Douglas Partners
Geotechnics • Environment • Groundwater

Integrated Practical Solutions

REPORT
on
SALINITY STUDY

PROPOSED M7 BUSINESS HUB
OLD WALLGROVE ROAD
EASTERN CREEK

Prepared for
MACQUARIE GOODMAN MANAGEMENT PTY LTD

Project 37899
AUGUST 2005

Douglas Partners
Geotechnics • Environment • Groundwater

REPORT
on
SALINITY STUDY

PROPOSED M7 BUSINESS HUB
OLD WALLGROVE ROAD
EASTERN CREEK

Prepared for
MACQUARIE GOODMAN MANAGEMENT PTY LTD

Project 37899
AUGUST 2005

Douglas Partners Pty Ltd
ABN 75 053 980 117

96 Hermitage Road
West Ryde NSW 2114
Australia

PO Box 472
WEST RYDE NSW 1685

Phone (02) 9809 0666
Fax (02) 9809 4095
sydney@douglaspartners.com.au

ACEA
The Association of Consulting Engineers Australia

TABLE OF CONTENTS

JL:ss

Project 37899

11 August 2005

REPORT ON SALINITY STUDY

PROPOSED M7 BUSINESS HUB

OLD WALLGROVE ROAD

EASTERN CREEK

1. INTRODUCTION

This report supercedes our Preliminary Report dated 7 July 2005 and presents the final results of a salinity study by Douglas Partners (DP) of the Western, Central and Eastern Precincts of the area of the proposed M7 Business Hub, a commercial development at Eastern Creek.

The development area lies between Old Wallgrove Road, Wallgrove Road and the Sydney Water Supply pipeline (Figure 1 on page 2). The Eastern Precinct is divided from the Western and Central Precincts by Reedy Creek, which flows northeast then east through the site. The western area contains an existing quarry and a heritage property (Southridge House) which are effectively inaccessible for the proposed study, leaving accessible areas of approximately 60 Ha in the West and Central Precincts and 30 Ha in the East Precinct.

Development includes placement of imported filling materials over most of the Eastern Precinct and this work had been substantially completed prior to commencement of the present study, which was commissioned by Henry & Hymas Consulting Engineers on behalf of Macquarie Goodman Management Pty Ltd (MGM).

The objective of the study was to provide information to MGM with regard to soil salinity as part of their overall site investigation programme for management of the development. The broader programme includes geotechnical investigations by DP, reported separately. The salinity study comprised a review of available site data, site inspections, non-intrusive electromagnetic (EM) profiling, test pitting, laboratory testing of soil samples from the test pits and of geotechnical drilling samples from the Western Precinct, and analysis of EM data and available laboratory results. This work followed pegging of an 100 m x 100 m grid by surveyors Hard & Forester on behalf of MGM. Pegs are labelled A to J northwards and 1 to 18 westwards, with A1 at 301120.8 mE, 6255751.6 mN (MGA94 Zone 56). Throughout this report, locations are indicated by specific or intermediate peg labels (e.g. G4, G4/5, G/H4 or G/H 4/5).

Details of work undertaken and results obtained, together with comments relating to salinity and relevant drawings are presented in the present report and the Appendix.

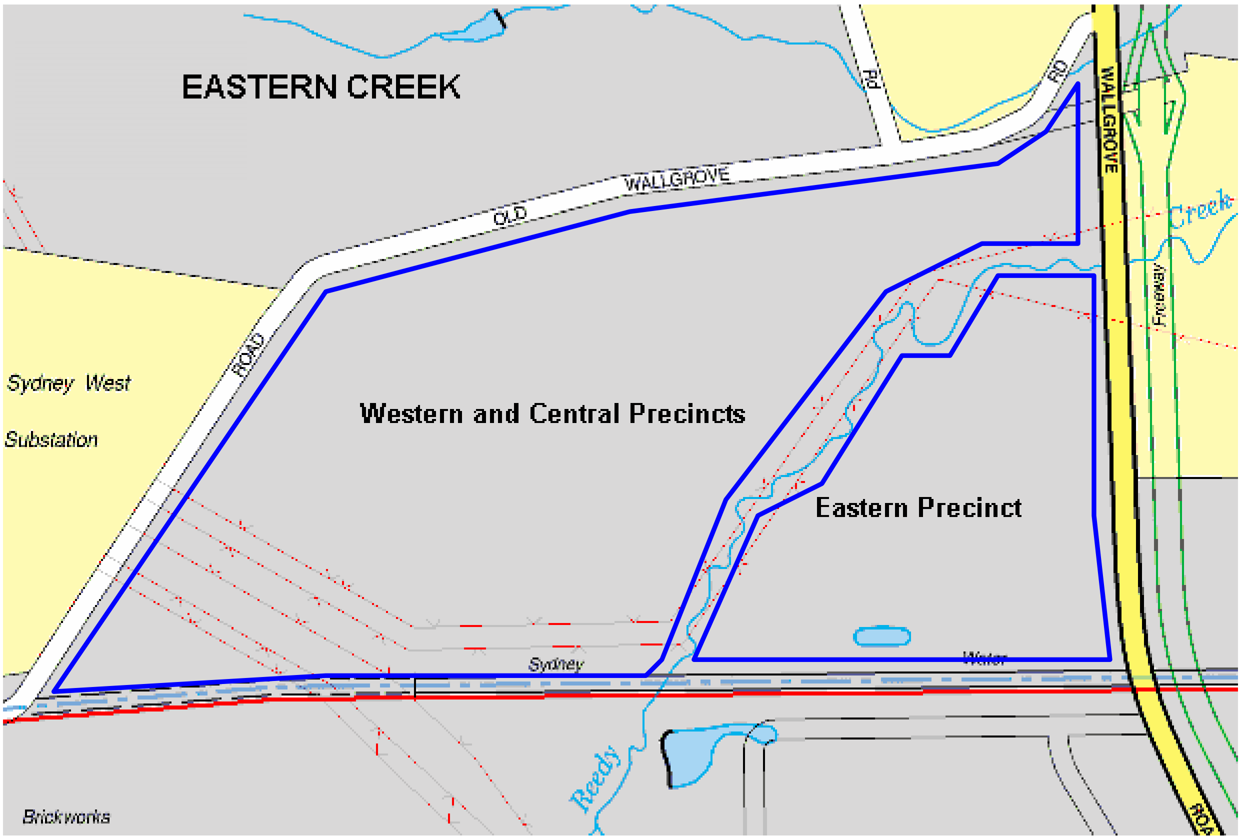


Figure 1 – Site Location

2. SCOPE OF WORK

The following scope of work was proposed:

2.1 Review data provided by MGM, existing DP data, published data and maps relevant to the understanding of the local geological and hydrogeological environment;

2.2 Carry out inspections for the identification and mapping of any visible indicators of salinity or potential salinity (based on geological and morphological features and vegetation) which may require investigation by EM profiling and/or test pitting and sampling;

2.3 Carry out EM profiling on a 100 m x 100 m grid over all accessible areas using a Geonics EM31 Ground Conductivity Meter mounted on a 4WD quad bike fitted with a differential global positioning system (DGPS);

2.4 Construct an apparent conductivity map from the EM data showing areas of high conductivity and potentially high soil salinity which may impact on the development;

2.5 Carry out test pitting and soil sampling in critical areas assessed (from the apparent conductivity map) likely to be of relatively high salinity;

2.6 Carry out laboratory salinity testing on the above samples and analyse these results to produce representative vertical soil salinity profiles for the investigation area and hence identify the likely soil horizon or depth zone contributing most to the high apparent conductivity measurements;

2.7 Complete a programme of test pitting or hydraulic push-tube sampling throughout the remainder of the investigation area to ensure the horizon of interest is adequately sampled in a statistical sense;

2.8 Complete laboratory salinity testing on the remainder of the samples;

2.9 Correlate laboratory salinities with apparent conductivities from the EM profiling, to assess the dependence of the apparent conductivities on soil salinity;

2.10 If the above dependence is established, determine the empirical relationship between apparent conductivities and salinities and calibrate (re-scale) the apparent conductivities to allow presentation of an apparent salinity map over the investigation area; and

2.11 Report on the findings and provide conclusions and recommendations regarding salinity management.

3. SITE DESCRIPTION

As shown in Drawing 1, most of the Eastern Precinct at the time of the investigation comprised new imported filling (from a number of sources throughout Sydney) which had been placed and graded between Wallgrove Road in the east, the steep embankment rising to the Sydney Water Supply pipeline in the south and a zone of dense vegetation in the west. Filling had been stockpiled in the northeast of the area and was being graded but was below final level. From the initial inspection by a senior DP engineering geologist, a zone of older filling was inferred between the dense vegetation and Reedy Creek in the central north of the area and a trench had been excavated through this material exposing inferred alluvial sediments.

The Western and Central Precincts comprise rolling grassy hills between Old Wallgrove Road in the north and west, the Sydney Water Supply pipeline in the south and the riparian zone of Reedy Creek in the east. Drawing 3 shows the inaccessible areas surrounding the existing quarry, Southridge House and adjacent electrically fenced horse paddocks. A ridge trends both north and southwest from D/E 14/15, west and south of which the ground falls by 13 m to 15 m. Another ridge trends north-northeast from G13 to Old Wallgrove Road. Between these ridges the ground drains northwards, while to the east gullies direct runoff east and south to small dams near Southridge House. A zone of lush growth occurs in this south-trending gully and there is some evidence of seepage in that area.

Some patches of bare soil and a zone of gully erosion were noted in the Western precinct and are shown on Drawing 3, along with two locations of exposed fine grained sandstone bedrock (near G/H10 and E/F 12/13).

4. GEOLOGY, SOILS, HYDROGEOLOGY AND SALINITY POTENTIAL

Reference to the Penrith 1:100 000 Geological Series Sheet indicates that the site is underlain by Bringelly Shale of the Wianamatta Group of Triassic age. Bringelly Shale comprises an interbedded sequence of shale, laminite, siltstone, fine sandstone and some minor coaly bands. These rock units typically weather to form clays of medium and high plasticity.

Reference to the Penrith 1:100 000 Soil Landscape Map indicates the site is underlain by residual soils belonging to the Blacktown Group. The Blacktown landscape typically comprises "gently undulating rises on Wianamatta Group shales and Hawkesbury shales, with local relief to 30m and slopes usually less than 5%". The land is typically cleared woodland or tall open forest. The Blacktown soils are shallow to moderately deep (<100 cm) red and brown podzolic soils on crests, upper slopes and well drained areas. Deep (150 – 300 cm) yellow podzolic soils are located on lower areas and in areas of poor drainage. These soils are derived from weathering of the underlying (typically shaly) bedrock and are moderately reactive and highly plastic, with low soil fertility and poor soil drainage.

The mapped regional geology and soil landscape are generally confirmed by previous geotechnical investigations (DP Projects 37389 and 37389A, 2005), initial salinity inspections and test pitting. Inspection has indicated alluvial soil immediately east of Reedy Creek however over much of the Eastern Precinct the natural surfaces are covered by silty clay filling materials. These appear to comprise older filling (probably spoil from local quarrying) and new filling (understood to have been imported from a variety of Sydney locations).

McNally (2005) describes the general hydrogeological framework relevant to western Sydney, including this site, where the shale terrain is known for saline groundwater (due to connate salt in shales of marine origin or to windblown sea salt) and the salt accumulates by evapo-transpiration (mostly in the B-horizon of residual soils). In areas of urban development this can lead to damage to building foundations, lower course brickwork, road surfaces and underground services, where these impact on the saline zone or where the salts are mobilised by changing groundwater levels. Seasonal water level changes of 1 - 2 m can occur in a shallow regolith aquifer or a deeper shale aquifer due to natural causes, however urban development should be carried out with a view to maintaining the natural water balance (between surface infiltration, runoff, lateral throughflow in the regolith, and evapo-transpiration) so that long term rises do not occur in the saline groundwater level.

The Department of Infrastructure Planning and Natural Resources (DIPNR) infers a "high salinity potential" in the lower slopes and drainage areas of Reedy Creek, on their map entitled "Salinity Potential in Western Sydney 2002". These DIPNR inferences are based on soil types, surface levels and general groundwater considerations but are not in general ground-truthed, hence it is not generally known if actual soil salinities are consistent with the potential salinities of DIPNR.

5. PREVIOUS SALINITY ASSESSMENTS

Studies by SMEC Australia Pty Ltd for Blacktown City Council (SMEC 2002) and the SEPP59 Landowner Group (SMEC 2003) covered a broader area of the Eastern Creek catchment but included the site presently under investigation. In terms of the present site, these field studies were limited to collection of:

- one surface soil sample and four water samples from Reedy Creek;
- soil samples from three shallow bores along Reedy Creek;
- groundwater samples from one bore along Reedy Creek; and
- soil samples from one shallow bore on the lower slopes of the northwest portion of the Western Precinct.

Samples were analysed and findings considered by DP to be relevant to the present site and proposed development were:

- Salinity levels in Reedy Creek were slightly elevated and in excess of the (then DLWC) water quality threshold of 2500 µS/cm;
- Groundwater was in general highly saline and unsuitable for most purposes;
- Maximum soil salinities of 3.65 - 5.11 dS/m (slightly – moderately saline) were determined from bore samples at depths of 0.5 - 4.0 m along Reedy Creek and 5.28 dS/m (moderately saline) at a depth of 1.5 m in the northwest Western Precinct;
- The site did not appear to be affected by large scale soil salinity, but future development had the potential to cause soil salinity problems if groundwater levels were raised significantly;
- Soil salinity varied from non-saline to moderately saline, and salinity was most evident in the deeper soil horizons;
- Low-lying areas were susceptible to increased salinity levels due to close proximity to the saline groundwater.

6. CAUSES OF URBAN SALINITY

Although saline soils and groundwater are a natural part of the Australian landscape, land management practices are now increasingly recognized as significant contributors to the expansion of salt affected areas. In particular, urban salinity is increasingly occurring around populated areas due to clearing and site development.

Salinity occurs when salts found naturally in the soil or groundwater are mobilised. Capillary rise and evaporation concentrate the salt on, and close to, the ground surface. Urban salinity becomes a problem when the natural hydrogeological balance is disturbed by human interaction. This may occur in urban areas due to changes to the water balance, increases in the volume of water into a natural system altering subsurface groundwater flows and levels, exposure of saline soils, and removal of deep rooted vegetation reducing rates of evapotranspiration. Even small changes in sensitive areas can result in the balance being irrecoverably altered and salinisation occurring.

Some building methods may also contribute to the process of urban salinity. For example, compaction of surfaces and fills in a manner which restricts groundwater flow could result in a concentration of salt in one area; cutting into slopes for building can result in saline soils or groundwater being exposed and intercepted; and the use of imported filling may be an additional source of salt or the filling may be less permeable, preventing good drainage. These issues may also result in problems with the design and construction of roads. In particular the building of embankments and the compaction of layers can interfere with groundwater flow. Also the inappropriate positioning, grading and construction of drains can result in surface and groundwater mixing and stagnant pools forming that evaporate leaving salt encrusted ground.

Salinity issues may also arise as the result of cumulative impacts. A common example is from the gradual removal of vegetation across a site, which can contribute to a change in the hydrological regime from reduced evapotranspiration, a consequential rise in the ground water table, and subsequent salinity problems. Where vegetation is gradually removed the watertable rises as a result of a smaller volume of water being used by the plants, allowing salts to be mobilised. Of more relevance in an urban landscape is the potential for an increase in water inputs into the hydrological regime. These increased inputs commonly come from the irrigation or watering of gardens and playing fields, infiltration of storm water and sewage and other service leakage. These inputs may seem minor on their own but their cumulative effects over time produce an elevated groundwater table and eventually high levels of salinity.

7. EFFECTS OF SALINITY IN AN URBAN ENVIRONMENT

Excess salinity in an urban environment can result in significant problems. It can manifest itself in a number of ways resulting in damage to buildings, vegetation, soils and roads.

The effects of salinity can be observed on building materials, infrastructure including pipework and roads as well as in vegetation. The effect of urban salinity is the result of both physical and chemical actions of the salt on concrete, bricks and metals. Salt moves into the pores of concrete and bricks and becomes concentrated when the water evaporates and can result in breakdown of materials and corrosion. Evidence of this may include crumbling, eroding or powdering of mortar or bricks, flaking of bricks, facing and cracking or corrosion of bricks.

High levels of salinity can result in damage to and even death of plants. Signs that vegetation is under stress from salinity include the discolouration and wilting of leaves and the death of less salt tolerant plant species. It may also be hard to establish lawns in areas that are subject to high salinity.

High levels of salinity may also affect soil structure, chemistry and productivity. This can reduce plant growth which in turn alters soil structure, chemistry and nutrient levels. As soils become more saline, plant and micro-organisms decline and soil structure deteriorates. Waterlogging may also occur following a decline in nutrient levels. Over time the alteration of soil structure can lead to the formation of gullies and other forms of soil erosion.

Salinity may also result in the corrosion of steel pipes, structural steel and reinforcement and can damage underground service pipes resulting in significant financial costs.

Salinity can also have a significant effect on roads and pavements including:

- Deterioration of the bitumen seal
- Blistering which can lead to the formation of cracks and potholes
- Staining
- Cracking
- Deformation
- Potholes
- Cracking and spalling of reinforced concrete pavements.

8. FIELD WORK METHODS

8.1 Horizontal Control

All field measurements and conductivity mapping for this project have been carried out using the Geodetic Datum of Australia 1994 (GDA94) and the Map Grid of Australia 1994 (MGA94), Zone 56. Digital mapping has been carried out in a Geographic Information System (GIS) environment using MapInfo software.

8.2 Electromagnetic Survey

An electromagnetic survey was undertaken as part of the salinity study, enabling rapid "continuous" measurement of apparent conductivity, to optimise sample locations and complement laboratory salinity testing of discrete samples taken from test pits.

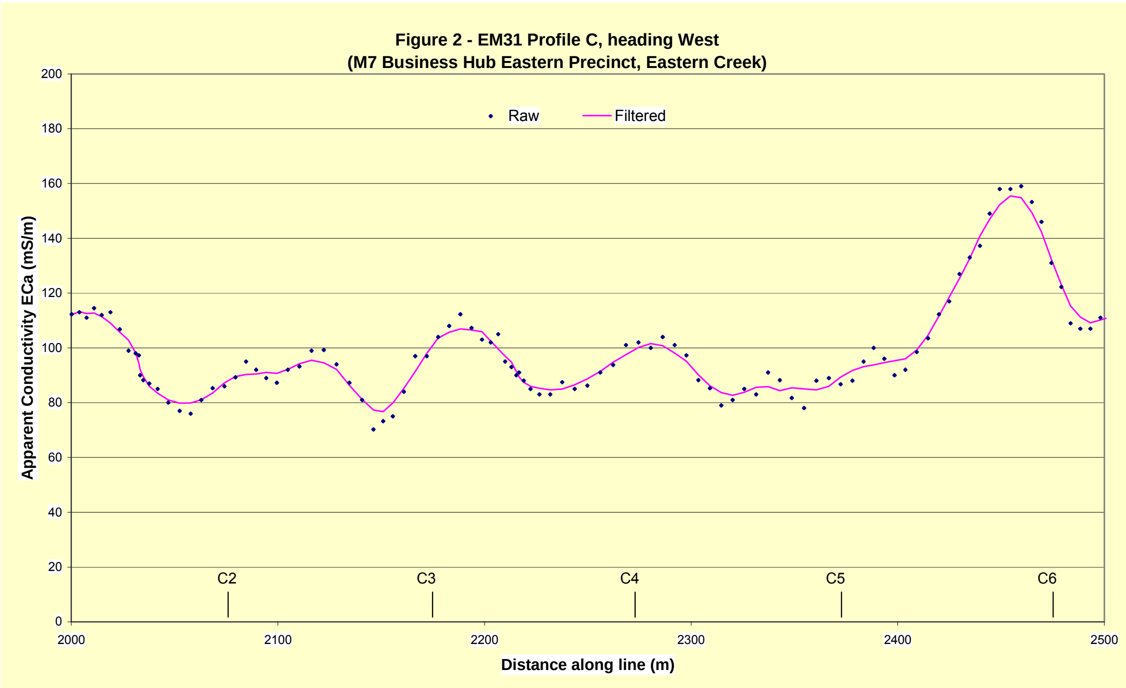
Apparent conductivity is variously referred to as ground conductivity, terrain conductivity, bulk conductivity or bulk electrical conductivity and is designated herein as ECa. Although measured apparent conductivities can include contributions from a variety of sources including groundwater, conductive soil and rock minerals and metals, it has been estimated (Baden Williams in Spies and Woodgate, 2004) that in 75 - 90% of cases in Australia, apparent conductivity anomalies can be explained by the presence of soluble salts. Apparent conductivity can therefore be considered, in the majority of cases, a good indicator of soil salinity.

The survey was undertaken using a Geonics EM31 ground conductivity meter mounted 1 m above the ground surface from the side of a quad bike. The EM31 was operated in the vertical dipole (horizontal coil) mode for a maximum depth of investigation of approximately 6 m. In this configuration approximately 50% of the system response arises within a depth of 3 m below the measurement coils.

A Trimble Ag114 DGPS receiver, antenna and data logger were mounted on the quad bike, enabling digital recording of coordinates and apparent conductivities at 1 second intervals as the quad bike was navigated around the survey areas.

Approximately 16,000 conductivity measurements were made along 45 km of traverse in all accessible parts of the site, along the 100 m x 100 m pegged lines where possible, with an average data point spacing of approximately 3 m. The locations of lines and measurement points are shown in Drawings 1 and 3.

Figure 2 is a typical example of an EM31 profile from the investigation.



8.3 Test Pitting and Soil Sampling

From the results of EM profiling in the Eastern Precinct (below), three locations were chosen as representative of high and low apparent conductivities in the filling areas and of high apparent conductivities in the alluvial zone west of the filling. A backhoe was used to excavate test pits to depths of 2 m (or prior refusal on rock) for collection of material at 1 m depth intervals in the filling and to obtain surface material in the base of the trench cut into the alluvium west of the filling. Materials were described on site by a geotechnical engineer and classified into soil texture groups following the methods of DIPNR, prior to sampling for laboratory salinity tests.

Bulk soil samples and rock cores from prior geotechnical bores BH1 to BH3 at the proposed Coles Myer Facility (straddling the western ridge in the Western Precinct), were resampled at depths of 1 - 2.5 m (soil) and 3 – 9 m (rock) for laboratory salinity testing relevant to that site, prior to more widespread test pitting and soil sampling. These samples were also described and classified into approximate textural groups.

From the results of EM profiling in the Western and Central Precincts (below), sixteen locations were chosen as representative of high and low apparent conductivities throughout the area. A backhoe was used to excavate test pits to depths of 3 m (or prior refusal on rock) for collection of material at 0.5 m depth intervals. Materials were described on site by a geotechnical engineer and classified into soil texture groups following the methods of DIPNR, prior to sampling for laboratory salinity tests.

9. DATA PROCESSING AND INTERPRETATION

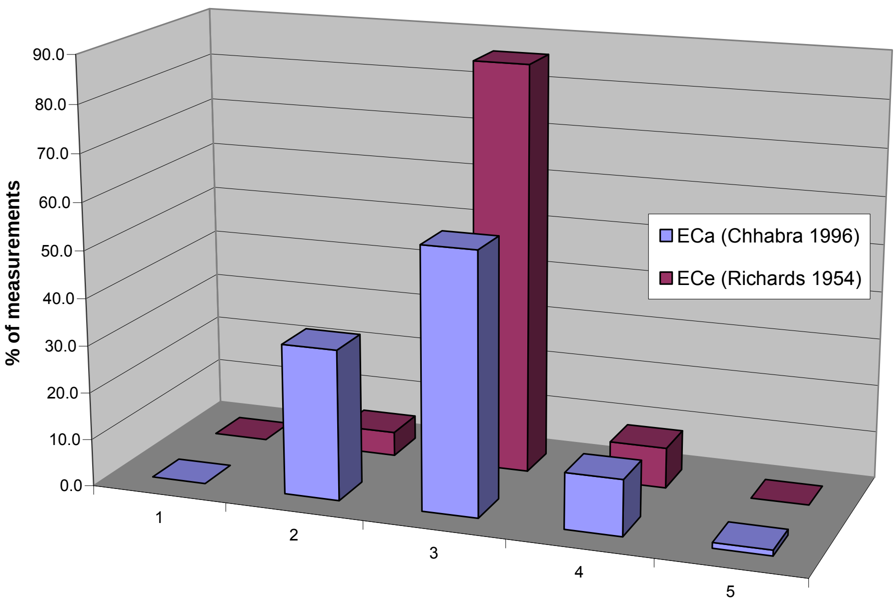
9.1 Eastern Precinct

On completion of EM31 profiling, field data were corrected for the conductivity response of the quad bike and were filtered as shown in Figure 2 above to reduce the noise induced by irregular quad bike motion (changes in height of the coils above the ground conductor).

Coordinate data and apparent conductivity data were used for GIS interpolation of apparent conductivities onto a regular grid throughout the area surveyed. Drawing 1 presents these apparent conductivities as a grid image with a continuous colour spectral scale in milliSiemens per meter (mS/m). Areas of high conductivity (potentially high salinity) correspond to the red end of the spectrum and areas of low conductivity correspond to the blue end of the spectrum.

The 4000 measured apparent conductivities are distributed statistically as shown by the ECa bars of the histogram (Figure 3) and associated table (Table 1) below.

Figure 3 and Table 1 - Distribution of Salinities from EM31 Profiling (M7 Business Hub Eastern Precinct, Eastern Creek)



Salinity (1=Non/Slightly/Moderately/Very/Highly or Extremely Saline)

ECa Range (mS/m)	<50	50-100	100-150	150-200	>200
Salinity Class (Chhabra 1996)	Non-saline	Slightly saline	Moderately saline	Very saline	Extremely saline
%ECa data - East Precinct	0	32	55	12	1

Because of the range of possible sources of the conductivity response (other than soluble salts), the statistical distribution of apparent conductivity and the apparent conductivity grid image should be viewed in terms of relative conductivities, trends and locations of anomalous zones. For initial interpretation however, using the ECa classification method of Chhabra (1996), the filling materials, soils, bedrock and groundwater within the depth of investigation of the EM31 system are inferred to be moderately saline over 55% of the investigated lines and very (or more) saline over 13% of those lines.

Drawing 1 shows that south of grid line D/E where the new filling had reached final levels (maximum height above water table and salt-bearing shale), apparent conductivities were lowest and slightly saline conditions were inferred. Where filling had not yet reached final level in the northeast corner of the Precinct, moderately saline conditions were generally inferred, becoming locally very saline near E1 and F/G 1/2. Very saline conditions were inferred in the trench excavated into saturated alluvium, near E4/5.

Test pits were sited to investigate the areas of both lowest and highest apparent conductivities. Table 2 below presents sample locations, descriptions, approximate textural classifications (equating filling materials with natural soils of similar lithologies and consistencies), results of laboratory tests for soil water paste conductivities ($EC_{1:5}$), calculated soil salinities (ECe) in deciSiemens per metre (dS/m) and salinity classes inferred from ECe values by the method of Richards (1954). The Richards classifications are employed by DIPNR to indicate the likely effects of soil salinity on crops but (unlike the Chhabra classifications) also provide a sample-controlled starting point for assessment of urban salinity.

As expected for the imported filling, calculated soil salinities and salinity classes were variable at B1 (2.9 – 5.3 dS/m, slightly to moderately saline) and E1 (2.8 – 9.7 dS/m, slightly to very saline). At the surface of the saturated alluvium between E4 and E5, salinities were consistently elevated (14.7 dS/m to 25.8 dS/m, very saline to highly saline).

TABLE 2 - TEST PIT SAMPLE SALINITIES, EAST PRECINCT

Grid Ref. (peg)	Coordinates (m MGA94) East	North	Sample Depth (m)	Description		Textural Factor [M] [DIPNR]	$EC_{1:5}$ [Lab.] (mS/cm)	EC_e [M x $EC_{1:5}$] (dS/m)	Salinity Class [Richards 1954]
B5	300721	6255852	0.0	Filling	Brown & grey silty clay filling with some ironstone, shale and igneous gravel	8	0.60	4.8	Moderately Saline
B5	300721	6255852	1.0	Filling	Orange, brown & grey silty clay filling with some ironstone and shale gravel	8	0.66	5.3	Moderately Saline
B5	300721	6255852	1.8	Filling	Orange, brown & grey silty clay filling with a trace of fine-grained sand and some shale, sandstone and ironstone gravel, charcoal, slag, metal, glass and tile fragments. Refusal on inferred bedrock at 1.8m	8	0.36	2.9	Slightly Saline
E1	301121	6256152	0.0	Filling	Brown & grey silty clay filling with a trace of sand, some sandstone gravel and shale gravel	8	0.63	5.0	Moderately Saline
E1	301121	6256152	1.0	Filling	Medium plasticity mottled brown and red-brown silty clay filling	8	0.35	2.8	Slightly Saline
E1	301121	6256152	2.0	Filling	Medium-high plasticity orange-brown and grey silty clay with a trace of ironstone gravel (inferred old filling)	7	1.38	9.7	Very Saline
E4/5	300771	6256152	0.0	Alluvium	Orange-brown and light grey silty clay	8.5	3.04	25.8	Highly Saline
E4/5	300771	6256152	0.0	Alluvium	Orange-brown and grey silty clay	8.5	1.73	14.7	Very Saline
E4/5	300771	6256152	0.0	Alluvium	Low plasticity brown and grey silty clay	8.5	2.30	19.6	Highly Saline

In order to extend the salinity classifications over the whole East Precinct development area, an approximate correlation was found between ECe values at the test pits in the filling and the measured ECa values at the closest points of the EM31 profiles. The assumption of a linear relationship between ECe and ECa with a trend through the ECe/ECa origin, was best met by using the ECe values from depths of 1.8 m to 2.0 m in the test pits, leading to an ECe:ECa ratio of 5.03. Applying this ratio to the 4,000 measured apparent conductivities produced "apparent salinities" ECe distributed statistically as shown by the ECe bars of the Figure 3 histogram (above) and the associated table (Table 3 below).

Table 3 – Distribution of Apparent Salinities from EM31 Profiling, Eastern Precinct

ECe Range (dS/m)	<2	2 - 4	4 - 8	8 - 16	>16
Salinity Class (Richards 1954)	Non-saline	Slightly saline	Moderately saline	Very saline	Highly saline
%ECe data - East Precinct	0	5	86	9	0

Using the classification method of Richards (1954) and assuming the calculated ECe values represent soluble salts, the filling materials, soils and bedrock within the depth of investigation of the EM31 system are inferred to be moderately saline over 86% of the investigated lines and very saline over only 9% of those lines.

Drawing 2 shows apparent salinities interpolated onto a regular grid throughout the area surveyed and displayed as a grid image with a continuous colour spectral scale in dS/m. Areas of high apparent salinity correspond to the red end of the spectrum and areas of low apparent salinity correspond to the blue end of the spectrum. In addition, 4 dS/m and 8 dS/m contour lines have been added to the image to allow identification of zones corresponding to the slightly, moderately and very saline classes of Richards. These contours define approximate salinity class areas of 6% slightly saline (<2 Ha), 89% moderately saline (~26 Ha) and 5% very saline (~1 Ha), very similar to the distribution defined in Table 3 by the number of measurements made. Test pit locations are also shown on Drawing 2, together with sample depths and salinities derived from laboratory measurements and approximate soil texture classes.

Where filling had not yet reached final level in the northeast corner of the Precinct, moderately and very saline conditions are inferred, the latter measured in a sample of inferred old filling at a depth of 2 m. Apparent salinities shown by the grid image are consistent with the sample ECe results from the test pit at E1, where an equivalent value of 6.0 dS/m (mid-range moderately saline) can be calculated over all sampled depths.

As inferred from apparent conductivities, south of grid line D/E where the new filling had reached final levels, apparent salinities were lowest. Moderately saline conditions predominate, however very saline conditions are approached or reached locally near C6, A7 and D4. Again, apparent salinities shown by the grid image are consistent with the sample ECe results from the test pit at B5, where an equivalent value of 4.3 dS/m (low end of moderately saline) can be calculated over all sampled depths. It is inferred that the recently imported filling is less saline than the underlying old filling.

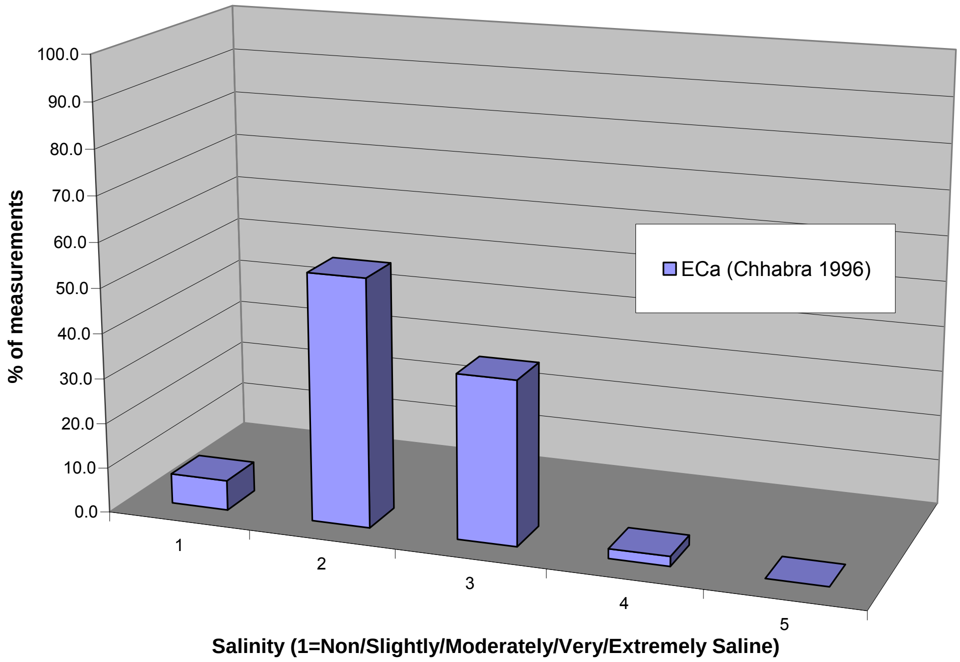
Because the ECe/ECa correlation was based on samples of filling only (from B5 and E1) and did not take into account the very saline to highly saline surface samples of alluvium from E4/5, the recalculated grid image (Drawing 2) underestimates the apparent salinities in the area of the trench in the alluvium. Very saline conditions are implied by the image, however this area should be considered highly saline as indicated by the sample ECe values of 14.7 – 25.8 dS/m.

9.2 Western and Central Precincts

As for the Eastern Precinct, on completion of EM31 profiling, apparent conductivity data were corrected for the conductivity response of the quad bike, filtered to reduce the bike motion noise and were interpolated onto a regular grid throughout the area surveyed. Drawing 3 presents these apparent conductivities as a grid image with a continuous colour spectral scale in mS/m. Areas of high conductivity (potentially high salinity) correspond to the red end of the spectrum and areas of low conductivity correspond to the blue end of the spectrum.

The 12,000 measured apparent conductivities are distributed statistically as shown by the ECa bars of the histogram (Figure 4) and associated table (Table 4) below.

Figure 4 and Table 4 - Distribution of Salinities from EM31 Profiling
(M7 Business Hub Western & Central Precincts, Eastern Creek)



ECa Range (mS/m)	<50	50-100	100-150	150-200	>200
Salinity Class (Chhabra 1996)	Non-saline	Slightly saline	Moderately saline	Very saline	Extremely saline
%ECa data – West & Central Precincts	7	55	36	2	0

For initial interpretation using the ECa classification method of Chhabra (1996), the natural soils, bedrock and groundwater within the depth of investigation of the EM31 system were inferred to be moderately saline over 36% of the investigated lines and very saline over only 2% of those lines.

Drawing 3 shows a large central area inferred to be predominantly non-saline to slightly saline, and zones along both western and southeastern boundaries inferred to be predominantly moderately saline.

The moderately saline western zones correspond with the lower slopes west and southeast of the western topographic ridge and include two areas of bare soil and an area of gully erosion (marked on Drawing 3).

Moderate salinity was also inferred within the riparian zone of Reedy Creek and for up to approximately 100 m up the adjacent lower slopes and in a zone trending north-northeast from H5. The latter zone does not have an obvious correlation with topography but gentle slopes indicate that shale underlies this area, unlike the higher ridges where siltstone and sandstone are more often found. This shale may have elevated salt levels, leading to higher salinity of the overlying soils.

Initial indications of salinity were obtained from bulk soil samples and rock core samples from previous geotechnical drilling at the proposed Coles Myer site, which straddles the western ridge in the Western Precinct. Table 5 below presents sample locations, depths, descriptions, inferred textural classifications, results of laboratory tests for soil water paste conductivities ($EC_{1:5}$), calculated soil salinities (ECe) in deciSiemens per metre (dS/m) and salinity classes inferred from ECe values by the method of Richards (1954).

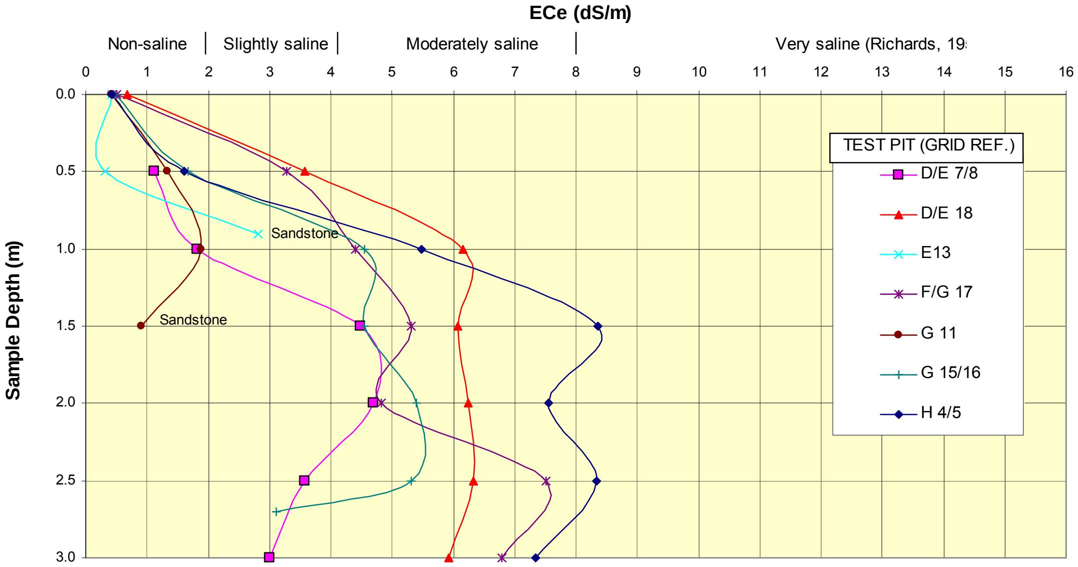
These limited tests indicate non-saline to slightly saline siltstone and sandstone (1.68 - 2.28 dS/m) overlain by non-saline to moderately saline silty clay soils (1.82 – 4.41 dS/m) both on the western ridge crest (BH1 and BH2) and lower slopes near the western site boundary (BH3).

TABLE 5 - GEOTECHNICAL BORE SAMPLE SALINITIES
Proposed Coles Myer Site, Western Precinct

Bore	**Sample Depth** (m)	**Material Description**	**Textural Factor [M]** [after DIPNR]	**$EC_{1:5}$** [Lab.] (mS/m)	**EC_e** [M x $EC_{1:5}$] (dS/m)	**Salinity Class** [Richards 1954]
BH1	2.5	Silty clay	7	0.63	4.41	Moderately saline
BH1	7.0	Siltstone	6	0.36	2.16	Slightly saline
BH2	2.5	Silty clay	7	0.26	1.82	Non saline
BH2	9.0	Sandstone	6	0.28	1.68	Non saline
BH3	1.0	Silty clay	7	0.33	2.31	Slightly saline
BH3	3.0	Siltstone	6	0.38	2.28	Slightly saline

From the 16 test pits excavated throughout the Western and Central Precincts, samples were extracted from all depths at seven locations showing extremes in apparent conductivities. These samples were sent for initial laboratory salinity tests, in order to construct the soil salinity profiles of Figure 5 below.

Figure 5 - Salinity Profiles from Test Pit Soil Samples
(M7 Business Hub Western & Central Precincts, Eastern Creek)



These profiles indicated highest salinities within the depth interval 1.0 – 2.5 m below surface, hence soil from remaining test pits was sub-sampled from this general depth range for laboratory salinity testing.

Table 6 below presents sample locations, descriptions, textural classifications, results of laboratory tests for soil water paste conductivities ($EC_{1:5}$), calculated soil salinities (ECe) in deciSiemens per metre (dS/m) and salinity classes inferred from ECe values by the method of Richards (1954) as a sample-controlled starting point for assessment of urban salinity.

In order to extend these salinity classifications over the whole Western and Central Precincts, various correlations were made between ECe values at the test pits and the measured ECa values at the closest points of the EM31 profiles. Figure 6 (below) shows the derived linear relationship (a ratio of 3.3:1) between ECe and ECa, where ECe is the average of measured salinities within the depth range 1.5 – 2.5 m inclusive (i.e. within the peak zone of the salinity profiles). It is inferred from this correlation that the EM31 system was responding to a large extent to soil salinities within that depth range (i.e. to salinities within the B and C soil horizons).

Figure 6 - Correlation of Test Pit Sample Salinities with Apparent Conductivities from EM31 Profiling (M7 Business Hub Western & Central Precincts, Eastern Creek)

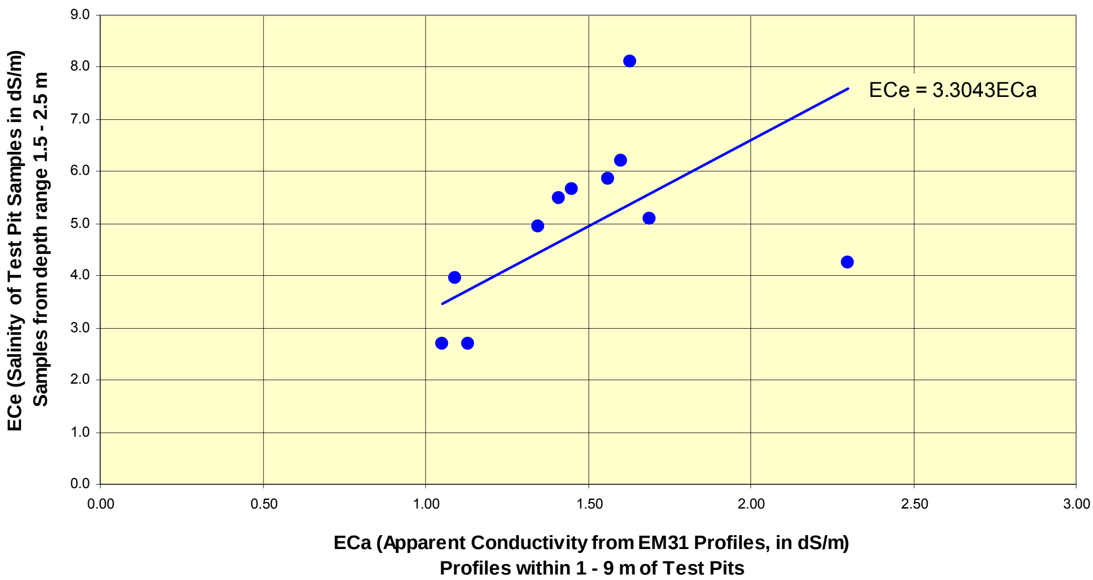


TABLE 6 - TEST PIT SAMPLE SALINITIES, WESTERN AND CENTRAL PRECINCTS									
Grid	Coordinates		Sample	Description		Textural	EC1:5	ECe	Salinity Class
Ref.	East	North	Depth			Factor [M]	[Lab.]	[M x EC1:5]	[Richards 1954]
(peg)	(m MGA94)		(m)			[after DIPNR]	(mS/cm)	(dS/m)	
B16/17	299571	6255852	0.0	CLAY	Silty (topsoil)	8.5			
			0.5	CLAY	Silty, stiff, high plasticity, mottled	7	0.39	2.7	Slightly Saline
			1.0	CLAY	Silty, very stiff, high plasticity, mottled, some iron-stained gravel	7			
			1.5	CLAY	Silty, very stiff, high plasticity, mottled, some iron-stained gravel	7	0.65	4.6	Moderately Saline
			2.0	CLAY	Shaley, very stiff, medium plasticity, some shale & iron-stained gravel	8	0.66	5.3	Moderately Saline
			2.5	SILTST.	Low strength, highly weathered (backhoe refusal)	6			
D/E 7/8	300461	6256137	0.0	CLAY	Silty, firm, medium plasticity, mottled	7			
			0.5	CLAY	Silty, firm, medium plasticity, mottled	7	0.16	1.1	Non Saline
			1.0	CLAY	Silty, firm-stiff, medium-high plasticity, mottled	7	0.26	1.8	Non Saline
			1.5	CLAY	Silty, firm-stiff, medium-high plasticity, mottled	7	0.64	4.5	Moderately Saline
			2.0	CLAY	Silty, stiff, high plasticity, mottled, trace iron-stained gravel	7	0.67	4.7	Moderately Saline
			2.5	CLAY	Silty, stiff, high plasticity, mottled, trace iron-stained gravel	7	0.51	3.6	Slightly Saline
			3.0	CLAY	Silty, stiff, high plasticity, mottled, trace iron-stained gravel	7	0.43	3.0	Slightly Saline
D/E18	299421	6256102	0.0	CLAY	Silty (topsoil)	8.5	0.08	0.7	Non Saline
			0.5	CLAY	Silty, stiff, medium-high plasticity, mottled	7	0.51	3.6	Slightly Saline
			1.0	CLAY	Silty, stiff, high plasticity, mottled, shale & iron-stained gravel bands	8	0.77	6.2	Moderately Saline
			1.5	CLAY	Silty, stiff, high plasticity, mottled, shale & iron-stained gravel bands	8	0.76	6.1	Moderately Saline
			2.0	CLAY	Silty, stiff, high plasticity, mottled, shale & iron-stained gravel bands	8	0.78	6.2	Moderately Saline
			2.5	CLAY	Shaley, very stiff, high plasticity, mottled, shale & iron-stained gravel	8	0.79	6.3	Moderately Saline
			3.0	CLAY	Shaley, very stiff, high plasticity, mottled, shale & iron-stained gravel	8	0.74	5.9	Moderately Saline
E10	300221	6256152	0.0	CLAY	Silty (topsoil)	8.5			
			0.5	CLAY	Silty, very stiff, medium-high plasticity, mottled	7	0.04	0.3	Non Saline
			1.0	VOLCs.	Very low to low strength, moderately weathered	6			
			1.5	VOLCs.	Low strength, extremely weathered	6			
			1.7	VOLCs.	Medium strength, moderately weathered (backhoe refusal)	6			
E13	299921	6256152	0.0	CLAY	Silty (topsoil)	8.5	0.05	0.4	Non Saline
			0.5	CLAY	Shaley, very stiff, medium plasticity, mottled	8	0.04	0.3	Non Saline
			0.9	SANDST.	Low-medium strength, moderately weathered	6	0.47	2.8	Slightly Saline
F8	300421	6256252	0.0	CLAY	Silty (topsoil)	8.5			
			0.5	CLAY	Silty, stiff, medium plasticity, mottled	7	0.08	0.6	Non Saline
			1.0	CLAY	Silty, stiff, medium plasticity, mottled	7			
			1.5	CLAY	Silty, stiff, medium plasticity	7	0.13	0.9	Non Saline
			2.0	CLAY	Silty, firm, low plasticity, traced iron-stained gravel	9			
			2.5	CLAY	Silty, firm, low plasticity, traced iron-stained gravel	9	0.50	4.5	Moderately Saline
			3.0	CLAY	Gravelly, silty, low plasticity, some iron-stained gravel	8			

TABLE 6 (cont.) - TEST PIT SAMPLE SALINITIES, WESTERN AND CENTRAL PRECINCTS

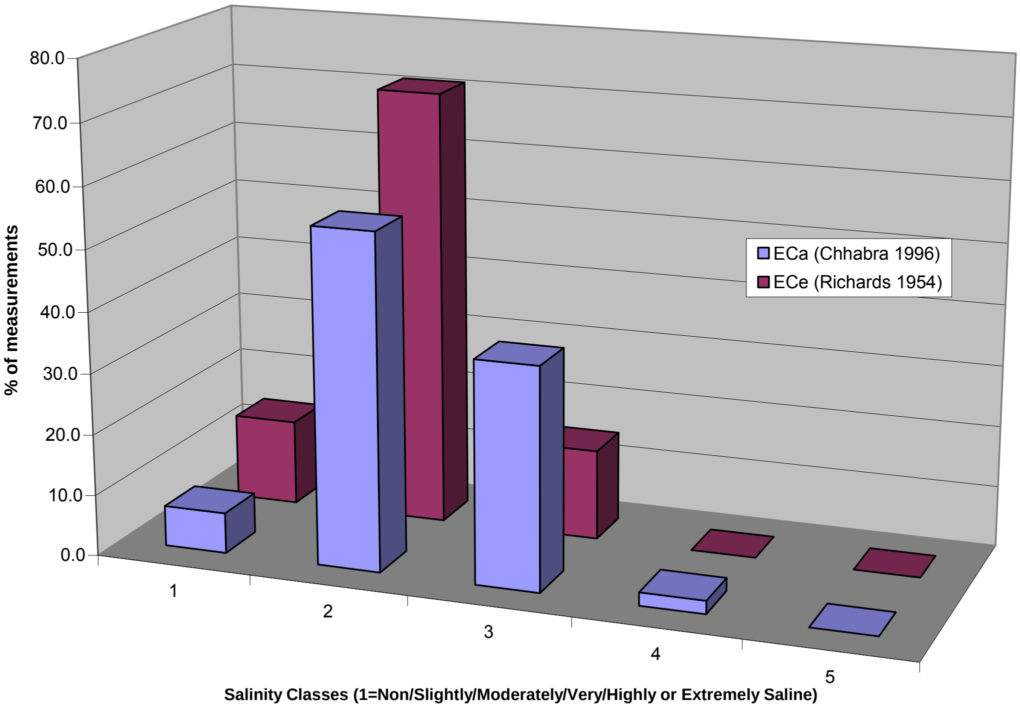
Grid Ref. (peg)	East (m MGA94)	North (m MGA94)	Sample Depth (m)	Description		Textural Factor [M] [after DIPNR]	EC1:5 [Lab.] (mS/cm)	ECe [M x EC1:5] (dS/m)	Salinity Class [Richards 1954]
F12	300021	6256252	0.0	CLAY	Silty, very stiff, medium-high plasticity, mottled	7			
			0.5	CLAY	Silty, very stiff, medium-high plasticity, mottled	7	0.09	0.6	Non Saline
			1.0	CLAY	Silty, very stiff, high plasticity, mottled, trace iron-stained gravel	7			
			1.5	CLAY	Silty, very stiff, high plasticity, mottled, trace iron-stained gravel	7	0.54	3.8	Slightly Saline
			2.0	CLAY	Silty, very stiff, high plasticity, mottled, trace iron-stained gravel	7			
			2.5	CLAY	Silty, very stiff, high plasticity, mottled, trace iron-stained gravel	7	0.58	4.1	Moderately
			2.7	SHALE	Low to medium strength, moderately weathered (backhoe refusal)	6			
F14	299821	6256252	0.0	CLAY	Silty (topsoil)	8.5			
			0.5	CLAY	Silty, hard, high plasticity, mottled	7	0.15	1.1	Non Saline
			1.0	CLAY	Silty, hard, high plasticity, mottled, some iron-stained gravel	7			
			1.5	CLAY	Silty, very stiff, high plasticity, mottled, some iron-stained & shaley bands	7	0.38	2.7	Slightly Saline
			2.0	SHALE	Low strength, highly weathered, some iron-indurated bands	6			
			2.5	SHALE	Low strength, highly weathered, some iron-indurated bands (backhoe refusal)	6			
F/G17	299521	6256282	0.0	CLAY	Silty (topsoil)	8.5	0.06	0.5	Non Saline
			0.5	CLAY	Silty, very stiff, high plasticity, mottled, trace iron-stained gravel	7	0.47	3.3	Slightly Saline
			1.0	CLAY	Silty, very stiff, high plasticity, mottled, trace iron-stained gravel	7	0.63	4.4	Moderately
			1.5	CLAY	Silty, very stiff, high plasticity, mottled	7	0.76	5.3	Moderately
			2.0	CLAY	Silty, very stiff, high plasticity, mottled	7	0.69	4.8	Moderately
			2.5	CLAY	Silty, stiff, high plasticity, mottled, some shale and ironstained gravel	8	0.94	7.5	Moderately
			3.0	CLAY	Silty, stiff, high plasticity, mottled, some shale and iron stained gravel	8	0.85	6.8	Moderately
G11	300121	6256352	0.0	CLAY	Silty (topsoil)	8.5	0.05	0.4	Non Saline
			0.5	CLAY	Silty, hard, high plasticity, mottled	7	0.19	1.3	Non Saline
			1.0	CLAY	Silty, hard, high plasticity, mottled	7	0.27	1.9	Non Saline
			1.5	SANDST.	Low strength, moderately weathered	6	0.15	0.9	Non Saline
			2.0	SANDST.	Low strength, moderately weathered (backhoe refusal)	6			
G15/16	299700	6256352	0.0	CLAY	Silty, medium plasticity, mottled, trace iron-stained gravel	8	0.06	0.5	Non Saline
			0.5	CLAY	Silty, very stiff, high plasticity, mottled	7	0.24	1.7	Non Saline
			1.0	CLAY	Silty, hard, medium plasticity	7	0.65	4.6	Moderately
			1.5	CLAY	Silty, hard, medium, plasticity	7	0.65	4.6	Moderately
			2.0	CLAY	Silty, very stiff, high plasticity, mottled	7	0.77	5.4	Moderately
			2.5	CLAY	Silty, very stiff, high plasticity, mottled	7	0.76	5.3	Moderately
			2.7	SILTST.	Low strength, highly weathered (backhoe refusal)	6	0.52	3.1	Slightly Saline
H4/5	300796	6256452	0.0	CLAY	Silty (topsoil)	8.5	0.05	0.4	Non Saline
			0.5	CLAY	Silty, hard, medium plasticity, mottled	7	0.23	1.6	Non Saline
			1.0	CLAY	Silty, sandy, very stiff, low plasticity	9	0.61	5.5	Moderately
			1.5	CLAY	Silty, sandy, very stiff, low plasticity	9	0.93	8.4	Very Saline
			2.0	CLAY	Silty, very stiff, medium-high plasticity, some iron-stained gravel	7	1.08	7.6	Moderately
			2.5	CLAY	Silty, very stiff, medium-high plasticity, some iron-stained gravel	7	1.19	8.3	Very Saline
			3.0	CLAY	Silty, very stiff, medium-high plasticity, some iron stained & shaley gravel	7	1.05	7.4	Moderately

TABLE 6 (cont.) - TEST PIT SAMPLE SALINITIES, WESTERN AND CENTRAL PRECINCTS

Grid Ref. (peg)	Coordinates East (m MGA94)	North	Sample Depth (m)	Description		Textural Factor [M] [after DIPNR]	EC1:5 [Lab.] (mS/cm)	ECe [M x EC1:5] (dS/m)	Salinity Class [Richards 1954]
H6	300621	6256452	0.0	FILLING	Silty clay, trace gravel and brick	8.5			
			0.5	FILLING	Silty clay, trace gravel and brick	8.5			
			1.0	FILLING	Silty clay, trace gravel and brick	8.5			
			1.5	FILLING	Silty clay, trace gravel and brick	8.5			
			2.0	FILLING	Silty clay, trace gravel and brick	8.5			
			2.5	FILLING	Silty clay, trace gravel, brick & glass	8.5			
			3.0	FILLING	Silty clay, trace gravel, brick & glass	8.5			
H13	299921	6256452	0.0	CLAY	Silty (topsoil)	8.5			
			0.5	CLAY	Silty, very stiff, high plasticity, mottled	7	0.20	1.4	Non Saline
			1.0	CLAY	Silty, sandy, hard, low plasticity	9	0.17	1.5	Non Saline
			1.5	SANDST.	Low to medium strength, moderately weathered	6			
			2.0	SILTST.	Low to medium strength, moderately weathered	6			
			2.4	SILTST.	Low to medium strength, moderately weathered (backhoe refusal)	6			
J4	300821	6256652	0.0	CLAY	Silty (topsoil)	8.5			
			0.5	CLAY	Silty, stiff, medium plasticity	7	0.08	0.6	Non Saline
			1.0	CLAY	Silty, firm, medium plasticity, mottled	8			
			1.5	CLAY	Silty, hard, high plasticity, mottled	7	0.90	6.3	Moderately
			2.0	CLAY	Shaley, very stiff-hard, high plasticity, mottled, some ironstone	7	0.71	5.0	Moderately
			2.4	SHALE	Low strength, highly weathered, some ironstone bands (backhoe refusal)	6			
J7	300521	6256652	0.0	CLAY	Silty (topsoil)	8.5			
			0.5	CLAY	Silty, firm, medium to high plasticity, mottled, trace iron-stained gravel	7	0.18	1.3	Non Saline
			1.0	CLAY	Silty, very stiff, high plasticity, trace iron-stained gravel	7			
			1.5	CLAY	Silty, very stiff, high plasticity, trace iron-stained gravel	7	0.70	4.9	Moderately
			2.0	CLAY	Shaley, very stiff, high plasticity, some iron-stained gravel	8			
			2.5	CLAY	Shaley, very stiff, high plasticity, some iron-stained gravel	8	0.76	6.1	Moderately
			3.0	SHALE	Low strength, highly weathered	6			

Applying the ECe:ECa ratio of 3.3 to the 12,000 measured apparent conductivities produced "apparent salinities" ECe distributed statistically as shown by the ECe bars of the Figure 7 histogram and associated table (below).

Figure 7 - Distribution of Salinities from EM31 Profiling
(M7 Business Hub Western and Central Precincts, Eastern Creek)



Distribution of Apparent Salinities from EM31 Profiling & Test Pits, Western & Central Precincts

ECe Range (dS/m)	<2	2 - 4	4 - 8	8 - 16	>16
Salinity Class (Richards 1954)	Non-saline	Slightly saline	Moderately saline	Very saline	Highly saline
%ECe data – West & Central Precincts	14	71	15	0	0

Using the classification method of Richards (1954) and assuming the calculated ECe values represent soluble salts, the soils within the depth of investigation of the EM31 system are inferred to be moderately saline over 15% of the investigated lines and very (or more) saline over less than 1% of those lines.

Drawing 4 shows apparent salinities interpolated onto a regular grid throughout the area surveyed and displayed as a grid image with a continuous colour spectral scale in dS/m. Areas of high apparent salinity correspond to the red end of the spectrum and areas of low apparent salinity correspond to the blue end of the spectrum. In addition, 2 dS/m and 4 dS/m contour lines have been added to the image to allow identification of zones corresponding to the non-saline, slightly saline and moderately saline classes of Richards. By comparison with the total area investigated, these contours define approximate salinity class areas of 12% non-saline (9 Ha), 78% slightly saline (62 Ha) and 10% moderately saline (8 Ha), similar to the distribution defined in Figure 7 by the number of measurements made. Test pit locations are also shown on Drawing 4, together with sample depths and maximum salinities derived from laboratory measurements and approximate soil texture classes.

Very saline soil (8.3 dS/m) was identified at a single location only, at a depth of 2.5 m in test pit H4/5 adjacent to Reedy Creek. Elsewhere Drawing 4 indicates moderately saline conditions at worst, adjacent to the riparian zone, on the lower slopes surrounding the western ridge and in a zone trending north-northeast from H5 inferred to be underlain by shale, possibly with elevated salt levels.

10. DISCUSSION OF RESULTS

10.1 Eastern Precinct

The proposed fieldwork and interpretation scheme has been applied and completed in the Eastern Precinct, which differs from the Western and Central Precincts in that the majority of the investigated area had been covered with imported filling materials prior to the commencement of this study. The EM31 conductivity system had a maximum depth of investigation of 6 m in the configuration used, with approximately 50% of the conductivity response arising from within 2 m of the ground surface. Our test pits indicated 1.8 m of new filling at B5 and 1 - 2 m of new filling at E1. The results of the study are therefore inferred to relate to a large degree to the salinity of the newly placed filling south of grid line D/E and to an increasing degree to the salinity of the older filling north of that grid line.

Importing filling (particularly from a variety of sources) would be expected to lead to an irregular distribution of materials including any attached salts and this irregularity is considered responsible for some patchiness of the apparent conductivity and apparent salinity grid images (Drawings 1 and 3), even where filling and grading had been completed south of grid line D/E.

Slightly to moderately saline conditions are generally inferred in this area, however very saline conditions are approached or reached near C6, A7 and D4.

Although moderately saline to very saline conditions are inferred in the northeast of the Precinct, filling had not been completed in this area and the higher salinities are inferred to be related to the older filling. The addition and grading of filling, if sourced and treated as in the south of the area, would be expected to reduce the near-surface salinities accordingly, to slightly to moderately saline.

10.2 Western and Central Precincts

The proposed fieldwork and interpretation scheme has also been applied and completed in the Western and Central Precincts, comprising predominantly natural residual soils developed on ridges and rolling hills and some alluvial soils along the lower slopes adjacent to Reedy Creek. The EM31 conductivity system had a maximum depth of investigation of 6 m in the configuration used, with approximately 50% of the conductivity response arising from within 2 m of the ground surface.

Evidence from apparent conductivity mapping over the whole accessible site integrated with laboratory salinity testing of soil samples indicates that the Western and Central Precincts are underlain for the most part by non-saline to slightly saline soils, becoming moderately saline on the lower slopes adjacent to Reedy Creek, on the lower slopes of the western topographic ridge and in a narrow zone in the northeast of the area between Reedy Creek and Old Wallgrove Road, where inferred underlying shales may have an elevated salt content. Highest salinities are developed in the zone from 1.0 – 2.5 m below ground surface, generally in firm to very stiff silty clays of the B and C soil horizons.

11. SALINITY MANAGEMENT STRATEGIES

In general the salinity study indicates that the high salinity potential inferred by DIPNR (2002) for the lower slopes and drainage areas of Reedy Creek, is not realised except within some alluvial sediments immediately adjacent to the creek. It is understood that the development will not impact on the riparian zone of the creek where most alluvium can be expected.

Elsewhere within the development area, non-saline to moderately saline conditions are inferred, with slightly saline conditions predominating on an areal basis. Efforts should be made however in the Reedy Creek catchment to prevent or restrict changes to the water balance that will result in rises in groundwater levels through the older more saline filling and through the more saline alluvium, bringing more saline water closer to the ground surface. As a precaution, development must be planned to mitigate against the effects of any potential salinisation that could occur.

These efforts need to be directed at all levels of the development process including:

- site design, vegetation and landscaping;
- commercial building and infrastructure construction.

In general, the following strategies are directed at:

- maintaining the natural water balance;
- maintaining good drainage;
- avoiding disturbance or exposure of sensitive soils;
- retaining or increasing appropriate native vegetation in strategic areas;
- implementing building controls and engineering responses where appropriate.

11.1 Site Design, Vegetation and Landscaping

Planning of the development of the site requires careful management with a view to controlling drainage and infiltration of both surface waters and groundwater to prevent rises in groundwater levels and minimise the potential for erosion.

Precautionary measures, applicable to the whole development area to reduce the potential for salinity problems, include:

- Avoiding water collecting in low lying areas, along shallow creeks, floodways, in ponds, depressions, or behind fill embankments or near trenches on the uphill sides of roads. This can lead to water logging of the soils, evaporative concentration of salts, and eventual breakdown in soil structure resulting in accelerated erosion.

- Roads and the shoulder areas should also be designed to be well drained, particularly with regard to drainage of surface water. There should not be excessive concentrations of runoff or ponding that would lead to waterlogging of the pavement or additional recharge to the groundwater. Road shoulders should be included in the sealing program.

- Surface drains should generally be provided along the top of batter slopes of greater than 2.5 m height to reduce the potential for concentrated flows of water down slopes possibly causing scour. Well graded subsoil drainage should be provided at the base of all slopes where there are road pavements below the slope to reduce the risk of waterlogging.

- With regard to surface slopes, a minimum of 1V:100H is suggested.

- Where possible materials and waters used in the construction of roads and fill embankments should be selected to contain minimal or no salt. This may be difficult for cuts and fills in lower areas where saline soils are exposed in cut or excavated then placed as filling. Under these circumstances where salinisation could be a problem, a capping layer of either topsoil or sandy materials should be placed to reduce capillary rise, act as a drainage layer and also reduce the potential for dispersive behaviour in any sodic soils.

- Gypsum should be mixed into filling containing sodic soils and cuts where sodic soils are exposed on slopes to improve soil structure.

- Salt tolerant grasses and trees should be considered if re-planting close to Reedy Creek and in areas of moderate and greater salinity to reduce soil erosion and maintain the existing evapotranspiration and groundwater levels. Reference should be made to an experienced landscape planner or agronomist.

11.2 Commercial Building and Infrastructure Construction

The extent of management measures adopted during construction, in particular the concrete, masonry and steel requirements, should depend on the particular level of salinity, aggressivity or corrosivity at the actual site. Measures are therefore grouped below into general strategies (applicable at all sites throughout the development area), strategies for moderately saline sites, and strategies for very saline sites.

11.2.1 General strategies

These include:

- As an alternative to slab on ground construction, suspended slab or pier and beam construction should be considered, particularly on sloping sites as this will minimise exposure to potentially aggressive/corrosive soils and reduce the potential cut and fill on site which could alter subsurface flows.

- Measures should be considered which improve the durability of concrete in saline environments. These include reducing the water cement ratio (hence increasing strength), minimising cracks and joins in plumbing on or near the concrete, reducing turbulence of any water flowing over the concrete and using a quality assurance supplier.

- It is essentially that in all masonry buildings a brick damp course be properly installed so that it cannot be bridged either internally or externally. This will prevent moisture moving into brick work and up the wall.

- There are various exposure classifications and durability ratings for the wide range of masonry available. Reference should be made to the supplier in choosing suitable bricks of at least exposure quality. Water proofing agents can also be added to mortar to further restrict potential water movement.

- In areas of elevated salinity, bricks that are not susceptible to damage from salt water should be used. These are generally less permeable, do not contain salts during their construction, and have good internal strength so that they can withstand any stress imposed on them by any salt encrustation.

- Consideration could be given to use of infrastructure service lines deeper than say 1.2 m, to promote subsurface drainage by incorporating slotted drainage pipes fitting into the stormwater pits in lower areas where pipe invert levels are within about 1 m of existing groundwater levels. This is probably likely to be more appropriate where good drainage can be planned as in certain situations poorly graded subsoil drainage and water collecting in pits may make things worse raising the water table and increasing the risk of salinisation.

- Service connections and stormwater runoffs should be checked to avoid leaky pipes which may affect off site areas lower down the slope and increase groundwater recharge resulting in increases in groundwater levels.

11.2.2 Strategies for moderately saline sites

For the construction of buildings or infrastructure (buried services) on moderately or more saline sites, additional strategies should be applied. These sites can be identified by the 4 dS/m contours of the apparent salinity images (Drawings 2 and 4) and/or by the proximity of any test pit showing a laboratory-determined salinity in excess of 4 dS/m. From Drawing 2 it can be seen that additional strategies should be applied to sites developed on filling from most (approximately 94%) of the Eastern Precinct. By contrast, Drawing 4 shows that such strategies need be applied to sites developed on only 10% of the natural soils within the Western and Central Precincts. Strategies include:

- Soil from specific building sites or services alignments in areas suspected to be moderately (or more) saline (ECe > 4 dS/m) should be sampled, tested and classified for soil salinity, aggressivity and corrosivity to the proposed depth of excavation. This sampling, testing and classification should preferably be carried out by a geotechnical consultant at the same time the site is classified for soil reactivity (shrink – swell behaviour). Classifications would involve limited additional testing of soil or water samples for pH, electrical conductivity, TDS, sodicity, and possibly sulphates and chlorides.

- On moderately or more saline sites use of a thick layer of sand (say 100 mm minimum) followed by a membrane of thick plastic is recommended under the concrete slab to act as a moisture barrier and drainage layer to restrict capillary rise under the slab.

- Where moderately saline conditions are mapped and site-specific tests confirm aggressive/corrosive conditions, consideration should be given to use of higher grade (more resistant) materials in all underground service lines.

11.2.3 Strategies for very saline sites

For construction on very saline or highly saline sites, an additional management strategies may need to be applied. These sites can be identified by the 8 dS/m contours of the apparent salinity images (Drawings 2 and 4) and/or by the proximity of any test pit showing a laboratory-determined salinity in excess of 8 dS/m. From Drawing 2 it can be seen that during the salinity study such sites occurred in approximately 5% of the Eastern Precinct, predominantly north of grid line E. It is expected however that addition of filling to final level will lead to a reduction in salinity within the proposed development depths, hence this strategy may not be applicable at the time of development. Drawing 4 shows that very saline soil was identified at a single location only in the Western and Central precincts, in test pit H4/5 adjacent to Reedy Creek.

The additional strategy suggested for very saline or highly saline sites is:

- Higher than normal strength concrete (≥N32) or sulphate resistant cement may need to be considered in potentially very saline to highly saline or aggressive areas in order to reduce the risk of reinforcement corrosion in concrete slabs. A minimum of 50-55 mm of concrete cover on slab reinforcement, proper compaction and curing concrete are also suggested to produce a dense low permeability concrete.

12. CONCLUSION

Site inspection, apparent conductivity mapping, test pitting, sampling and laboratory testing have been completed in the Eastern, Western and Central Precincts of the M7 Business Hub development area.

Drawing 2 indicates in general slightly saline to moderately saline conditions throughout the Eastern Precinct where imported filling had reached final levels. Moderately saline to very saline conditions were indicated in the northeast corner of this Precinct where filling had not been completed to final level and the underlying older filling was inferred to be more saline.

Drawing 4 indicates non-saline to slightly saline soils, becoming moderately saline on the lower slopes adjacent to Reedy Creek, on the lower slopes of the western topographic ridge and in a narrow zone in the northeast of the area between Reedy Creek and Old Wallgrove Road, probably underlain by shale. Highest salinities are developed in the zone from 1.0 – 2.5 m below ground surface, generally in firm to very stiff silty clays of the B and C soil horizons.

The results of this study are consistent with the results of previous limited sampling within the M7 development area by SMEC Australia Pty Ltd and with the overall findings of the SMEC studies.

A number of salinity management strategies have been suggested which are applicable throughout the M7 development area. Additional strategies have been suggested which are applicable at proposed sites where conditions are moderately saline or very saline.

DOUGLAS PARTNERS PTY LTD Reviewed by:

J Lean
Principal

Dr T J Wiesner
Principal

REFERENCES:

Chhabra, R. 1996. Soil Salinity and Water Quality. A.A. Bakema/ Rotterdam/Brookfield. New York, 284 pp.

McNally, G. 2005. Investigation of urban salinity – case studies from western Sydney. UrbanSalt 2005 Conference Paper, Parramatta.

NSW Department of Mineral Resources, NSW, 1991. Penrith 1:100 000 Geological Sheet 9030.

Richards, L. A. (ed.) 1954. Diagnosis and Improvement of Saline and Alkaline Soils. USDA Handbook No. 60, Washington D.C.

Soil Conservation Service of NSW, 1990. Penrith 1:100 000 Soil Landscape Sheet 9030.

SMEC Australia Pty Ltd, 2002. Eastern Creek Soil Salinity Study for Blacktown City Council. Project Number 31295.001, August 2002.

SMEC Australia Pty Ltd, 2002. Eastern Creek Precinct Salinity Assessment for SEPP59 Landowner Group. Project Number 31387.001, November 2003.

Spies, B. and Woodgate, P. 2004. Salinity Mapping Methods in the Australian Context. Technical Report. Natural Resource Management Ministerial Council, January 2004.

Douglas Partners
Geotechnics • Environment • Groundwater

NOTES RELATING TO THIS REPORT

Introduction

These notes have been provided to amplify the geotechnical report in regard to classification methods, specialist field procedures and certain matters relating to the Discussion and Comments section. Not all, of course, are necessarily relevant to all reports.

Geotechnical reports are based on information gained from limited subsurface test boring and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, Geotechnical Site Investigations Code. In general, descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions.

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (eg. sandy clay) on the following bases:

Soil Classification	Particle Size
Clay	less than 0.002 mm
Silt	0.002 to 0.06 mm
Sand	0.06 to 2.00 mm
Gravel	2.00 to 60.00 mm

Cohesive soils are classified on the basis of strength either by laboratory testing or engineering examination. The strength terms are defined as follows.

Classification	Undrained Shear Strength kPa
Very soft	less than 12
Soft	12—25
Firm	25—50
Stiff	50—100
Very stiff	100—200
Hard	Greater than 200

Non-cohesive soils are classified on the basis of relative density, generally from the results of standard penetration tests (SPT) or Dutch cone penetrometer tests (CPT) as below:

Relative Density	SPT "N" Value (blows/300 mm)	CPT Cone Value (q_c — MPa)
Very loose	less than 5	less than 2
Loose	5—10	2—5
Medium dense	10—30	5—15
Dense	30—50	15—25
Very dense	greater than 50	greater than 25

Rock types are classified by their geological names. Where relevant, further information regarding rock classification is given on the following sheet.

Sampling

Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing with a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling are given in the report.

Drilling Methods.

The following is a brief summary of drilling methods currently adopted by the Company and some comments on their use and application.

Test Pits — these are excavated with a backhoe or a tracked excavator, allowing close examination of the in-situ soils if it is safe to descent into the pit. The depth of penetration is limited to about 3 m for a backhoe and up to 6 m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (eg. Pengo) — the hole is advanced by a rotating plate or short spiral auger, generally 300 mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling — the hole is advanced by pushing a 100 mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling in soils, since moisture content is unchanged and soil structure, strength, etc. is only marginally affected.

Continuous Spiral Flight Augers — the hole is advanced using 90—115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling — the hole is advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

Rotary Mud Drilling — similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. from SPT).

Continuous Core Drilling — a continuous core sample is obtained using a diamond-tipped core barrel, usually 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in very weak rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

Standard Penetration Tests

Standard penetration tests (abbreviated as SPT) are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" — Test 6.3.1.

The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150 mm of say 4, 6 and 7

  as 4, 6, 7
  N = 13

- In the case where the test is discontinued short of full penetration, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm

  as 15, 30/40 mm.

The results of the tests can be related empirically to the engineering properties of the soil.

Occasionally, the test method is used to obtain samples in 50 mm diameter thin walled sample tubes in clays. In such circumstances, the test results are shown on the borelogs in brackets.

Cone Penetrometer Testing and Interpretation

Cone penetrometer testing (sometimes referred to as Dutch cone — abbreviated as CPT) described in this report has been carried out using an electrical friction cone penetrometer. The test is described in Australian Standard 1289, Test 6.4.1.

In the tests, a 35 mm diameter rod with a cone-tipped end is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on a separate 130 mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected by electrical wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20 mm per second) the information is plotted on a computer screen and at the end of the test is stored on the computer for later plotting of the results.

The information provided on the plotted results comprises: —

- Cone resistance — the actual end bearing force divided by the cross sectional area of the cone — expressed in MPa.
- Sleeve friction — the frictional force on the sleeve divided by the surface area — expressed in kPa.
- Friction ratio — the ratio of sleeve friction to cone resistance, expressed in percent.

There are two scales available for measurement of cone resistance. The lower scale (0—5 MPa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main scale (0—50 MPa) is less sensitive and is shown as a full line.

The ratios of the sleeve friction to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 1%—2% are commonly encountered in sands and very soft clays rising to 4%—10% in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range:—

$$q_c \text{ (MPa)} = (0.4 \text{ to } 0.6)\ N \text{ (blows per 300 mm)}$$

In clays, the relationship between undrained shear strength and cone resistance is commonly in the range:—

$$q_c = (12 \text{ to } 18)\ c_u$$

Interpretation of CPT values can also be made to allow estimation of modulus or compressibility values to allow calculation of foundation settlements.

Inferred stratification as shown on the attached reports is assessed from the cone and friction traces and from experience and information from nearby boreholes, etc. This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties, and where precise information on soil classification is required, direct drilling and sampling may be preferable.

Hand Penetrometers

Hand penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 150 mm increments of penetration. Normally, there is a depth limitation of 1.2 m but this may be extended in certain conditions by the use of extension rods.

Two relatively similar tests are used.

- Perth sand penetrometer — a 16 mm diameter flat-ended rod is driven with a 9 kg hammer, dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.
- Cone penetrometer (sometimes known as the Scala Penetrometer) — a 16 mm rod with a 20 mm diameter cone end is driven with a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). The test was developed initially for pavement subgrade investigations, and published correlations of the test results with California bearing ratio have been published by various Road Authorities.

Laboratory Testing

Laboratory testing is carried out in accordance with Australian Standard 1289 “Methods of Testing Soil for Engineering Purposes”. Details of the test procedure used are given on the individual report forms.

Bore Logs

The bore logs presented herein are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable, or possible to justify on economic grounds. In any case, the boreholes represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes, the frequency of sampling and the possibility of other than ‘straight line’ variations between the boreholes.

Ground Water

Where ground water levels are measured in boreholes, there are several potential problems;

- In low permeability soils, ground water although present, may enter the hole slowly or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report.
- The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Engineering Reports

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. a three storey building), the information and interpretation may not be relevant if the design proposal is changed (eg. to a twenty storey building). If this happens, the Company will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface condition, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- unexpected variations in ground conditions — the potential for this will depend partly on bore spacing and sampling frequency
- changes in policy or interpretation of policy by statutory authorities
- the actions of contractors responding to commercial pressures.

If these occur, the Company will be pleased to assist with investigation or advice to resolve the matter.

Site Anomalies

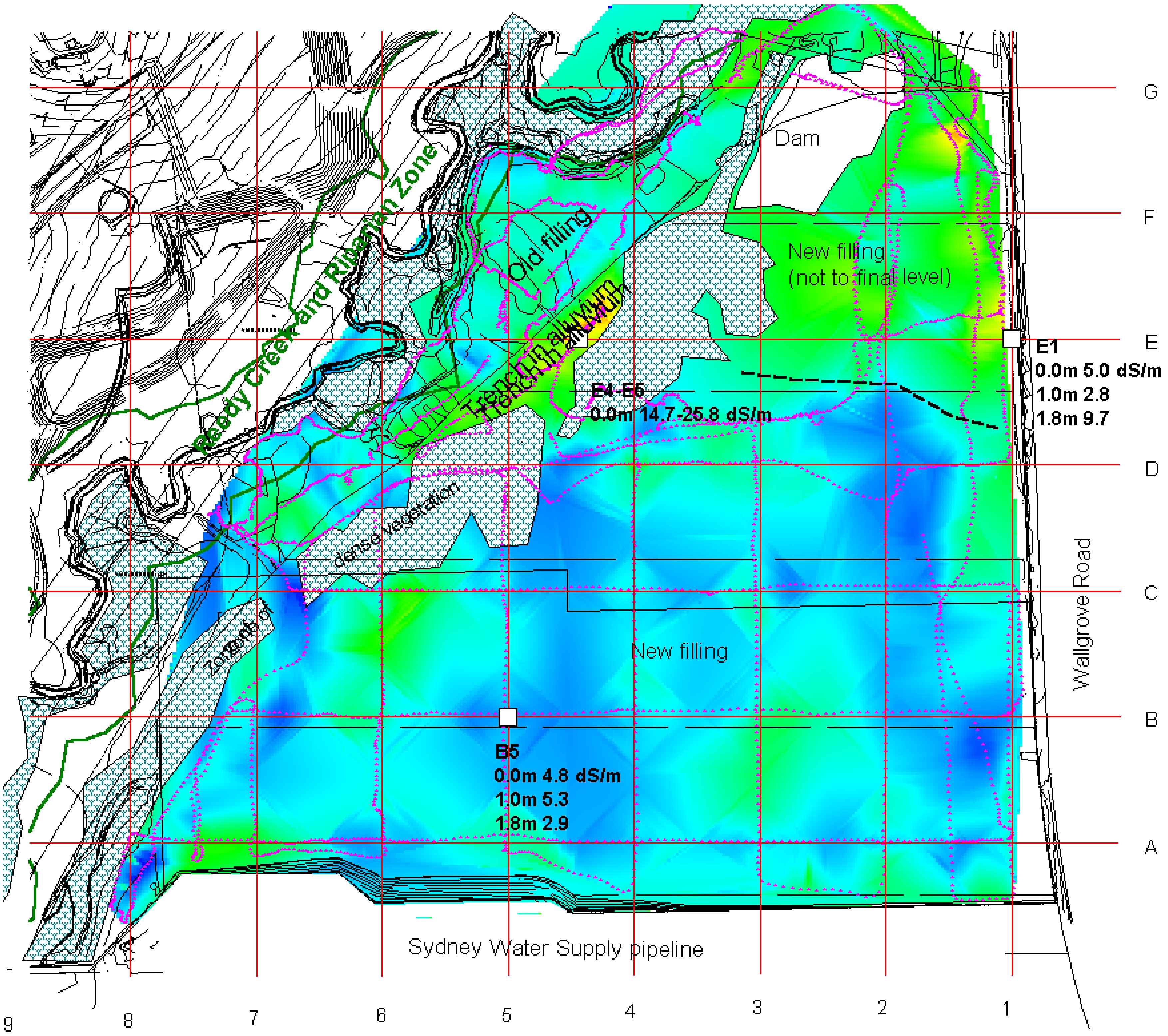
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some later stage, well after the event.

Reproduction of Information for Contractual Purposes

Attention is drawn to the document “Guidelines for the Provision of Geotechnical Information in Tender Documents”, published by the Institution of Engineers, Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. The Company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The Company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.



Grid : GDA94 / MGA94:
100m x100m graticule shown:
A1 grid reference = 301120.8288, 6255751.5960
(Based on Hard & Forester Dwg 111053007_00.dwg)

Measurement points along EM31 profiles

Location of test pit for soil samples and salinity tests

Apparent Conductivity (mS/m)
from EM31 measurements

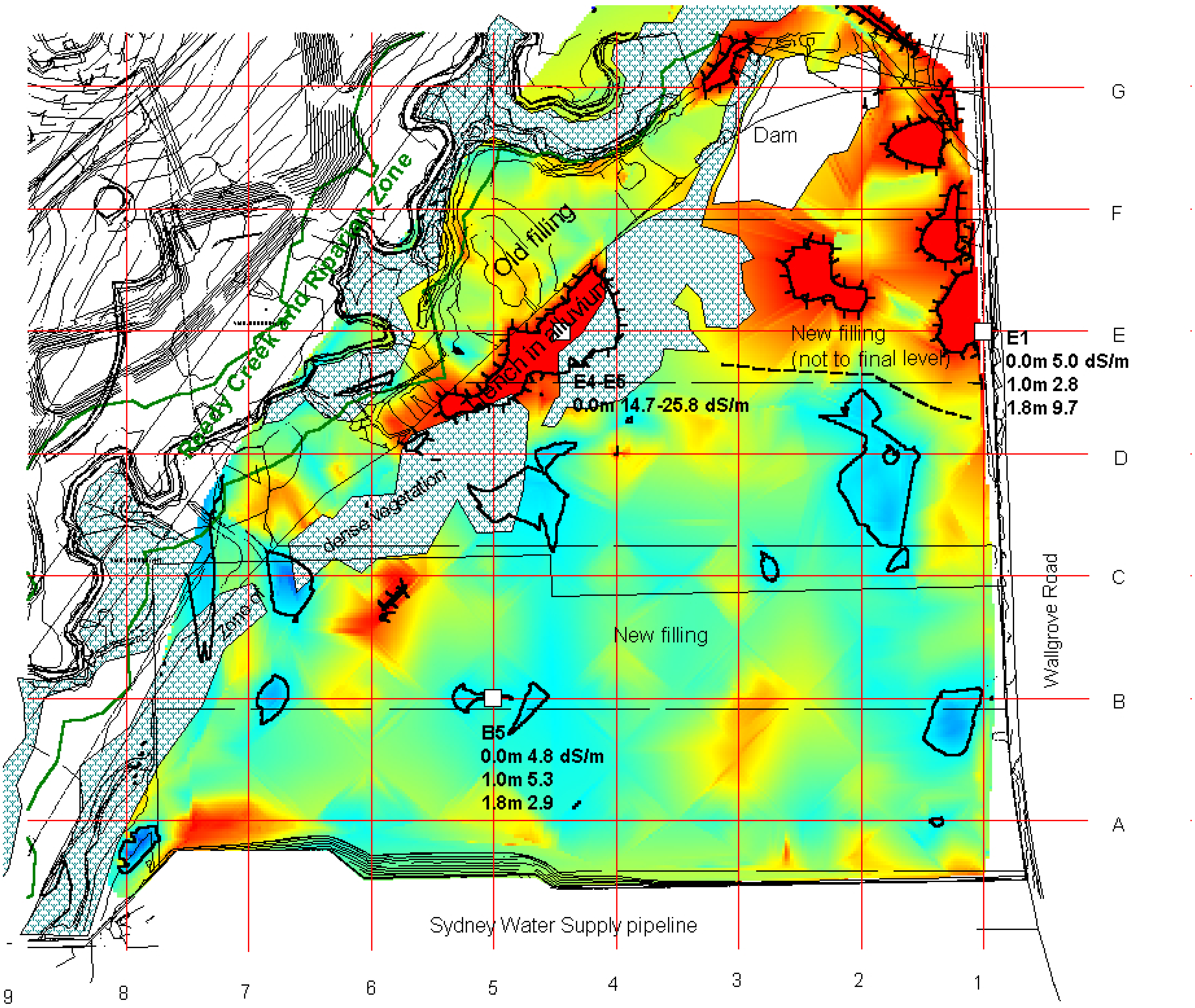
200
150
100
50

Douglas Partners
Geotechnics • Environment • Groundwater

Sydney, Newcastle, Brisbane, Melbourne, Perth, Wyong, Campbelltown, Townsville Cairns, Wollongong

TITLE: **Apparent Conductivities ECa (mS/m)**
Salinity Study,
Proposed Commercial Development,
M7 Business Hub, Eastern Precinct,
Eastern Creek.

CLIENT:	Macquarie Goodman Pty Ltd						
DRAWN BY:	JL	SCALE:	As shown	PROJECT No:	37899	OFFICE:	SYDNEY
APPROVED BY:				DATE:	22 March 2005	DRAWING No:	1



Grid : GDA94 / MGA94:
100m x 100m graticule shown:
A1 grid reference = 301120.8288, 6255751.5960
(Based on Hard & Forester Dwg 111059007_00.dwg)

Location of test pit for soil samples and salinity tests

Apparent Salinities ECe (dS/m) from EM31 and lab measurements. Contour lines at salinity class boundaries (Richards 1954)

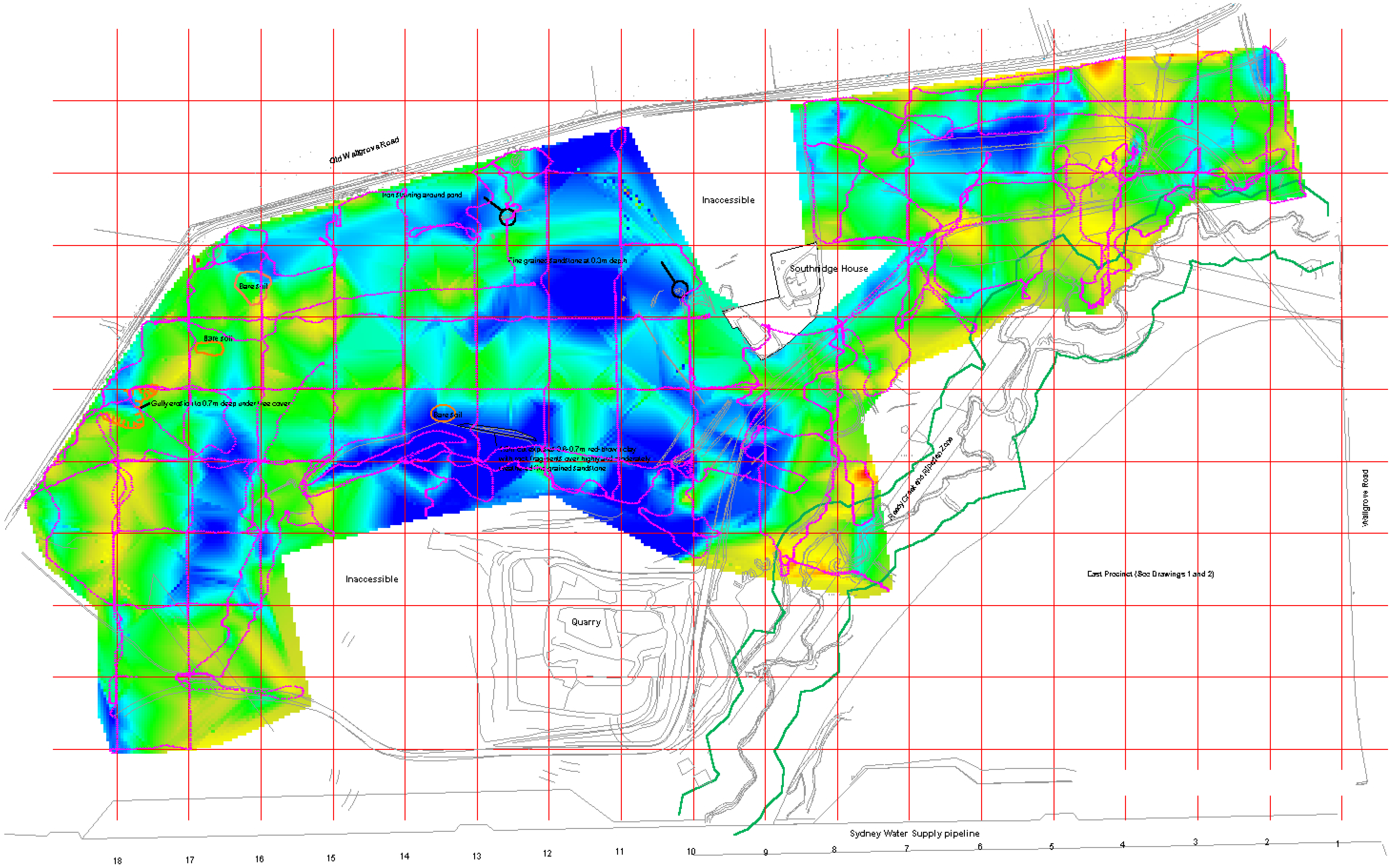
8	Very saline
7	
6	Moderately saline
5	
4	Slightly saline
2	Non saline (not found/shown)

Douglas Partners
Geotechnics • Environment • Groundwater

Sydney, Newcastle, Brisbane, Melbourne, Perth, Wyong, Campbelltown, Townsville, Cairns, Wollongong, Darwin

TITLE: **Apparent Salinities ECe (dS/m)**
Salinity Study,
Proposed Commercial Development,
M7 Business Hub, Eastern Precinct,
Eastern Creek.

CLIENT: Macquarie Goodman Pty Ltd			
DRAWN BY: JL	SCALE: As shown	PROJECT No: 37899	OFFICE: SYDNEY
APPROVED BY:		DATE: 3 June, 2005	DRAWING No: 2



LEGEND

Grid : GDA94 / MGA94:
100m x 100m graticule shown:
A1 grid reference = 301120.8288, 6255751.5963
(Based on Hard & Forester Dwg 1110SS007_00.dwg)

Measurement points along EM31 profiles

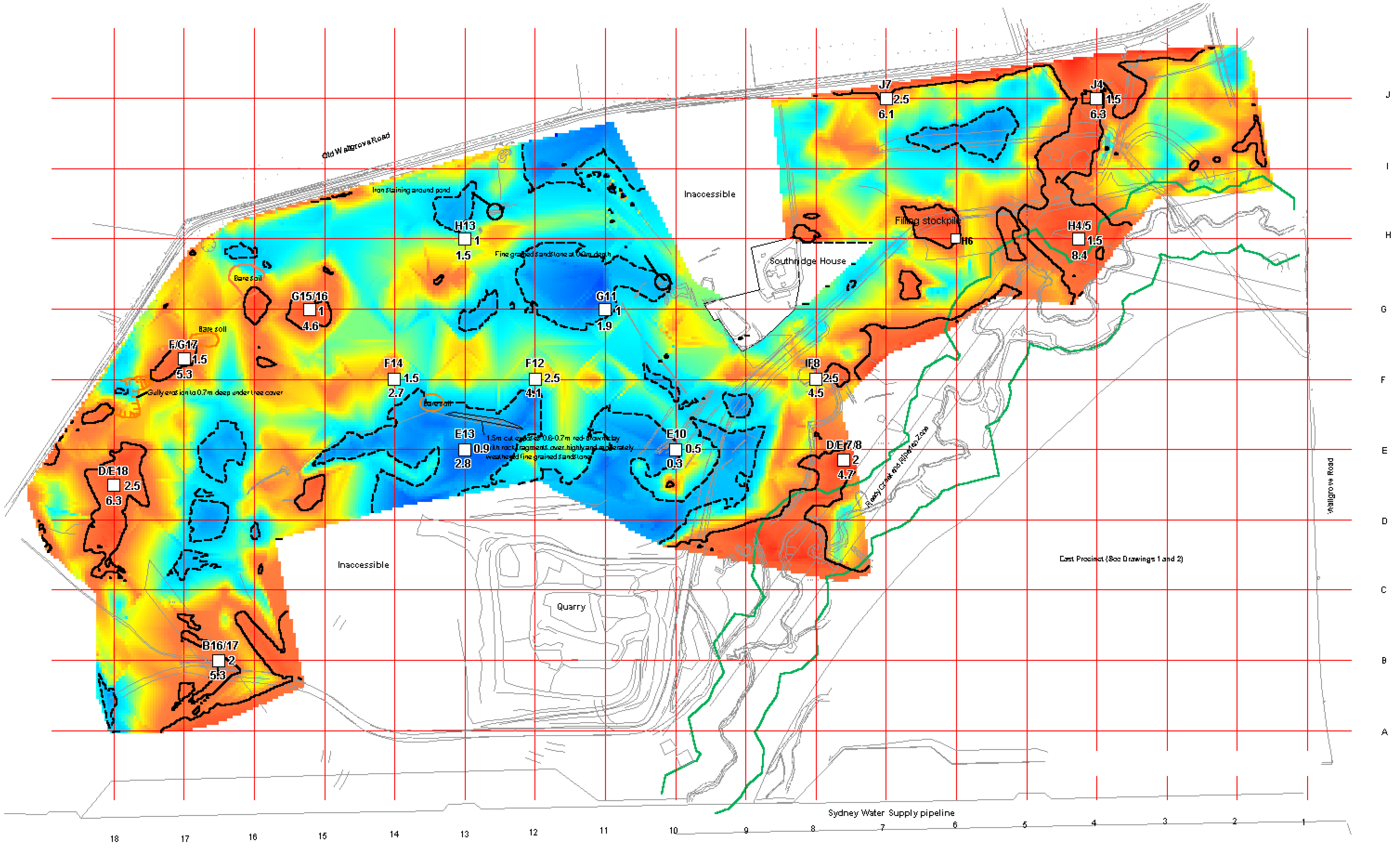
Apparent Conductivity (mS/m) from EM31 measurements

- 200
- 150
- 100
- 50

Douglas Partners
Geotechnics • Environment • Groundwater

Sydney, Newcastle, Brisbane, Melbourne, Perth, Wyong, Campbelltown, Townsville, Cairns, Wollongong, Darwin

TITLE:	**Apparent Conductivities (mS/m)** Salinity Study, Proposed Commercial Development, M7 Business Hub, Western and Central Precincts, Eastern Creek.				
CLIENT:	Macquarie Goodman Pty Ltd				
DRAWN BY: JL	SCALE: As shown	PROJECT No:	37899	OFFICE:	SYDNEY
APPROVED BY:		DATE:	27 June 2005	DRAWING No:	3



Grid : GDA94 / MGA94:
100m x 100m graticule shown:
A1 grid reference = 301120.8288, 6255751.5960
(Based on Hard & Forester Dwg 11105S007_00.dwg)

B16 — 1.0m — 0.65 dS/m: Location of test pit for soil samples and salinity tests showing depth and value of maximum salinity

Apparent Salinities ECe (dS/m) from EM31 and lab measurements. Contour lines at salinity class boundaries (Richards 1954)

- Moderately saline
- 4
- Slightly saline
- 2
- Non saline

Douglas Partners
Geotechnics • Environment • Groundwater

Sydney, Newcastle, Brisbane, Melbourne, Perth, Wyong, Campbelltown, Townsville, Cairns, Wollongong, Darwin

TITLE: **Apparent Salinities ECe (dS/m)**
Salinity Study,
Proposed Commercial Development,
M7 Business Hub, Western and Central Precincts,
Eastern Creek.

CLIENT:	Macquarie Goodman Pty Ltd						
DRAWN BY:	JL	SCALE:	As shown	PROJECT No:	37899	OFFICE:	SYDNEY
APPROVED BY:				DATE:	11 August 2005	DRAWING No:	4