsoils are more clayey.
- Sheet erosion hazard – low for red-coloured soils (i.e. better drained positions such as ridges, crests and upper slopes), high for yellow or brown coloured soils (lower slope positions).
- Gully erosion hazard – extreme risk if subsoil horizons are exposed in drainage lines.
- Most soils have mildly to moderately acidic topsoils (pH 5.0 to 7.0).
- Salinity hazard – low in upper slope areas, moderate to high on lower slopes, particularly where profile drainage is poor.
- Topsoils set hard when dry.
- Soils are uniformly deficient in Nitrogen and Phosphorus.
- Soils are highly susceptible to structural decline if worked when too moist or too dry.
- All soils have low fertility.

2.1.2 Byng Soil Landscape

Kovac *et al.* (1990) identified the Byng Soil Landscape as undulating low hills east of Orange. Soils are mainly brown cracking clays or duplex soils on gentle hillslopes and footslopes, with wiesenbodens in flat areas and drainage depressions. Soils are formed from both *in situ* weathering of underlying parent material (mainly tuff and andesite) and from colluvial materials washed down from surrounding hills. In footslope positions within the Study Area, colluvial materials are mainly derived from the North Orange Soil Landscape.

Slopes generally range from 6 to 10%, but can be up to 20%. Lower-lying areas typically have slopes around 4 to 5%.

Some of the identified soil and landscape limitations of the Byng Soil Landscape include (Kovac *et al.*, 1990).

- Shrink/swell hazard – high to very high across all soil types.
- Sheet erosion hazard – low providing adequate vegetation cover is maintained.
- Gully erosion hazard – minor risk if subsoil horizons are exposed in drainage lines.
- Most soils are neutral (pH around 7.0).
- Salinity hazard – low to moderate, but mainly confined to subsoil horizons.
- Wiesenbodens, found on low-lying, relatively flat areas and drainage depressions, are prone to severe shrink-swell and surface cracking. They are inherently poor for engineering purposes.
- Soils are uniformly deficient in Nitrogen and Phosphorus.
- Soils are moderately susceptible to structural decline if worked when too moist or too dry.
- All soils have moderate fertility.
- Soil drainage is often poor.

2.2 Site Review of Soil Landscape Mapping

Site and soil investigations by SEEC Morse McVey staff revealed that the soil landscape mapping is mostly accurate given the scale at which it was produced (1:250,000).

An analysis of the above descriptions by Kovac *et al.* (1990) indicates that, while both soil landscapes occur on similar parent material, the Byng Soil Landscape tends to delineate very gently inclined slopes, footslope and flat areas, whereas the North Orange Soil Landscape delineates slightly more elevated, more inclined and better-drained areas.

As such, we conclude that many of the footslope areas along the road corridor between Phillip Street and Ophir Road, although mapped as North Orange, are actually the Byng Soil Landscape. Notwithstanding this, given the relatively consistent underlying geology along the road corridor, topographic position generally had the greatest influence on soil types and soil properties. Small, narrow ridges showed redder soils, indicating better drainage. These are reminiscent of the North Orange Soil Landscape. However, most sideslopes in this area lay at the lower edge of a longer hillslope, often near the edge of a minor alluvial plain. Those areas, although mapped as North Orange Soil Landscape, had poor drainage and soils reminiscent of the Byng Soil Landscape.

As such, we conclude the following

- The gently-inclined section of the Study Area from just north of Blackman's Swamp Creek through to just south of Icely Road lies on the Byng Soil Landscape.

- Apart from a narrow, 65 m-wide drainage flat where the road corridor crosses Dairy Creek, the remainder of the corridor lies on the North Orange Soil Landscape.
- The narrow, 65m stretch where the road corridor crosses Dairy Creek lies on the Byng Soil Landscape.

These delineations are shown in **Figure 2**.

3 SOIL SURVEY

3.1 Methodology

Soil survey of the site involved excavation of 27 test pits, plus a single surface sample at a point of suspected saline groundwater seepage. **Figure 2** shows the approximate locations of all test pits. In general, a test pit was excavated every 300m or so, although this varied slightly according to accessibility and landform.

Test pits 1 to 15 were excavated using a powered rotary auger post hole digger, while test pits 16 to 27 were excavated using a backhoe. The surface sample of the suspected saline area near Test Pit 15 was sampled using a spade. Test pits were typically excavated to a depth of 2m, except where anticipated cutting depths exceed this depth. In this situation, the test pit was excavated, as far as practicable, to the depth of the proposed cutting (see **Table 1**).

At each test pit, the following details were recorded.

- Chainage.
- GPS location (using AGD66 coordinates).
- Slope percent gradient and slope position.
- Apparent soil drainage.
- The soil profile characteristics (see below).
- Soil depth (if applicable).
- Any other physical features that might affect the proposed earthworks and construction activities.

The soil profile was recorded at each test pit. This included the following.

- Depth of each soil layer.
- Soil colour in each layer (moist Munsell colour).
- Soil texture in each layer.
- Soil structure grade in each layer.

Table 1
Test Pit Locations and Basic Characteristics

Test pit	Depth (m)	Location (AGD66)		Slope (%)	Slope Position	Soil Landscape	Soils
		Easting	Northing				
1	1.3	698234	6315569	5	Midslope	Byng	BP/BC
2	1.7	698305	6315316	4	Ridge	Byng	BRE/C
3	1.5	698377	6315073	4	Depression	Byng	BC
4	1.7	698443	6314831	1	Flat	Byng	W
5	1.7	698527	6314575	3	Footslope	Byng	BC
6	1.5	698596	6314347	3	Footslope	Byng	BC/C
7	1.7	697965	6316055	5	Footslope	Byng	BC
8	1.4	697801	6316244	6	Ridge on footslope	Byng	RP to BP
9	1.7	697597	6316418	8	Footslope	Byng	BC
10	1.7	697448	6316536	1	Flat	Byng	A to GC
11	1.7	698089	6315886	5	Footslope	Byng	BC
12	1.7	697210	6316778	4	Lower slope	Byng	BC
13	1.7	697112	6317038	10	Midslope	N.O	BRE
14	1.7	697071	6317192	9	Midslope	N.O	BRE
15	1.7	697264	6316696	2	Footslope	Byng	BC
16	1.8	698794	6313144	8	Ridge	N.O	RBE to RE
17	1.4	698820	6313012	20	Saddle	N.O	YP/SC
18	2.0	698920	6312819	22	Steep sideslope	N.O	RE/BRE
19	1.9	698978	6312684	19	Steep sideslope	N.O	RE/BRE
20	1.6	699114	6312397	6	Depression	N.O	YP/SC
21	1.7	699208	6312130	2	Flat	Byng	W
22	0.9	699241	6311999	11	Midslope	N.O	RE
23	0.9	699278	6311824	9	Depression	N.O	BC
24	0.7	698657	6314094	3	Footslope	Byng	BC
25	2.0	698681	6313911	12	Lower slope	N.O	YE to YP
26	1.7	698709	6313668	20	Slight rise	N.O	BC to YP
27	1.5	698736	6313413	10	Lower slope	N.O	BP

Key to abbreviations:

- N.O = North Orange
- BP = Brown Podzolic Soil
- BC = Brown Clay
- C = Chocolate Soil
- W = Wiesenboden
- BRE = Brown Earth
- RP = Red Podzolic Soil
- YP = Yellow Podzolic Soil
- A = Alluvial Soil
- GC = Grey Clay
- RBE = Red-brown Earth
- RE = Red Earth
- SC = Solodic Soil
- YE = Yellow Earth.

- Presence of structural cracking.
- Presence, frequency and type of coarse fragments in each layer.
- Presence, frequency and colour of mottling in each layer.
- Moisture condition of each layer.

3.2 Sampling Locations

Basic information about each of the test pits is contained in **Table 1**. Full soil profile details are contained in the tables in **Annexure 1**.

3.3 Soil Profile Summary

3.3.1 General Conditions

Although there were distinct variations in the soil conditions at each survey location, in general the soils were relatively homogenous. Variations were mainly due to the soil's landscape position and local topography.

Crests, ridges and rises tended to have better soil drainage, more red-coloured soils and more earthy soils with less clay content than footslopes and depressions which tended to have brown or yellow clays at depth and showed evidence of poor soil drainage. Very flat areas (<2% slope), particularly associated with drainage flats or floodplains, had black, cracking clay soils (wiesenbodens) that are prone to shrinking and swelling (i.e. highly reactive).

Using the above characteristics, the Study Area was delineated into five mapping units (A to E) (**Figure 2**). Typical profiles for each are described below. Note that these are a representative summary, allowing for some variations in depth.

3.3.2 Unit A: Byng Soil Landscape – Footslopes

These soils were found extensively along the proposed route, which tends to run along the footslope areas at the edge of the North Orange Soil Landscape (where it transitions into the Byng Soil Landscape). This soil unit was identified in Test Pits 3, 5, 7, 9, 11, 12, 15 and 24. Slopes range from about 1 to 5%. Soils show a mixture of residual weathering of parent material and colluvial influence from upslope materials. The typical profile is as follows.

Layer 1	0 – 400 mm	A1 horizon. Dark brown to black sandy clay loam to sandy clay. Moderately to strongly pedal. Few coarse fragments. Often highly organic. Gradual, diffuse boundary to layer 2, sometimes with mild bleached A2 at base of A1 horizon.
Layer 2	400 – 1,200 mm	B2 horizon. Dark yellowish brown, moderately pedal, light to medium clay or sandy clay. Up to 5% coarse fragments (parent material). Occasional mottling, which increases with depth. Gradual, diffuse boundary to layer 3.
Layer 3	1,200 – 1,800 mm+	BC horizon. Brownish yellow, mottled (grey), apedal clayey sand to gravelly clay. Common coarse fragments (parent material). Layer continues below 1.8 m.

3.3.3 Unit B: Byng Soil Landscape – Drainage Flats

These soils were found on drainage flats, narrow floodplains and where slopes were less than 2%. They were identified in Test Pits 4, 10 and 21. Soils are black, cracking clays, also known as wiesenbodens or vertosols. They are subject to very high shrink/swell as moisture levels change and are a poor engineering medium. The typical profile is as follows.

Layer 1	0 – 300 mm	A horizon. Very dark brown to black sticky, cracking medium clay or silty clay. Strongly pedal. 2% coarse fragments of mixed origin. Often highly organic. Little or no mottling. Gradual, diffuse boundary to layer 2.
Layer 2	300 – 1,300 mm	B2 horizon. Very dark greyish brown to black, cracking, moderately to strongly pedal, medium to heavy clay or silty clay. Up to 5% coarse fragments of varying origin. Little or no mottling. Gradual, diffuse boundary to layer 3.
Layer 3	1,300 – 2,000 mm+	B3 to BC horizon. Dark yellowish brown, highly mottled (grey), apedal clayey sand to gravelly clay. Common coarse fragments (mainly parent material). Layer continues below 2.0 m.

3.3.4 Unit C: Byng Soil Landscape – Rises

These soils are similar to those found on footslopes but, being better drained and less prone to colluvial influences, tend to be a little shallower, less mottled and slightly redder in colour. Additionally, soils were more earthy, with less clay in the upper two horizons. Minor rock outcropping occurs on these rises, indicating that soil depth is variable. Slopes ranged from 4 to 10%. The soil unit was identified in Test Pits 1, 2 6 and 8. The typical profile is as follows.

Layer 1	0 – 350 mm	A1 horizon. Dark brown, strongly pedal sandy loam to sandy clay loam. Little or no coarse fragments. Often strongly organic. Gradual boundary to layer 2.
Layer 2	350 – 800 mm	B2 horizon. Greyish-brown to dark yellowish brown, moderately pedal coarse sandy clay loam to sandy clay. Occasional light mottling, which increases with depth. Up to 5% coarse fragments (parent material plus iron-indurated nodules). Gradual boundary to layer 3.
Layer 3	800 – 1,800 mm+	B3/BC horizon. Dark grey to dark greyish brown, weakly pedal gritty clay. Mottling and coarse fragments are common. Layer continues below 1.8 m.

3.3.5 Unit D: North Orange Soil Landscape – Hillslopes

Hillslopes on the North Orange Soil Landscape had significant variations in slope, ranging from 5% to 25%, although soils were relatively consistent. Steeper areas had thinner topsoils, greater incidences of rock outcrop and had a slight colluvial influence in addition to the *in situ* weathered parent materials. In other areas, soils are generally formed from *in situ* weathering of the underlying volcanics (andesite and tuff). This soil unit was identified in Test Pits 13, 14, 16, 18, 19, 22, 23, 25, 26 and 27. The typical profile is as follows.

Layer 1	0 – 250 mm	A1 horizon. Dark reddish brown to strong brown, moderately to strongly pedal sandy clay loam. Up to 5% coarse fragments. Sometimes strongly organic. Sharp boundary to layer 2.
Layer 2	250 – 700 mm	B2 horizon. Dark reddish brown to dark yellowish brown, weakly to moderately pedal sandy/silty clay to light-medium clay. Mildly subplastic. Occasionally mottled at depth. <10% coarse fragments. Gradual boundary to layer 3.
Layer 3	700 – 1,800 mm+	B3/BC horizon. Dark yellowish brown, mottled, weakly pedal clayey sand to sandy clay. Gritty appearance, with extensive cementations, nodules and fragments. Layer continues, becoming more saprolitic with depth.

3.3.6 Unit E: North Orange Soil Landscape – Drainage Depressions and Saddles

Drainage depressions on the North Orange Soil Landscape had similar topsoils (A1 horizon) to those on hillslopes but had an obvious, bleached, apedal, silty A2 horizon immediately below. Subsoils below the A2 horizon were similar to those found on hillslopes of the North Orange Soil Landscape. Slope ranges from 5 to 15%. This soil unit was identified in Test Pits 17 and 20. The typical profile is as follows.

Layer 1	0 – 250 mm	A1 horizon. Dark reddish brown to dark brown, moderately to strongly pedal sandy clay loam. Less than 5% coarse fragments. Sharp boundary to layer 2.
Layer 2	250 – 600 mm	A2 horizon. Bleached, massive silty clay loam to silty clay. Light grey in colour but with occasional yellow spotting. Thickness of this layer varies between 50mm and 500mm. Abrupt boundary to layer 3.
Layer 3	600 – 1,800 mm+	B2/BC horizon. Dark yellowish brown, mottled, weakly pedal, gravelly clayey sand to sandy clay. Gritty appearance, with extensive cementations, nodules and fragments. Layer continues, becoming more saprolitic with depth.

4 LABORATORY TESTING

4.1 Analysed Samples

Soil samples from specific layers in representative profiles were sent to the Department of Lands Scone Research Centre for soil testing. **Table 2** details the location from which each sample was collected and the suite of tests performed on each. The majority of the proposed route involves filling over the existing ground surface, with only minor areas of cut, mainly on the steeper hills in the south. Where extensive cutting is anticipated, soils were tested for their ability to support vegetation and be used for rehabilitation purposes following construction.

Table 2
Analysed Samples and Test Undertaken

Test Pit	Layer	Landscape Unit	Physical Tests	Chemical Tests
4	1	Unit B	PSA, D%, EAT, OC%	
6	3	Unit C	PSA, D%, EAT, OC%	
10	2	Unit B	PSA, D%, EAT, OC%	
11	1	Unit A	PSA, D%, EAT, OC%	
11	2	Unit A	PSA, D%, EAT, OC%	
13	1	Unit D	EAT, Texture	pH, EC, CEC, Exch Cations, P
13	2	Unit D	PSA, D%, EAT, OC%	
15	1	Unit A	Texture	pH, EC
16	1	Unit D	EAT, Texture	pH, EC, CEC, Exch Cations, P
16	2	Unit D	EAT, Texture	pH, EC, CEC, Exch Cations
17	2	Unit E	PSA, D%, EAT, OC%	
18	2	Unit D	PSA, D%, EAT, OC%	
18	3	Unit D	PSA, D%, EAT, OC%	
22	2	Unit D	PSA, D%, EAT, OC%	

Key to Abbreviations:

- Unit A = Byng Soil Landscape – footslopes
- Unit B = Byng Soil Landscape – drainage flats
- Unit C = Byng Soil Landscape – rises
- Unit D = North Orange Soil Landscape – hillslopes
- Unit E = North Orange Soil Landscape – depressions and saddles.
- PSA = Particle size analysis
- D% = Dispersion percentage
- EAT = Emerson aggregate test
- OC% = Organic carbon percentage
- Texture = Soil field texture
- EC = Electrical conductivity
- CEC = Cation exchange capacity
- Exch Cations = Exchangeable cations (Sodium, Potassium, Calcium, Magnesium)
- P = Available phosphorus

4.2 Analysis of Results

4.2.1 Introduction

Tables 3, 6 and **7** contain a summary of the laboratory test results for the fourteen samples tested. The full results as sent by the laboratory are included as **Annexure 2**. **Figure 2** shows the extent of each unit within the Study Area.

Table 3
Summary and Analysis of Key Erosion and Sediment Control Factors

Test Pit	Layer	Unit	Relative Layer	Disp %	Organic Matter	K-factor	Erodibility	% Whole Soil Dispersible*	Significantly Dispersible*	EAT
4	1	B	Topsoil	29	2.43	0.035	Moderate	16	yes	5
6	3	C	Subsoil	26	0.95	0.056	High	11	yes	3(1)
10	2	B	Subsoil	32	1.27	0.064	Very high	13	yes	3(1)
11	1	A	Topsoil	25	2.83	0.048	High	5.6	no	3(1)
11	2	A	Subsoil	43	0.40	0.033	Moderate	3.9	no	3(1)
13	2	D	Subsoil	30	0.18	0.054	High	11	yes	5
17	2	E	Topsoil	50	0.35	0.089	Very high	7.8	no	3(1)
18	2	D	Subsoil	22	1.69	0.026	Moderate	11	yes	5
18	3	D	Subsoil	23	1.27	0.028	Moderate	11	yes	3(1)
22	2	D	Subsoil	11	1.71	0.027	Moderate	5.2	no	3(1)
* Note: The percent of the whole soil dispersible is calculated from the PSA and the dispersion percent as follows: (Clay % + Half of the silt %) x Dispersion percent. If this value exceeds 10%, the soil is considered to be “significantly dispersible” – i.e. it is a Type D (dispersible) soil according to Landcom (2004).										
Key to Abbreviations: EAT = Emerson aggregate test										

4.2.2 Erosion and Sediment Control

Soil Erodibility

Soil erodibility or K-factor, is determined using the particle size analysis (PSA), soil structure, permeability and organic carbon content. It is a value typically between about 0.005 and 0.09, although values can theoretically exceed this. Here, K-factors were derived by inputting laboratory test data into the SOILOSS 5.3 program, developed by Rosewell (2005) and based on the Revised Universal Soil Loss Equation (RUSLE).

Table 4 contains a summary of the soil erodibility classes based on K-factors. This shows that most of the samples tested have moderate to high erodibility (K-factors between 0.02 and 0.06). Only two samples had a K-factor exceeding 0.06. These were as follows.

- Layer 2 in Test Pit 17 has a K-factor of 0.089, which is extreme. This layer was a bleached, apedal, silty A2 horizon, which tends to occur in drainage depressions on the North Orange Soil Landscape.
- Layer 2 in Test Pit 10 has a K-factor of 0.064, which is very high. This layer occurred as a mottled A2 horizon on the narrow floodplain associated with Blackman’s Swamp Creek in the Byng Soil Landscape.

Table 4
Soil Erodibility Ratings (Rosewell and Edwards, 1988)

K-factor	Erodibility Rating
0.00 – 0.01	Very low
0.01 – 0.02	Low
0.02 – 0.04	Moderate
0.04 – 0.06	High
> 0.06	Very high

Figures for Organic Matter are included in **Table 3**. These are calculated as 1.72 x Organic carbon % (Hazelton and Murphy, 1992).

4.2.3 Soil Loss and Erosion Hazard

The annual soil loss was calculated using SOILOSS 5.3 (Rosewell, 2005), which is based on the Revised Universal Soil Loss Equation (RUSLE). For the purposes of this analysis, the following inputs were used (as recommended in Landcom, 2004).

- R-factor (rainfall factor): 1,300 in Rainfall Zone 7.
- Maximum K-factors for each landscape unit.
- Typical slope gradients for each landscape unit, plus a slope length of 80 m.
- A rill:interill ratio of 3:1.
- P-factor (Conservation practice) of 1.3 (i.e. assuming no specific conservation practices).
- C-factor (Ground cover factor) of 1.0 (i.e. assuming bare soils).

The results of this analysis are contained in **Table 5**. Note that two values are provided for mapping unit D due to the wide variation in slope in this unit.

Table 5
Soil Loss Calculations Using the RUSLE and SOILOSS 5.3

Landscape Unit	Maximum K-factor (from lab data)	Typical Slope Gradient	Calculated Soil Loss (t/ha/yr)	Soil Loss Class (from Landcom, 2004)
A	0.048	4%	74	1 (very low)
B	0.064	2%	44	1 (very low)
C	0.056	8%	194	2 (low)
D	0.054	10%	256	3 (low-moderate)
D	0.054	20%	668	5 (high)
E	0.089	10%	422	4 (moderate)

Under the guidelines and recommendations contained in Landcom (2004), construction activities in rainfall zone 7 can occur at any time of year using the standard suite of Best Management Practices (BMPs) for erosion and sediment control if the soil loss class is 4 or less. For soil loss class 5 or above, additional measures are required at certain times for year.

For soil loss class 5, namely soils of soil landscape unit D on slopes greater than 16%, additional measures are required for any works that occur between 1 December and 28 February. At other times of year, works can proceed with the standard suite of BMPs for erosion and sediment control where the soil loss class is 5.

The steeper areas in the southern section of the Study Area have a high erosion hazard (soil loss class 5 or above).

To meet the requirements of Landcom (2004) on these lands, the following should be implemented.

- Schedule works for the period from 1 March to 30 November.
- If this is not possible, ensure that:
  - disturbed lands have a C-factor (ground cover factor) higher than 0.1 only when the 3-day weather forecast suggests that rain is unlikely; and
  - management regimes are in place to facilitate stabilisation of ground surfaces to achieve a C-factor of 0.1 or less within 24 hours if the forecast proves incorrect.

Landcom (2004) states that waterfront lands are to be automatically considered as Soil Loss Class 6. Here, we assume that this will apply to all construction works within 20m of the top-of-bank of Blackman's Swamp Creek and Dairy Creek. To meet the requirements of Landcom (2004) on these lands, the following should be implemented.

- Schedule works for the period from 1 April to 30 September.
- If this is not possible, ensure that:
  - disturbed lands have a C-factor (ground cover factor) higher than 0.1 only when the 3-day weather forecast suggests that rain is unlikely; and
  - management regimes are in place to facilitate stabilisation of ground surfaces to achieve a C-factor of 0.1 or less within 24 hours if the forecast proves incorrect.

With the exception of the abovementioned areas of high erosion hazard, all other lands have a very low to moderate erosion hazard.

4.2.4 Dispersion

Emerson Aggregate Testing (EAT) of each of the samples in **Table 3** indicates that all samples are only slightly dispersible and are unlikely to be sodic (Hazelton and Murphy, 1992). However, an analysis of the dispersion percent and PSA, using the method in Landcom (2004), indicates that most of the subsoils tested have significantly dispersible fine fractions (clay and silt). For the purposes of road construction, all subsoils should be assumed to be dispersible and appropriate erosion and sediment control measures applied.

4.3 Soil Chemical Properties

4.3.1 Electrical Conductivity and Salinity

The results of electrical conductivity testing of representative soil samples are included in **Table 6**, along with an analysis of their salinity levels. Testing shows that salinity was not identified on the North Orange soil landscape (Units D and E), whereas salinity was identified on the footslopes of the Byng Soil Landscape (Unit A). Salinity was not noted in Units B and C and we do not expect surface salinity to be an issue in those locations due to the prevailing topography.

Table 6
Results and Analyses of Soil Chemical Properties

Test Pit	Layer	Land-scape unit	EC (dS/m)	Soil texture	Multi-plier factor	ECe	Salinity	pH	Condition
13	1	D	0.02	Sandy loam	11	0.22	Non-saline	6.0	Moderately acidic
15	1	A	2.92	Silty clay loam	9	26.3	Extremely saline	10.6	Very strongly alkaline
16	1	D	0.05	Sandy clay loam	9	0.45	Non-saline	6.2	Slightly acidic
16	2	D	0.02	Light medium clay	7	0.14	Non-saline	6.5	Slightly acidic

Surface expression of salinity was identified in one location, nearing the vicinity of Test Pit TP15 (**Figure 2**). In this location, a saline sub-surface flow appears to discharge onto the ground surface when the water table is elevated, causing vegetation decline (**Figure 3**). Layer 1 in TP15 is extremely saline (**Table 6**), indicating a subsurface saline groundwater flow. Following completion of the borehole, it proceeded to fill with water. At the time of inspection, this flow was at a depth of around 0.8 to 1.0m depth.

This saline discharge is assumed to be influenced by the following.

- Excessive amounts of groundwater recharge in the upslope catchment. Deep-rooted vegetation has been largely removed in that area, meaning that less groundwater is being removed by plants and trees. This leads to artificially raised groundwater levels, particularly in the lower reaches of the catchment.
- Nearby roads. Subsoil compaction during road construction can impede the lateral movement of water through the soil. This has a damming effect upslope and can cause locally elevated water tables and/or groundwater seepage at the surface. Additionally, compacted subsoils can exacerbate capillary rise of groundwater.

The occurrence of this saline seepage scald indicates that salts are a naturally-occurring phenomenon in the subsoils of the Byng footslopes. Under most conditions, these salts remain undissolved in the soil. However human or construction activities can cause elevated groundwater tables to dissolve these salts and rise into the plant root zone or the compacted zone beneath an engineered structure (e.g. a road). This can cause vegetation decline and can damage structures.

In the case of roads, saline groundwater can lead to pavement blistering, cracking, potholing, tessellation and deformation (DIPNR, 2003). Increased maintenance costs are likely unless appropriate measures are taken to address salinity in the road's design.

4.3.2 Soil pH

Table 6 presents the results of pH testing for representative soil samples. The saline seepage at TP15 was found to be very strongly alkaline. This is typical of highly saline soils and, along with the influence of the saline water, will cause vegetation to die. Similarly, salt-affected soils will be unsuitable as a growth medium for vegetation during site stabilisation works following construction.

Figure 3
Surface Discharge of Saline Groundwater causing Vegetation Decline

All other samples were found to have a pH in the range of 6.5 to 6.0. These soils are slightly to moderately acidic and are not considered to be a limiting factor for plant growth, nor should they have a negative effect on the proposed road construction. Hazelton and Murphy (1992) noted that soils with a pH of 6.0 or higher do not generally require any sort of treatment for pasture establishment.

4.3.3 CEC and Exchangeable Cations

4.3.3.1 Results and Analysis

Tables 7 and **8** include the results and analysis of testing for Cation Exchange Capacity (CEC) and exchangeable cations. Full laboratory results are presented in **Annexure 2**.

Table 7
Cation Exchange Capability and Key Cation Ratios

Test Pit	Layer	Unit	CEC		Ca:Mg Ratio		Exchangeable Sodium		Exch. Sodium Percentage	
			Value (me/100g)	Class	Value (me/100g)	Class	Value (me/100g)	Class	Value (me/100g)	Class
13	1	D	9.7	Low	3.9	Calcium low	0.4	Mod	4.1	Non-sodic
16	1	D	27.0	High	1.0	Calcium deficient	0.8	High	3.0	Non-sodic
16	2	D	39.6	High	0.8	Calcium deficient	0.6	Mod	1.5	Non-sodic

Table 8
Analysis of Cation Concentrations

Test Pit	Layer	Calcium		Magnesium		Potassium		Sodium	
		% of CEC	Desirable range	% of CEC	Desirable range	% of CEC	Desirable range	% of CEC	Desirable range
13	1	53	65 – 80	13	10 – 15	2	1 – 5	4	0 – 1
16	1	42	65 – 80	43	10 – 15	3	1 – 5	3	0 – 1
16	2	40	65 – 80	51	10 – 15	1	1 – 5	2	0 – 1

4.3.3.2 Cation Exchange Capacity (CEC)

CEC indicates the soil's ability to hold and exchange cations and is a major controlling factor for soil structural stability and nutrient availability for plant growth. It also influences soil pH and the soil's reaction to fertilizers and ameliorants (Hazelton and Murphy, 1992).

Within the Study Area, the soil CEC range from low to high, although two of the three values obtained are in the higher range. While soils were found to be fairly infertile (Section 4.3.4), the CEC results indicate that soils would respond relatively well to fertilizers or ameliorants. These soils are unlikely to leach excessive amounts of applied nutrients and would facilitate plant availability of these nutrients. High CEC values generally contribute to good soil structure and mild pH conditions. Throughout the Study Area, soils were found to be well-structured and, apart from some minor examples discussed in Section 4.3.2, have mild pH values. As such, we conclude that CEC values throughout the Study Area are predominantly moderate to high.

4.3.3.3 Calcium:Magnesium Ratio and Exchangeable Calcium

Low calcium to magnesium ratios (< 2) can be indicative of clay dispersion in a soil. TP16 was found to have low calcium values, indicating the potential for clay dispersion in subsoils. This is addressed further in Section 4.2.4. Additionally, the low calcium concentrations might reduce plant growth during rehabilitation/stabilisation works although we do not expect this to be a limiting factor.

4.3.3.4 Exchangeable Sodium Percentage

Although all of the samples tested had very high sodium concentrations, the Exchangeable Sodium Percentage (ESP) is less than 5% for all samples tested. This indicates that soils are generally non-sodic and are not highly susceptible to gully erosion providing adequate ground cover is provided.

4.3.3.5 Potassium and Magnesium

Potassium concentrations as a percentage of CEC were found to be within the desirable range for all samples. Magnesium concentrations were well outside the desirable range in both Layers 1 and 2 in TP16. However, high magnesium levels do not generally have an adverse effect on plant growth and so are unlikely to impact the potential to use these soils for rehabilitation or stabilisation purposes.

4.3.4 Available Phosphorus and Organic Content

Two topsoil samples were sent for testing for Available Phosphorus, to determine their relative fertility and potential to be used in site rehabilitation or stabilisation activities. The results of this testing are presented in **Table 9.**

Table 9
Analysis of Available Phosphorus

Test Pit	Layer	Available Phosphorus (mg/kg)	Analysis
13	1	2	Very low
16	1	1	Very low

Testing indicates that topsoils have very low available phosphorus. Additionally, organic matter content conducted as part of an alternative suite of testing (Table 3) ranged from extremely low to moderate, with most soils having very low organic matter. As such, soils within the Study Area are assumed to be relatively infertile.

4.4 Soil Drainage and Permeability

Soil drainage was inferred in the field using observations of soil characteristics. Indicators of soil drainage include field texture, soil structure, presence/absence of mottling, soil colour and topographic position. From this, we conclude the following.

- Unit A (footslopes on the Byng Soil Landscape) has slow, impeded drainage below approximately 0.8m depth, indicated by extensive mottling. Above this depth, soils are moderately permeable. This unit is also affected by high run-on. This is unlikely to impact the design of the road pavement but should be considered when designing the associated stormwater drainage system within the area of Unit A.
- Unit B (drainage flats on the Byng Soil Landscape) has very slow drainage throughout the soil profile and has indications of periodic waterlogging. It is also subject to high run-on. Issues relating to soil drainage will need to be considered for road and stormwater design within the area of Unit B.
- Unit C (rises on the Byng Soil Landscape) has moderate to slow drainage, although this is mainly confined to the subsoils below about 0.8m depth. Above that depth, profiles are moderately permeable. Soil drainage is unlikely to necessitate specialised design within the area of Unit C.
- Unit D (hillslopes on the North Orange Soil Landscape) has moderate to slow drainage, with sporadic mottling in the subsoils below 1.2 m. Topsoils tend to be moderately to highly permeable, depending on soil structure and vegetation conditions. Soil drainage is unlikely to necessitate specialised design within the area of Unit D.

- Unit E (drainage depressions and saddles on the North Orange Soil Landscape) has impeded drainage and is affected by high levels of run-on. Nutrient leaching is obvious in the highly permeable topsoils above 0.6m depth, although soils below this depth are poorly structured and mottled, indicating impeded drainage. This is unlikely to impact the design of the road pavement but should be considered when designing the associated stormwater drainage system within the area of Unit E.

All units are assumed to be Soil Hydrologic Group D, as per the classification system used in Landcom (2004).

4.5 Soil Structure and Reactivity

Geotechnical issues are to be addressed by Envirowest Consulting and provided separately to Council. We note the following soil characteristics that will impact on the design of the road and its associated stormwater infrastructure.

- Unit A soils are brown clays, with stable, well-structured topsoils (0 – 0.4 m) and moderately reactive subsoils (0.4m and below). These soils will require appropriate compaction during construction to minimise the impacts of changing soil moisture. The road drainage system will require appropriate design to pipe excess water beneath the road pavement.
- Unit B soils are mainly black cracking clays (wiesenbodens) that are typically prone to extreme shrink/swell throughout the profile as they wet and dry. This issue will require appropriate mitigation or design measures, possibly including maintenance of constant moisture levels within the soils.
- Unit E soils are mainly yellow solodic soils, with moderately reactive subsoils below about 0.6m depth. These soils will require appropriate compaction during construction to minimise the impacts of changing soil moisture. The road drainage system will require appropriate design to pipe excess water beneath the road pavement.

5 CONSTRAINTS AND OPPORTUNITIES SUMMARY

The following section presents a summary of the constraints and opportunities for the proposed development related to the soils of the Study Area. **Figure 2** presents the location of each of the soil units discussed below.

5.1 Unit A: Byng Soil Landscape – Footslopes

Soils in this unit are primarily brown clays. Key characteristics that will affect the road design process and the management of soils during construction in areas of Unit A include the following.

- Moderate subsoil (below 0.8 m) shrink/swell rates as moisture content changes.
- High run-on from upslope areas.

- Slow soil drainage and occasionally elevated water tables.
- Moderate salinity hazard in subsoils (below 0.8m depth).
- Very low erosion hazard.
- Potential for deep subsoils (below 1.2 m) to be dispersive.
- Soils have low fertility and might need fertilizer application(s) to assist vegetation growth in drains, on batters and on other disturbed lands.
- Average stripping depth for topsoil is 0.4 m.
- Well structured soils. Should not be worked when too wet or too dry to avoid destroying soil structure. A moist condition is best.

5.2 Unit B: Byng Soil Landscape – Drainage Flats

Soils in this unit are primarily black cracking clays (wiesenbodens). Key characteristics that will affect the road design process and the management of soils during construction in areas of Unit B include the following.

- Very high shrink/swell rates throughout the soil profile; i.e. highly reactive soils.
- Low wet bearing strength (assumed – typical of wiesenbodens).
- Soils present major constraints to engineered structures.
- High run-on from upslope areas.
- Potential for seasonal waterlogging of soils and/or elevated groundwater tables.
- High organic matter content in topsoils to 400mm depth.
- Very strong blocky structure – poor seedbed conditions for rehabilitation and stabilisation.
- High waterholding potential and moderate fertility.
- Very slow soil drainage.
- Dispersive soils throughout the profile.
- Minor salinity risk at depth (below 1.4 m).
- Stripping topsoils will not necessarily expose material suitable for engineered structures or compaction.
- Very low erosion hazard.

5.3 Unit C: Byng Soil Landscape – Rises

Soils in this unit are primarily brown earths and brown clays. Key characteristics that will affect the road design process and the management of soils during construction in areas of Unit C include the following.

- Dispersive subsoils.
- Average stripping depth for topsoil is 0.35 m.

- Occasional rock outcrop.
- Low erosion hazard.
- Moderate to imperfect soil drainage.
- Well structured soils. Should not be worked when too wet or too dry to avoid destroying soil structure. A moist condition is best.

5.4 Unit D: North Orange Soil Landscape – Hillslopes

Soils in this unit are primarily red-brown earths and brown earths. Key characteristics that will affect the road design process and the management of soils during construction in areas of Unit D include the following.

- Moderate to high erosion hazard, depending on slope.
  - Slopes below 15% are moderate erosion hazard.
  - Slopes exceeding 15% are high erosion hazard and will require special consideration for erosion and sediment control.
- Dispersive soils.
- Localised areas of high run-on.
- Soils have low to moderate fertility and might need fertilizer application(s) to assist vegetation growth in drains, on batters and on other disturbed lands.
- Average stripping depth for topsoil is 0.25 to 0.3 m.
- Occasional rock outcrop.
- Well structured soils. Should not be worked when too wet or too dry to avoid destroying soil structure. A moist condition is best.

5.5 Unit E: North Orange Soil Landscape – Depressions and Saddles

This unit is characterised by brown podzolic or yellow solodic soils, all with a distinct bleached A2 horizon. Key characteristics that will affect the road design process and the management of soils during construction in areas of Unit E include the following.

- Highly erodible soil layers. Layers 1 and 2 (to 0.6m depth) are prone to sheet and rill erosion. Layer 3 is prone to rill and gully erosion if exposed.
- Layer 2 is apedal and silty, making it a very poor growth medium for vegetation.
- All layers have low fertility, particularly layer 2.
- Soils are dispersible and contain significant volumes of silt and find sand.
- High run-on from surrounding hills.
- Slow soil drainage and periodic soil saturation below 0.8m depth.

- Moderate erosion hazard.
- Average stripping depth for topsoils is 0.6 m. This includes the two topsoil horizons. They should be bulked together when stockpiled to allow organic material in layer 1 to help stabilise layer 2.

6 DESIGN AND MANAGEMENT RECOMMENDATIONS

6.1 Erosion and Sediment Control

To address the requirements of Landcom (2004) during construction activities, we recommend the following.

- Soils are to be assumed to be dispersible; i.e. Type D soils. Management of these soils will require the following.
  - A greater emphasis should be placed on erosion control over sediment control.
  - Sediment filtering structures (e.g. sediment fences) will not be as effective because of the risk that dispersible fine particles can pass through them.
  - Sediment basins will require flocculation to achieve adequate settling of fine material to achieve 50 mg/L of suspended sediment in the discharge waters.
- Construction activities should proceed in stages to minimise the amount of land disturbed at any one time.
- Topsoil should be stripped and stockpiled according to Standard Drawing SD 4-1 in Landcom (2004).
- Topsoil should be used for rehabilitating cut and fill batters. Replacement of topsoil should accord with Standard Drawing SD 4-2 in Landcom (2004).
- The standard suite of BMPs for erosion and sediment control be employed on all construction areas.
- Any lands with an upslope gradient steeper than 16% should be classified as having a high erosion hazard (Soil Loss Class 5 or higher). Following the guidelines and recommendations in Landcom (2004), this means that construction activities on such lands should occur only during the period 1 March to 30 November. If this is not possible, ensure that:
  - disturbed lands have a C-factor (ground cover factor) higher than 0.1 only when the 3-day weather forecast suggests that rain is unlikely; and
  - management regimes are in place to facilitate stabilisation of ground surfaces to achieve a C-factor of 0.1 or less within 24 hours if the forecast proves incorrect.
- The riparian areas either side of Blackman's Swamp Creek and Dairy Creek should be classified as having a high erosion hazard. This means that construction activities in the core riparian zone (width to be determined by

Council or the Department of Water and Energy) should occur only during the period 1 April to 30 September. If this is not possible, ensure that:

- disturbed lands have a C-factor (ground cover factor) higher than 0.1 only when the 3-day weather forecast suggests that rain is unlikely; and
- management regimes are in place to facilitate stabilisation of ground surfaces to achieve a C-factor of 0.1 or less within 24 hours if the forecast proves incorrect.

- Batter slopes should not exceed 1(V):2(H) in areas of high erosion hazard (i.e. any lands with upslope gradients steeper than 16% and within the core riparian zone either side of Blackman's Swamp Creek and Dairy Creek).
- Slope lengths in disturbed areas should be shorter than 80m, unless erosion hazard is assessed with an alternative value using the RUSLE.
- Sediment basins, if required, should be designed using the following criteria.
  - R-factor of 1300.
  - The worst-case K-factor for that unit (refer to **Table 3**).
  - The prevailing slope, whether cross-fall or long-fall.
  - A default slope length of 80m, unless shorter or longer lengths can be justified.
  - A 5-day, 75th percentile rain depth of 16.8 mm (Table 6.3, Landcom, 2004)
  - A volumetric runoff coefficient (Cv) of 0.39 (Table F3, Landcom, 2004).
- Stabilise disturbed areas (e.g. batters) to achieve the following.
  - A C-factor of 0.15 or less within 20 working days of completion of works during the period 1 April to 30 September.
  - A C-factor of 0.1 or less within 20 working days of completion of works during the period 1 October to 31 March, AND set in motion a program to ensure C-factors drop to 0.05 within a further 60 days.
  - Note that riparian lands should be stabilised to achieve a C-factor of 0.05 or less within 10 working days of completion of works.

6.2 Stripping and Stockpiling of Topsoil

Topsoils in areas of Units A, C, D and E are well-structured and coherent. They are suitable for stripping and stockpiling for later re-use during stabilisation activities. Soils should not be stripped or worked when they are too wet or too dry – a moist condition is best to minimise the risk of structural decline. Recommended stripping depths are as follows (refer to **Figure 2** for the location of each unit).

- Unit A: 0.4 m.
- Unit B: Unsuitable for use during rehabilitation. Stripping is unlikely to expose suitable material for foundations.

- Unit C: 0.35.
- Unit D: 0.25 to 0.3.
- Unit E: 0.6 m.

Unit B consists of black, cracking clay soils that have high shrink/swell characteristics and are unsuitable for use during rehabilitation. Additionally, the underlying materials are also highly reactive and are a poor engineering foundation material.

Stockpiling of topsoils should accord with Standard Drawing SD 4-1 in Landcom (2004). Stockpiles should be stabilised within 10 days of formation to achieve a C-factor of 0.1 or less.

6.3 Road Design

6.3.1 Salinity Issues

Our soil survey identified that salinity is an issue in the subsoils (below 0.8m depth) in Unit A (**Figure 2**) and that surface discharge of saline groundwater is occurring in a single location near TP15. If appropriate mitigation or road design measures are not included, there is a significant risk of the following.

- Elevated saline groundwater may impact the road, causing pavement damage. This may lead to safety issues and increased maintenance costs.
- The road itself could exacerbate or cause localised salt scalding. Subsoil compaction associated with roads running on footslope areas parallel to the contour can lead to elevated water tables on the uphill side of the road. This water can bring dissolved salts into the root zone of plants.

At the existing discharge point near TP15, the road will need specific measures included in its design to minimise the risk of pavement damage. In this location, we recommend that a capillary break (e.g. Tensar Geogrid or equivalent) be installed below the pavement to divert any elevated groundwater laterally into the adjacent stormwater drainage system. This will also help to stiffen the pavement.

For the remainder of the area of Unit A, the risk of salt damage to the road is lower but should still be considered during road design. DIPNR (2003) discusses a number of techniques that could be employed to address these issues. Note that in most cases, successful treatment involves employing a number of the following.

- Installation of a capillary break between the subgrade and the road pavement.
- Increasing the pavement stiffness.
- Increasing the thickness of fill material over the natural ground level to increase formation heights.
- Use of lime as a stabilising material in the subgrade.
- Appropriate roadside drainage.

- Groundwater pumping.
- Targeted vegetation planting to lower water tables.
- Sealing road shoulders to increase the overall road strength.
- Ensuring that imported fill material is free from or contains minimal salts.
- Minimising pavement surface permeability to reduce the effects of evaporative draw.
- Locating sedimentation or detention basins away from the roadway and, preferably, on the downhill side.
- Altering the proposed road alignment to avoid saline areas.

6.3.2 Shrink/Swell Potential

Although a comprehensive geotechnical assessment will be prepared by Envirowest Consulting, soils in Unit B were identified in our literature review and using field tests as being highly reactive and prone to excessive shrinking and swelling as moisture regimes change. Road design in this area should allow for the potential for the underlying subgrade material to move significantly.

7 CONCLUSION

This report details the results of an assessment of the soils within the Study Area. It includes a review of existing soil information and a detailed assessment of the soil conditions along that route.

The soils along the route are delineated into five distinct units, A to E. A summary of the constraints and opportunities of each unit is included in Section 5 of this report. Recommendations for erosion and sediment control during construction and for road design to address various soil-related issues are included in Section 6.

8 REFERENCES

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ANNEXURES

(No. of pages excluding this page = 12)

Annexure 1 Soil Profile Descriptions

Annexure 2 Laboratory Test Results

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Annexure 1

Soil Profile Descriptions

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TP1	GPS: 698234 6315569	Slope gradient: 5%
Ch 8140	Soil mapping unit: C	Landscape position: midslope
Layer 1	0 – 350 mm	Dark brown to grey clay loam to light clay. Strongly pedal and highly organic.
Layer 2	350 – 850 mm	Moderately pedal, dark brownish grey medium clay. Extensive cementations, nodules and fragments.
Layer 3	850 – 1300 mm+	Dark grey, apedal clayey sand to sandy clay. Fragments and nodules absent.
Notes	Imperfectly drained.	

TP2	GPS: 698305 6315316	Slope gradient: 4%
Ch 8390	Soil mapping unit: C	Landscape position: crest/upper slope
Layer 1	0 – 450 mm	Dark reddish-brown, strongly pedal clay loam to light clay.
Layer 2	450 – 1,000 mm	Brownish grey, noduled gritty medium clay. Not whole coloured – yellow, grey, red mottling.
Layer 3	1,000 – 1,700 mm+	Dark grey, saprolitic B3 to BC horizon. Clayey sand to sandy clay. Apedal.
Notes	Better drainage than TP1. Surface rock nearby – andesite or tuff.	

TP3	GPS: 698377 6315073	Slope gradient: 4%
Ch 8640	Soil mapping unit: C	Landscape position: vague depression
Layer 1	0 – 700 mm	Dark brown, strongly pedal light-medium clay loam to clay.
Layer 2	700 – 1,500 mm+	Dark brownish yellow sandy clay to clayey sand. Slightly greenish colour. Weakly pedal.
Notes	Slow drainage indicated by yellowed and mildly gleyed subsoils, plus less red in the topsoil.	

TP4	GPS: 698234 6315569	Slope gradient: 1%
Ch 8900	Soil mapping unit: B	Landscape position: drainage flat
Layer 1	0 – 400 mm	Sticky, black cracking medium clay. Strongly pedal. Friable/self-mulching. Soapy feel – potentially sodic.
Layer 2	400 – 1,400 mm	Very dark greyish brown to black subplastic medium to heavy clay. Strongly structured and cracked.
Layer 3	1,400 – 1,700 mm+	Dark yellowish brown to dark green (gleyed) sandy clay. Weakly pedal.
Notes	Wiesenboden. Very flat and low-lying area. Evidence of potential seasonal waterlogging.	

TP5	GPS: 698527 6314575	Slope gradient: 3%
Ch 9150	Soil mapping unit: A	Landscape position: footslope
Layer 1	0 – 400 mm	Dark brown to strong brown, moderately to strongly pedal sandy clay loam. No coarse fragments.
Layer 2	400 – 1,200 mm	Dark yellowish brown to greyish brown moderately pedal light-medium clay. Common coarse fragments (parent material).
Layer 3	1,200 – 1,700 mm+	Brownish yellow clayey sand to sandy clay. Apedal. No coarse fragments.
Notes	Better drainage than TP4. Natural ground surface is 2 to 3%. Proposed road slope about 1%.	

TP6	GPS: 698596 6314347	Slope gradient: 3%
Ch 9400	Soil mapping unit: C	Landscape position: slight rise on footslope
Layer 1	0 – 350 mm	A1 horizon. Dark brown sandy clay loam. Moderately pedal. Grades to dark yellowish-brown with depth and clay fraction increases.
Layer 2	350 – 700 mm	Grey-brown and yellow slightly mottled medium clay. Common coarse fragments (parent material). Moderately pedal. NB Layer is sometimes absent.
Layer 3	700 – 1,500 mm+	Strong brown, moderately pedal medium sandy clay. 5% coarse fragments.
Notes	Soil continues but gets more saprolitic in BC horizon. Topsoils similar to TP1, 2 and 5.	

TP7	GPS: 697965 6316055	Slope gradient: 4 - 5%
Ch 7570	Soil mapping unit: A	Landscape position: lower slope
Layer 1	0 – 300 mm	Dark brown to black organic-rich sandy clay loam to clay loam. Strongly pedal.
Layer 2	300 – 1150mm	Moderately pedal, dark brown, subplastic, reactive medium clay. <5% coarse fragments.
Layer 3	1150 – 1,700mm+	Dark brownish grey saprolitic, weathered serpentinite.
Notes	4 to 5% natural slope. Road traverses slope at approximately 1% grade.	

TP8	GPS: 697801 6316244	Slope gradient: 5 - 6%
Ch 7320	Soil mapping unit: C	Landscape position: Very low ridge on footslope
Layer 1	0 – 280mm	Red-brown friable, strongly pedal sandy clay loam. Little or no coarse fragments.
Layer 2	280 – 1,200mm	Strong brown, moderately pedal, potentially reactive medium-heavy clay. Up to 5% coarse fragments.
Layer 3	1200 – 1,400mm+	Dark brown gravely sandy clay. Slightly mottled.
Notes	On a slight rise – better drained than the surrounding footslopes and, subsequently, with slightly redder soils.	

TP9	GPS: 697597 6316418	Slope gradient: 8%
Ch 7060	Soil mapping unit: A	Landscape position: footslope – edge of rise
Layer 1	0 – 250mm	Red-brown friable, strongly pedal sandy clay loam. Little or no coarse fragments.
Layer 2	250 – 1,700mm+	Yellowish-brown to orange, moderately pedal sandy medium clay.
Notes	Moderately well drained. Potentially reactive. Maximal lower slope at edge of plain.	

TP10	GPS: 697448 6316536	Slope gradient: 0 - 1%
Ch 6860	Soil mapping unit: B	Landscape position: Plain – floodplain of BS Ck
Layer 1	0 – 150mm	Organic-rich, dark brown to black, strongly pedal alluvial clay loam to light clay.
Layer 2	150 – 1,400mm	Moderately pedal yellowish-brown to dark grey mottled, plastic, reactive gravely medium-heavy clay.
Layer 3	1,400 – 1,700mm+	Moist, brownish-yellow and grey, mottled light-medium clay. Common cementations and fragments.
Notes	Alluvial clay soils approximately 10m from the bank of Blackman's Swamp Creek. Olive colour increases with depth.	

TP11	GPS: 698089 6315886	Slope gradient: 5%
Ch 7780	Soil mapping unit: A	Landscape position: footslope
Layer 1	0 – 800mm	Friable, well-structured, organic-rich, very dark brown to black clay loam. 5% coarse fragments.
Layer 2	800 – 1,700mm+	Greyish brown and mottled (yellow) gravely clayey sand. Highly weathered, saprolitic BC horizon.
Notes	Immediately upslope (approximately 70m to creek and dam) from wide depression. Footslope position. Slope increases upslope (to the west).	

TP12	GPS: 697210 6316778	Slope gradient: 4%
Ch 6520	Soil mapping unit: A	Landscape position: footslope – long (bottom of)
Layer 1	0 – 500 mm	Strong brown, moderately pedal clay loam. Less organic material than nearby test pits. 5% coarse fragments.
Layer 2	500 – 1,200 mm	Weak to moderately pedal, yellowish-brown to grey mottled medium clay. Potentially reactive. 5% coarse fragments.
Layer 3	1,200 – 1,700 mm+	Weakly pedal, grainy and gravely, mixed colours (yellow, grey, brown – highly mottled) medium-heavy clay to sandy clay. Similar in texture to highly weathered fine sandstone or siltstone.
Notes	Grey mottling increases with depth. Layer 3 is a progression of layer 2 – very vague boundary.	

TP13	GPS: 697112 6317038	Slope gradient: 9 - 10%
Ch 6230	Soil mapping unit: D	Landscape position: midslope
Layer 1	0 – 200mm	Strong brown, moderately pedal silty clay loam. 5% coarse fragments
Layer 2	200 – 1,700mm	Dark yellowish brown to strong brown (and slightly mottled) silty clay to fine sandy clay. 5 to 10% coarse fragments.
Notes		

TP14	GPS: 697071 6317192	Slope gradient: 8 - 9%
Ch 6080	Soil mapping unit: D	Landscape position: midslope
Layer 1	0 – 200mm	Light brown to strong brown, moderately pedal fine sandy clay loam. Less than 5% coarse fragments.
Layer 2	200 – 1,700mm+	Dark yellowish brown, weakly pedal, mildly plastic medium sandy clay. 5 to 10% coarse fragments.
Layer 3		
Notes	Mottling increases with depth. Near end of existing road construction.	

TP15	GPS: 697264 6316696	Slope gradient: <2%
Ch 6620	Soil mapping unit: A	Landscape position: depression
Layer 1	0 – 200mm	Light greyish brown, weakly pedal fine sandy clay loam.
Layer 2	200 – 1,200mm	Mottled grey and yellow light medium clay. Apedal. Less than 5% coarse fragments.
Layer 3	1,200 – 1,700mm	Grey and yellow clayey sand to sandy clay. Gravelly, with ferromanganiferous and ironstone nodules/fragments.
Notes	Saline scald nearby at chainage 6610. Groundwater at approximately 0.5m to 1.0m depth.	

TP16	GPS: 698794 6313144	Slope gradient: 8%
Ch 10630	Soil mapping unit: D	Landscape position: midslope
Layer 1	0 – 220mm	Reddish brown, strongly pedal fine, sandy clay loam to clay loam. Heavy clay fraction.
Layer 2	220 – 520mm	Reddish brown to strong brown, moderately pedal medium heavy fine sandy clay.
Layer 3	520 – 1,800 mm+	Yellowish brown, gritty sandy clay. Saprolitic, weathered parent material at depth. Common nodules, fragments and cementations. Blocky structure.
Notes	On a small ridge – site of extensive cut for road construction.	

TP17	GPS: 698820 6313012	Slope gradient: 15%
Ch 10770	Soil mapping unit: E	Landscape position: saddle
Layer 1	0 – 220mm	Reddish brown, strongly pedal fine, sandy clay loam to clay loam. Heavy clay fraction.
Layer 2	220 – 600mm	Bleached, light grey, massive, silty clay A2 horizon. Chalky, powdery texture.
Layer 3	600 – 900mm	Moderately pedal, yellowish brown, mottled medium clay.
Layer 4	900 – 1,400 mm+	BC horizon. Grey, yellow and brown, highly mottled gravely clayey sand. Common nodules and coarse fragments.
Notes	Pronounced bleached A2 horizon in saddle.	

TP18	GPS: 698920 6312819	Slope gradient: 22%
Ch 10990	Soil mapping unit: D	Landscape position: steep sideslope
Layer 1	0 – 200mm	Friable, well-structured (crumb – granular), dark brown sandy clay loam.
Layer 2	200 – 550mm	Variable depth layer, sometimes absent. Moderately pedal, dark yellowish brown silty medium clay.
Layer 3	500 – 2,000mm+	Saprolitic BC horizon. Yellowish brown sandy clay, grades to grey colour at depth.
Notes	Layer 3 here is similar to layer 3 in TP16. Road to be cut into sideslope up to 2.5m at this point. Note gradual boundaries between soil layers.	

TP19	GPS: 698978 6312684	Slope gradient: 19%
Ch 11140	Soil mapping unit: D	Landscape position: sideslope
Layer 1	0 – 150mm	Dark brown, moderately pedal sandy clay loam. High organic content.
Layer 2	150 – 550mm	Medium brown to dark yellowish brown, blocky, moderately pedal medium clay.
Layer 3	550 – 1,900mm	B2 to BC horizon (gradual boundary to layer 4). Yellowish brown, weakly pedal medium-heavy clay. Rock increases with depth.
Layer 4	1,900 mm+	Saprolitic weathered rock.
Notes	Gradual boundary between most layers. Occasional rock fragments in profiles and outcropping nearby.	

TP20	GPS: 699114 6312397	Slope gradient: 6%
Ch 11450	Soil mapping unit: E	Landscape position: depression
Layer 1	0 – 270mm	Dark brown, fine sandy loam. Moderate granular structure and sandy fabric.
Layer 2	270 – 600mm	Mildly bleached, light grey fine sandy loam to silty loam. Very rare yellow mottling.
Layer 3	600 – 1,600mm	Highly cemented gravely clayey sand. Light grey, brown and yellow – mottled.
Notes	In drainage depression.	

TP21	GPS: 699208 6312130	Slope gradient: 1 - 2%
Ch 11710	Soil mapping unit: B	Landscape position: small floodplain
Layer 1	0 – 220mm	Very dark brown to black, moderately pedal heavy clay loam. Organic rich. 5% coarse fragments. Very gradual boundary to layer 2.
Layer 2	220 – 660mm	Very dark greyish brown to black medium clay. Weakly to moderately pedal. 5% coarse fragments.
Layer 3	660 – 1,200mm	Black, weak to moderately pedal, stiff, cracked, heavy clay. Potentially reactive. 5% coarse fragments.
Layer 4	1,200 – 1,700 mm+	Yellowish-brown, gravely clay. Highly mottled.
Notes	On minor floodplain associated with Dairy Creek. Wiesenboden soils. Self-mulching. Coarse fragments throughout the profile.	

TP22	GPS: 699241 6311999	Slope gradient: 11%
Ch 11850	Soil mapping unit: D	Landscape position: midslope
Layer 1	0 – 340mm	Dark reddish brown, moderately pedal, fine and light sandy clay loam. <5% coarse fragments.
Layer 2	340 – 600mm	Dark reddish brown, weakly pedal fine sandy clay. 10% coarse fragments.
Layer 3	600 – 900mm	Reddish brown with yellow mottles and 10% dark coarse fragments sandy clay. Saprolitic at depth.
Notes	Nearby rock outcropping and floaters.	

TP23	GPS: 699278 6311824	Slope gradient: 9%
Ch 12010	Soil mapping unit: D	Landscape position: vague drainage depression
Layer 1	0 – 200mm	Dark reddish brown, friable, organic-rich, weakly pedal sandy clay loam.
Layer 2	200 – 700mm	Dark brown to dark reddish brown, weakly pedal, medium-heavy fine sandy clay to clay. 5 to 10% coarse fragments.
Layer 3	700 – 900mm +	Refusal at 900mm on increasing rock – cemented, saprolitic BC horizon.
Notes	Not as well drained as TP22. Common rock outcropping nearby. In very slight drainage depression near to where the road meets the existing Mitchell Highway.	

TP24	GPS: 698657 6314094	Slope gradient: 2-4%
Ch 9680	Soil mapping unit: A	Landscape position: footslope
Layer 1	0 – 200 mm	Dark brown, weakly pedal, fine sandy clay loam. Sandy fabric.
Layer 2	200 – 280 mm	Thin, slightly bleached A2 horizon. Light brown, massive to weakly pedal silty clay loam.
Layer 3	280 – 700 mm	Dark brown to dark reddish brown, strongly pedal medium-heavy clay. Gradual boundary from layer 3 to layer 4.
Layer 4	700 – 1,200 mm+	Dark grey and highly mottled, weathered rock. Clayey sand.
Notes	Test pit is right at the edge of the footslope where it meets the drainage plain.	

TP25	GPS: 698681 6313911	Slope gradient: 12%
Ch 9850	Soil mapping unit: D	Landscape position: Long hillslope (lower slope)
Layer 1	0 – 300 mm	Moderately pedal, dark brown fine, light, sandy clay loam. Pedality increases with depth. No coarse fragments. Gradual boundary to layer 2 and 3.
Layer 2	300 – 800 mm	Layer 2 is a grading between layers 1 and 3. Clay increases and colour becomes more yellow.
Layer 3	800 – 2,000 mm+	Light yellowish brown and mottled, cemented clayey sand. Massive and saprolitic.
Notes	Mottling increases with depth in layer 2.	

TP26	GPS: 698709 6313668	Slope gradient: 20%
Ch 10025	Soil mapping unit: D	Landscape position: midslope
Layer 1	0 – 300 mm	Weakly pedal, dark brown fine, medium sandy clay loam. <5% coarse fragments.
Layer 2	300 – 810 mm	Moderately to strongly pedal dark brown medium silty clay to clay. 10 to 20% coarse fragments (small).
Layer 3	810 – 1,700 mm+	Dark, strong brown with slight olive colour, weathered, saprolitic material. Clayey sand to sandy clay texture. Cementation increases with depth.
Notes	On a short, maximal slope within a he long hillslope to the west. 25% upslope, 15% downslope. No rock encountered in test pit although coarse fragments were common.	

TP27	GPS: 698736 6313413	Slope gradient: 10%
Ch 10380	Soil mapping unit: D	Landscape position: mid to lower slope
Layer 1	0 – 130 mm	Mid brown, weakly to moderately pedal fine sandy clay loam.
Layer 2	130 – 330 mm	Very slightly bleached A2 horizon. Light greyish brown, massive, fine sandy clay loam.
Layer 3	330 – 800 mm	Dark greyish brown, weakly pedal medium clay. 5 to 10% coarse fragments.
Layer 4	800 – 1,500 mm	Dark greyish-brown, weakly pedal, blocky medium-heavy sandy clay. Partly mottled. Coarse fragments increase with depth to about 10%, then to refusal on rock.
Notes	On a minimal slope below a low bench to the west. Bench has rock outcrop. Refusal at 1.5m on rock.	

Annexure 2

Laboratory Test Results

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Department of Lands
Land Administration & Management
Property & Spatial Information

Soil Conservation Service

SOIL TEST REPORT

Page 1 of 4

Scone Research Centre

REPORT NO:	SCO08/143R1
REPORT TO:	Andrew Macleod SEEC Morse McVey PO Box 1098 Bowral NSW 2576
REPORT ON:	Fourteen soil samples Ref: 07000631
PRELIMINARY RESULTS ISSUED:	Not issued
REPORT STATUS:	Final
DATE REPORTED:	14 April 2008
METHODS:	Information on test procedures can be obtained from Scone Research Centre

TESTING CARRIED OUT ON SAMPLE AS RECEIVED
THIS DOCUMENT MAY NOT BE REPRODUCED EXCEPT IN FULL

G Holman
(Technical Officer)

Scone Research Centre, PO Box 283 Scone 2337, 709 Gundy Road Scone 2337
Ph: 02 6545 1666, Fax: 02 6545 2520

SOIL AND WATER TESTING LABORATORY
Scone Research Service Centre

Report No: SCO08/143R1
Client Reference: Andrew Macleod
SEEC Morse McVey
PO Box 1098
Bowral NSW 2576

Lab No	Method	P7B/1 Particle Size Analysis (%)						P8A/2	P9B/2
	Sample Id	clay	silt	vf sand	cf sand	c sand	gravel	D%	EAT
1	07000631 TP4 L1	56	17	11	5	11	<1	29	5
2	07000631 TP6 L3	42	20	20	6	9	3	26	3(1)
3	07000631 TP10 L2	41	24	15	5	15	<1	32	3(1)
4	07000631 TP11 L1	18	26	27	10	14	5	25	3(1)
5	07000631 TP11 L2	11	4	13	6	40	26	43	3(1)
7	07000631 TP13 L2	33	23	20	7	16	1	30	5
11	07000631 TP17 L2	10	27	45	15	2	1	50	3(1)
12	07000631 TP18 L2	50	16	13	4	15	2	22	5
13	07000631 TP18 L3	48	17	11	7	17	<1	23	3(1)
14	07000631 TP22 L2	52	13	9	5	16	5	11	3(1)

SOIL AND WATER TESTING LABORATORY
Scone Research Service Centre

Report No: SCO08/143R1
Client Reference: Andrew Macleod
SEEC Morse McVey
PO Box 1098
Bowral NSW 2576

Lab No	Method	P7C/1 Particle Size Analysis - mechanical dispersion (%)						C6A/2
	Sample Id	clay	silt	vf sand	cf sand	c sand	gravel	OC (%)
1	07000631 TP4 L1	40	31	11	7	11	<1	1.38
2	07000631 TP6 L3	24	40	19	6	8	3	0.54
3	07000631 TP10 L2	21	38	26	11	4	<1	0.72
4	07000631 TP11 L1	10	25	29	17	14	5	1.61
5	07000631 TP11 L2	6	6	12	9	41	26	0.23
7	07000631 TP13 L2	20	32	18	10	19	1	0.10
11	07000631 TP17 L2	1	29	48	18	3	1	0.20
12	07000631 TP18 L2	39	21	14	7	17	2	0.96
13	07000631 TP18 L3	38	20	15	8	19	<1	0.72
14	07000631 TP22 L2	35	24	11	7	18	5	0.97

SOIL AND WATER TESTING LABORATORY
Scone Research Service Centre

Report No: SCO08/143R1
Client Reference: Andrew Macleod
SEEC Morse McVey
PO Box 1098
Bowral NSW 2576

Lab No	Method	C1A/4	C2A/3	C5A/3 CEC & exchangeable cations (me/100g)					C8A/2	P9B/2	
	Sample Id	EC (dS/m)	pH	CEC	Na	K	Ca	Mg	P (mg/kg)	EAT	Texture
6	07000631 TP13 L1	0.02	6.0	9.7	0.4	0.2	5.1	1.3	2	5	fine sandy loam
8	07000631 Near TP15	2.92	10.6	nt	nt	nt	nt	nt	nt	nt	nt
9	07000631 TP16 L1	0.05	6.2	27.0	0.8	0.8	11.4	11.5	1	3(1)	clay loam
10	07000631 TP16 L2	0.02	6.5	39.6	0.6	0.5	16.0	20.2	nt	3(1)	nt

nt = not tested

END OF TEST REPORT