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Geotechnics • Environment • Groundwater

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REPORT

on

LAND CAPABILITY AND CONTAMINATION ASSESSMENT

TURNER ROAD PRECINCT

CATHERINE FIELD AND CURRANS HILL

Prepared for

GROWTH CENTRES COMMISSION

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EXECUTIVE SUMMARY

This report presents the results of a land capability and contamination assessment undertaken of a 536 ha parcel known as the Turner Road Precinct, lying in the suburbs of Catherine Field and Currans Hill (henceforth "the site", refer Drawing 1). The work was commissioned by the Growth Centres Commission (GCC). The site comprises two large land holdings held by the Marist Brothers and NSW Clubs Ltd (part of which is used as Camden Valley Golf Course) and several blocks fronting onto Turner Road.

It is understood that the area has been identified by GCC and Camden Council for potential re-zoning and urban development. GCC and Council require that the area be investigated to assess its constraints for urban development with regards to:

- slope instability;
- soil erosion risks;
- soil salinity hazard;
- geotechnical factors; and
- site contamination .

To address these matters, this investigation comprised:

- Site history searches for environmental reporting. Searches were undertaken with historical societies and government agencies to identify potential areas of environmental concern, based on the sites past uses (the searches undertaken are detailed in Section 6).
- Site mapping for slope instability and erosive features. A senior engineering geologist undertook a site walkover and produced maps of current and historic landslips and soil erosion features (refer Section 8.1).
- Electromagnetic surveying for salinity potential. A EM31sonde mounted to an all terrain vehicle traversed the site collecting salinity data for salinity mapping.
- Samples were collected from 90 test pits to ground truth the EM31 data. (This process is further explained in Section 10).
- Ecavation of a further 20 test pit locations based on the results of the salinity mapping were targeted across the site to provide further information for the preparation of a preliminary salinity management plan (see Section 11.3.6)

- Soil testing for geotechnical purposes was undertaken from selected test pits. This data allowed the development of preliminary values for geotechnical conditions including footings, pavement design, site preparation (refer Section 11.6).

Based on these investigations, constraint maps were developed, as described below:

- Geotechnical Constraint (refer Drawing 7): This map shows areas of constraint with respect to geotechnical factors such as landslip and erosion. The map details areas of minor constraint which should be managed by sound earthworks practices.

- Salinity Constraint (refer Drawing 16): This map shows areas of constraint with respect to very saline soil conditions and moderately saline soil conditions. Management strategies for both soil types are provided in Section 11.3.6).

- Aggressivity and Sodicity Mapping (refer Drawings 17-20). Soils at the site have been shown to be aggressive and dispersive, with risk areas by depth shown on the maps. Response strategies to these constraints are provided in Section 11.3.6).

- Areas of Environmental Concern (refer Drawing 21): This map shows areas of the site where further site investigation will be required for contamination purposes. It is considered that all sites are likely to be able to be remediated and made suitable for the proposed land use and hence are not likely to present a constraint to development.

Further investigation will be required as conceptual design/planning progresses together with additional work during the construction phase. Specific investigation would include but not necessarily be limited to:

- Detailed environmental investigation (comprising subsurface sampling and laboratory testing) in the nominated areas of environmental concern (AEC), primarily in those areas which lie within the proposed “development footprint”. The purpose of this work would be to quantify the level of contamination (if any) and delineate contaminated areas in order to facilitate the preparation of remediation action plans (RAP).
- Additional hazardous building material assessments should be undertaken of all buildings in the Turner Road sector and in buildings in the golfcourse that are to be

demolished/renovated. A site walkover should also be undertaken at all Turner Road properties to confirm the low potential for contamination previously assessed..

- Remediation and validation monitoring of areas subject to an RAP, to render such areas appropriate for the proposed land use, from the contamination viewpoint.
- Additional investigation should be undertaken in development areas which are to be excavated deeper than 3 m or into rock at shallower depth, where direct sampling and testing of salinity has not been carried out. Salinity management strategies herein should be modified or extended following additional investigation by deep test pitting and/or drilling, sampling and testing for soil and water pH, electrical conductivity, TDS, sodicity, sulphates and chlorides.
- Installation of groundwater bores well in advance of construction and monitoring/sampling/analysis before, during and after construction, to assess changes in groundwater quality, electrical conductivity and level as a result of the development. The bores would be strategically located on a catchment basis near creek lines.
- Routine inspections and earthworks monitoring during construction.
- Detailed geotechnical investigations on a stage-by-stage basis for determination of pavement thickness designs and lot classifications.
- Further investigation into the potential for future coal mining and correspondence with the relevant authorities regarding subsidence and any foreseen restrictions on the development.

SUMMARY OF LAND CAPABILITY FOR SITE DEVELOPMENT

Based on the results of the assessment thus far compiled, the following summary points are noted:

- No evidence of hillslope instability was observed within the site. It is considered that hillslope and stream bank instability do not impose significant constraints on the proposed site development.
- The presence of erosive soils on site should not present significant constraints to development provided they are well managed during earthworks and site preparation stages. Gully erosion already present on site should be remediated during site works as discussed earlier in Section 11.2.

- Development will be constrained by moderately saline soils over a significant portion of the Precinct however very saline soils are generally confined to the riparian corridor of South Creek and should have minor impact on the development if construction does not take place in this creek corridor.
- Although mild aggressivity to concrete is widespread in the far north and central section of the Precinct, constraint regions due to moderately aggressive soils are limited in area and can be managed using standard practices, such as those detailed in the Piling code of Australia.
- Highly sodic soils appear widespread and will require management to reduce dispersion, erosion and to improve drainage.
- Based on the extensive site history review, inspection/field mapping and groundwater, surface water and sediment investigation, the overall potential for contamination at the subject site is considered to be low and limited to the identified areas of environmental concern.

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CCK
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28 February 2007

REPORT ON LAND CAPABILITY & CONTAMINATION ASSESSMENT
TURNER ROAD PRECINCT
CATHERINE FIELD & CURRANS HILL

1. INTRODUCTION

This report presents the results of a land capability and contamination assessment undertaken of a 536 ha parcel known as the Turner Road Precinct, lying in the suburbs of Catherine Field and Currans Hill (henceforth "the site", refer Drawing 1). The work was commissioned by the Growth Centres Commission (GCC).

It is understood that the area has been identified by GCC and Camden Council for potential re-zoning and urban development. GCC and Council require that the area be investigated to assess its suitability for urban development with regards to slope instability, soil salinity, the potential for soil contamination and soil erosion risks.

The investigation comprised site history searches, site inspections intrusive and non-intrusive site investigation and reporting.

Details of all work undertaken and results obtained are given within, together with comments relating to land capability, engineering design and construction practice. Whilst pertinent results of field work and laboratory test results are included in the text, further details are provided in the following Appendices:

A Drawings
B Photograph Plates

C Electromagnetic Survey - Field and Processing Methods
D PAEC Identification and Inspection Logs
E Notes from Interviews
F Bore Logs and Construction Notes for Groundwater Wells
G Test Pit Logs
H Laboratory Results for Soil Sample Tests
I Laboratory Results for Groundwater and Surface Water Analysis
J Guide to Home Owners on Foundation Maintenance and Footing Performance (CSIRO Publication)

2. SITE DESCRIPTION

The site is approximately 536 ha in plan area and comprises two large land holdings held by the Marist Brothers and NSW Clubs Ltd (part of which is used as Camden Valley Golf Course) and several blocks fronting onto Turner Road.

The site is generally cleared and grass covered. Remnant stands of trees surround creek lines. Low lying areas are vegetated with salt-resistant vegetation, including Bulrushes and Spiny Reeds.

In addition to salt-resistant vegetation, salt scalds and eroded soils were also noted across the site. Many salt scalds show salt efflorescence at the surface.

Topographical relief across the majority of the site is slight.

3. PROPOSED DEVELOPMENT

The site is located within the Camden Local Government Area. Douglas Partners Pty Ltd (DP) understands that this area is to be developed and forms one of the first precincts to be released by the Growth Centres Commission. The site encompasses an area of 536 ha and is proposed to provide approximately 4000 housing lots as well as significant areas of commercial space. The site is essential divided into three ownership sectors:

- The Marist Brothers Lands – Currently used as agricultural property for St Gregory's College.
- NSW Club Lands – Incorporates the golf course and a large parcel of land to the south currently adgisted to St Gregory's College.
- Turner Road Properties – 28 properties fronting on to Turner Road or Camden Valley Way.

The following sections provide general comment on development constraints relevant to geotechnical factors, soil chemistry and environmental contaminants to assist in the conceptual planning of the site. It is noted that further investigations will need to be undertaken as the conceptual planning and more detailed design proceeds.

4. REGIONAL SOIL LANDSCAPE, GEOLOGY AND HYDROGEOLOGY

4.1 Soil Landscapes

Reference to the 1:100 000 Soil Landscapes of the Wollongong – Port Hacking Sheet (Ref. 1) indicates that the site area is predominantly included within the Blacktown Soil Landscape which is characterised by topography of *"gently undulating rises on Wianamatta Group Shale, with local relief to 30 m and slopes usually less than 5%"*. This is a residual landscape which the mapping indicates comprises up to four soil horizons that range from shallow red-brown hard-setting sandy clay soils on crests and upper slopes, to deep brown to yellow sand and clay soils, overlying grey plastic mottled clay on mid to lower slopes. These soils are typically of low fertility, are moderately reactive and have a generally low wet-bearing strength.

The soils landscape mapping indicates that the Luddenham Soil Landscape is present in the ridge crest area immediately adjacent to parts of the eastern margin of the site. This soil landscape is characterised by *"undulating to rolling low hills on Wianamatta Group Shales, often associated with Minchinbury Sandstone with local relief 50 – 80 m, and slopes 5% – 20%*. The mapping indicates that it is an erosional unit with shallow (<1.0 m) Brown Podsolic Soils and massive earthy clays on crests and ridges, and moderately deep (0.7 – 1.5 m) Red Podsolic Soils on upper slopes.

The South Creek Soil Landscape is mapped as a narrow (less than 300 m) zone about a 750 m long section of the South Creek valley floor extending south-easterly from the Camden Valley Way boundary. This soil landscape is characterised by *"flat to gently sloping alluvial plain with occasional terraces or levees providing low relief <10 m and slopes <5%."* The alluvial soils are often very deep layered sediments over bedrock or residual soils. Where pedogenesis has occurred, structured plastic clays or structured loams are characteristic in and adjacent to the drainage lines and yellow podsolic soils are most common on the terraces.

Due to the scale of the published mapping, it is difficult without intrusive sampling to precisely delineate the various boundaries (see Drawing 4). As such, it is possible that some of the Luddenham Soil Landscape soil group may also be locally extend into the site. Similarly, as alluvium also underlies sections of the valley floor of South Creek within the central sections of the site, the South Creek Soil Landscape may also be more widely distributed than that shown on the published mapping.

4.2 Geology

Reference to the Wollongong - Port Hacking 1:100 000 Geological Series Sheet (Ref. 2) indicates that the site is underlain by Bringelly Shale (mapping unit Rwb) of the Wianamatta Group of Triassic age. This formation typically comprises shale, carbonaceous claystone, laminite and some minor coaly bands. Unnamed, fine to medium grained, quartz-lithic sandstone members (mapping unit Rwbs) are mapped within the site area, particularly within the topographically higher sections of the site (see Drawing 5).

The published mapping also indicates the approximate locations of two faults extending through the site.

4.3 Hydrogeology

McNally (2005, Ref 3) describes some general features of the hydrogeology of Western Sydney which are relevant to this site. The shale terrain of much of Western Sydney is known for saline groundwater, resulting either from the release of connate salt in shales of marine origin or from the accumulation of windblown sea salt. This salt is concentrated by evapo-transpiration and often reaches highest concentrations 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 groundwater level changes of 1 - 2 m can occur in a shallow regolith aquifer or a deeper shale aquifer due to natural influences, 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 former Department of Infrastructure Planning and Natural Resources (DIPNR), on their map entitled "Salinity Potential in Western Sydney 2002" (Ref. 4), infers "moderate salinity potential" over most of the site and "high salinity potential" or "known salt occurrence" in the lower slopes and drainage areas of the north-westerly trending South Creek and its tributary gullies which drain all but the southern margin of the study area, and the south-flowing headwater gullies of the Narellan Creek drainage system.

The DIPNR mapping (see Drawing 6 for approximate boundaries) is based on soil type, surface level and general groundwater considerations but is not in general ground-truthed, hence it is not generally known if actual soil salinities are consistent with the potential salinities of DIPNR.

Groundwater investigations undertaken by DP in the Camden area and previous studies of areas underlain by the Wianamatta Group and Quaternary river alluvium indicate that:

- the shales have a very low intrinsic permeability and groundwater flow is likely to be dominated by fracture flow with resultant low yields (typically < 1 L/s) in bores;
- the groundwater in the Wianamatta Group is typically brackish to saline with total dissolved solids (TDS) in the range 4000 – 5000 mg/L (but with cases of TDS up to 31750 mg/L being reported). The dominant ions are typically sodium and chloride and the water is generally unsuitable for livestock or irrigation.

5. SCOPE OF WORKS

From the brief provided by the GCC, DP identified the following scope of works for the site. For clarity, the scope of works undertaken for the assessment was divided up based upon the individual tasks required for the site.

5.1 Stability and Erosion

The initial stage of the study comprised the collection and review of background information, predominantly from published data and aerial photographs. Subsequently, field mapping was undertaken by a senior engineering geologist to identify potential unstable areas and to nominate locations for subsurface investigation.

The locations (Mapping Reference Points 1 – 16) of individual features of note were determined using a hand held GPS receiver, thus enabling positioning (to GDA/MGA94 co-ordinate system) of features in relation to digital aerial photographs and basemaps, provided for generation of the drawings within this report.

Subsurface investigation comprised the excavation of 110 test pits across the site with a rubber-tyred backhoe to profile the subsurface strata. The pits incorporated regular soil samples to assist in strata identification and for laboratory testing to determine soil plasticity, erosion potential and salinity potential.

5.2 Soil Salinity

An electromagnetic survey was undertaken as part of the examination of soil salinity potential, enabling rapid continuous measurement of apparent conductivity, to supplement the laboratory electrical conductivity 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 generally designated as σ_a or ECa. Although measurement of 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, Ref. 7) 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, as a good indicator of soil salinity.

Most portable instruments measure apparent conductivity in milliSiemens per metre (mS/m) and typical measurement ranges (Table 1) have been suggested as indicative of salinity classes (Chhabra 1996, Ref. 8).

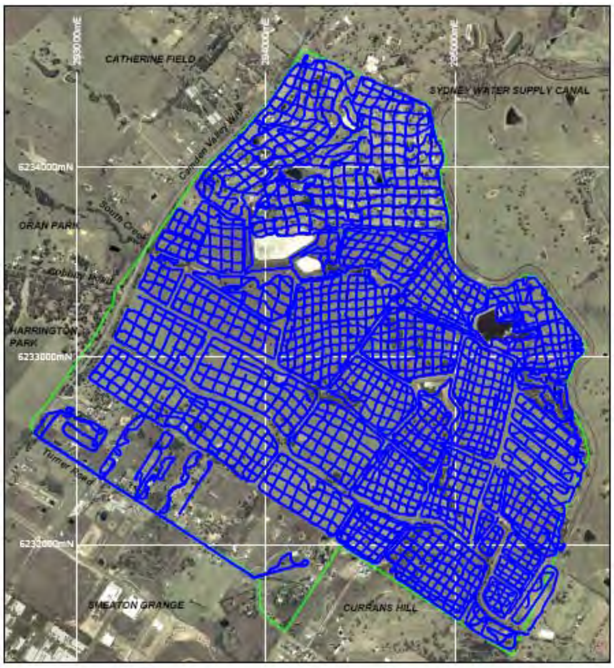
Table 1 – Salinity Classes in Relation to Apparent Conductivity

Class	ECa (mS/m)
Non Saline	<50
Slightly Saline	50 – 100
Moderately Saline	100 – 150
Very Saline	150 – 200
Extremely Saline	>200

The survey was undertaken using a Geonics EM31 ground conductivity meter mounted 1 m above the ground surface from the side of an all terrain vehicle (ATV). 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 coils (i.e. from material at depths of up to 2 m below ground surface). Other EM systems and configurations can be employed for greater near-surface resolution, however a system with a significant response to material within 2 m of surface is considered appropriate given that excavation for proposed urban development is likely to extend to this depth.

A Trimble AgGPS114 Differential Global Positioning System (DGPS) receiver, antenna and iPAQ hand-held computer were employed to digitally record grid coordinates at 1 second intervals as the ATV was navigated around the survey area. ECa data were acquired at a 1 second repetition rate and logged to a Geonics Polycorder digital data logger, synchronised to the DGPS.

Data were obtained along approximately 215 km of linear traverse (90,500 data points) in all accessible parts of the site, with an average data point spacing of 2.4 m. Access was not possible to some areas of existing development, including large dams in the north of the Precinct and a number of private properties off Turner Road with no owner permission. A grid of primary survey lines approximately 100 m apart however was achieved in the accessible areas as shown by the ECa measurement points (track of the ATV) in Drawing 13 (Appendix A and thumbnail image below). Further details of field methods, data processing and interpretation are given in Appendix C.



Locations of EM31 Profiles (See Drawing 13, Appendix A)

5.3 Soil Contamination

5.3.1 Potential Sources of Contamination

In order to determine the potential for land contamination and particular environmental constraints in the release area, a Phase 1 Environmental Site Assessment was conducted. This included primarily an appraisal of the potential for site contamination that may have resulted from past and present land uses.

Based on the information relating to the proposed development, the Phase 1 assessment included the following scope of works:

- Field mapping by an environmental engineer.
- A search through the NSW EPA Land Information records to confirm that there are no statutory notices current on any parts of the release area under the *Contaminated Land Management Act* (1997).
- A WorkCover search request on licences to Keep Dangerous Goods for selected sites to ascertain KDG if licences have / had been held for these properties.
- A review of historical aerial photography for the area through the Land Information Section of the Department of Lands.
- A review of previous site ownership records including land title records archived at the Land Titles Office. These records were compiled by Peter S. Hopley Pty Ltd.
- A search of historical Council and property attributes records pertaining to previous site use and any information relating known areas of flood prone land, or site contamination.
- Interviews with local residents and land owners (where possible) to obtain anecdotal information regarding the potential nature and extent of site filling.
- Based on the findings of the above testing a list of Potential Areas of Environmental Concern (PAEC) was developed.
- Each PAEC was assessed individually and depending on the risk or presence of contamination certain PAEC were declared Areas of Environmental Concern (AEC) there will be subject to subsequent Phase 2 Investigations.
- Installation and development of a groundwater bore into the shallow groundwater system.
- A groundwater, surface water and sediment sampling program, one week after the installation of groundwater bores. The groundwater and surface water investigation was used to confirm the results of the preliminary assessment.

At the conclusion of the Phase 1 assessment, a list of all identified Areas of Environmental Concern (AECs) and any associated chemicals of concern was prepared. This formed the basis for recommendations regarding the need for further field-based environmental investigations.

5.4 Soil Management Plan

A preliminary soil management plan was prepared to address management procedures and development criteria. The overall plan includes the preparation of constraint maps that will address problematic areas and provide development criteria which will be suitable for inclusion in future planning documents. These controls will incorporate recommendations for areas that require further testing. A response strategy for potential future problems in relation to soil conditions will also be developed.

5.5 Horizontal and Vertical Control

The coordinates of the field tests and other pertinent features were determined by use of a GPS receiver. This enabled positioning of features in relation to digital aerial photographs and maps, and allowed generation of the drawings within this report. This receiver has an accuracy of ±3m which was considered suitable for the scale of mapping produced.

All field measurements and 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. All reduced levels are given in relation to Australian Height Datum (AHD) and are interpolated from the contour maps provided.

6. ENVIRONMENTAL HISTORY REVIEW

An extensive site history investigation was undertaken for the site. Every issue pertinent to contamination was logged as a Potential Area of Environmental Concern (PAEC). These PAEC Identification & Inspection Logs described site observations and the potential for contamination and further classified each individual area as an Area of Environmental Concern (AEC), where required.

The following sections detail the methodology of investigations undertaken with results of the investigations discussed in Section 11.5. PAEC Identification & Inspection Logs are contained in Appendix D, which contain detailed information and observations relating to each identified area, and provide the rationale for declaring a site's AEC status.

6.1 Historical Title Search

A search of land title ownership information held by Land Titles Office in Sydney was compiled by Peter S. Hopley Pty Ltd and covered records dating back to circa 1919. Detailed copies of titles and survey plans were analysed: no PAEC were logged during this investigation.

6.2 Historical Aerial Photography

Historical aerial photographs from six periods of photography, archived by the Land Information Section of the Department of Land, were inspected and indicated that the site has undergone changes in layout since the earliest available aerial photograph dated January 1947. Aerial photographs examined included:

- January 1947 (Run 19, Prints 54 – 147)
- 1961 (Run 44 and 45, Prints 1043-5200 and 834 – 5050)
- 6 July 1970 (Run 24, Prints 1906-5175)
- 14 May 1978 (Run 23W, Prints 2714 -181)
- 8 October 1984 (Run 2, Prints 3410 – 61 and 3410 – 63)
- 4 January 1994 (Run 1, Prints 01-22)

All photographs were scanned at high resolution and geocoded for use in a GIS database. Photos were examined and all PAEC were logged. Aerial photographs examined have been included in Appendix A (Drawings 8 – 11).

6.3 Regulatory Notices Search

A search was conducted through the NSW EPA web site for any Regulatory Notices that may be current on the site under the *Protection of the Environment Operations Act* (1997). The search results indicated that a licence (licence number: 1617) is issued to The Rugby League Country Club Ltd (trading as Camden Valley Golf Resort) for 810 Camden Valley Way, Catherine Field. The licence is issued for a Sewage Treatment – processing by small plants (<10000ML per year). The PEAC resulting form the NSW EPA search was logged. The relevant NSW EPA search documents are attached in Appendix E**.**

A search was conducted through the NSW EPA web site for any Regulatory Notices that may be current on the site under the *Contaminated Land Management Act* (1997). No Notices or Orders to investigate or remediate have been issued for the site under the *Contaminated Land Management Act* (1997).

6.4 Council Records Review and Property Attributes

Council Records were inspected on site at Camden Council. Records were available for the site dating back to c.1985. Earlier information was not available. The records indicated complaints regarding illegal pumping of raw sewage from a septic tank onto paddocks/ ground surface, illegal excavation/ land forming activities, underground storage tank, approval for a septic tank, obstruction to watercourse, filling in creek bed and dilapidated stables. These PAEC were logged.

Property attribute prints obtained from the Camden Council for the site were reviewed. The attributes indicated DA approvals for a Leagues Club, Camden Valley Golf Resort, approval for golf driving range, St Gregory's (Agricultural) college, Veterinary Clinic, resited building and an irrigation dam. These PAEC were logged.

6.5 WorkCover Authority Search

The WorkCover Authority was requested to undertake a search of their database for Licenses to Keep Dangerous Goods for the Golf Course and the Marist Brothers land (St Gregrory's College). The Authority searched the Stored Chemical Information Database and the microfiche records for information.

The Authority had the following records relating to the Marist Brothers land

- 1 above ground (A/G) gas tank – 1 tonne
- 1 A/G diesel oil tank – 9000 Litres
- 1 A/G petrol tank – 2250 Litres
- 1 diesel oil underground storage tank (UST) – 4500 Litres

Full details of the WorkCover Authority database search can be found in Appendix E, including a map showing the locations of each tank.

A letter of authorisation to proceed (a WorkCover requirement) was not provided by the golf course within the timeframe of this assessment, and as such the investigation was not undertaken, this should be undertaken as part of subsequent environmental investigations at the site.

6.6 DNR Groundwater Bore Search

A registered groundwater bore search was conducted by the Department of Natural Resources (DNR) on the 7th of February 2007. None of the registered groundwater bores were found to occur within the Turner Road Precinct boundaries. The three closest groundwater bores found are as follows;

- GW035211 – approximately 1.9 km north-east from the centre of the precinct indicating topsoil to 0.6m, shale to 51.81m, basalt to 54.25m, sandstone to 57.61m and shale to 60.96m. Water quality details were not provided.
- GW014161 – approximately 1.6 km north-west from the centre of the precinct indicating clay to 6.70m, shale to 73.6 and sandstone to 79.85m. Water quality details were not provided.

- GW072777 – approximately 2 km to the south-east from the centre of the precinct indicating topsoil to 0.3m, clay to 1.50m, shale to 88.50m and sandstone to 250 m. Water quality details were not provided.

6.7 Interviews

Anecdotal evidence was compiled from informal interviews conducted with the caretakers of the sites, current and previous lessees, and owners. Interviews were carried out in a format of 20 prescribed questions; additional questions and anecdotal evidence were also noted. The following people were interviewed:

- Brother Luke – Farm Manager of St Gregory's College;
- Mr John Simpson – Greens Manager, Camden Valley Golfcourse;
- Mr Doug Jones – General Manager, Camden Valley Golfcourse.

Completed Standard Interview Sheets are provided in Appendix E for review. All PAEC resulting from the interview process were logged.

6.8 Geotechnical Test Pit Logs

As part of the land capability study, 110 test pits were excavated across the site for geotechnical purposes. The logs for these test pits were examined and areas of filling were identified and logged as PAEC.

6.9 Fly Tipping Investigation

An investigation into the extent of fly tipping (illegal dumping) was conducted by field inspection of the roads surrounding the site. This was further supplemented by interviews with property managers and review of aerial photography. All areas of PAEC were investigated and logged.

6.10 Cattle Tick Dip Site Investigation

Considering the site's previous and current rural use, an investigation into the location of Cattle Tick Dip Sites was undertaken. Review of various relevant guidelines produced by the Department of Agriculture (now Department of Primary Industries) was undertaken and contact with the Cattle Tick Dip Site Management Committee (DIPMAC) was made. Previous advice from DIPMAC indicated that a register of dip sites in NSW did not reveal the presence of any sites south of Taree. Further to this, DIPMAC noted that as ticks were not generally a problem in the Sydney region, farmers tended to spray cattle as opposed to using the more difficult process of dipping. Only farms within the Northern Tick Quarantine Area (near the Queensland Border) were required to dip cattle.

This information was supported by various past and present workers on the site who had not used dips on the site and did not believe that it would be likely that they had ever been used. In light of this information, no PAEC resulted from this investigation.

6.11 Site History

The report by Godden Mackay Logan regarding site history was not available during the preparation of this draft report. A review of the Cultural Heritage consultants report will be made prior to finalisation. All relevant PAEC identified will be logged.

6.12 Site Inspections

Numerous site inspections were undertaken during the course of the investigation. The majority were informal, to gain familiarity with the site, or related to tasks such as the groundwater monitoring well installation and monitoring. Each visit to site was used as an opportunity to inspect the site for PAEC, and all resultant findings were recorded on PAEC identification logs (see Appendix D).

A formalised visit on 21-23 February 2007, was undertaken with the intent of visiting all logged areas of PAEC which required site inspection. During this visit all sites were visited, photos were taken and site inspection logs recorded. Details are provided in the PAEC Identification Logs in Appendix D. Site photos are included in Appendix B.

7. GROUNDWATER AND SURFACE WATER INVESTIGATION

7.1 Monitoring Well Installation and Sampling

Five groundwater bores were installed at selected locations to establish an understanding of groundwater quality across the site and to use the results as an indication of overall catchment contaminant levels.

The monitoring well locations were selected on a catchment basis using GIS interpretation of the topographic data. The bores were placed at the exit points of the major catchments at the site (see Drawing 3).

The monitoring wells were installed using a trailer mounted GEMCO 210B drill rig drilling with solid flight augers. The wells were constructed of Class 18 UPVC casing and machine slotted screen sections with screw joints. The bores were backfilled with sand and sealed with bentonite plugs 0.5 – 1 m above the screened section. Bore logs and monitoring well construction details are included in Appendix F.

The monitoring wells were sampled seven days after installation. Due to the low hydraulic conductivity of the soil units, the wells were purged until dry using disposable bailers and allowed to recover before a sample was taken. Samples were preserved in appropriate laboratory provided sampling media. Samples to be analysed for metals were filtered using a 0.45-micron filter before preservation in a nitric acid preserved bottle. Samples were cooled on ice prior to dispatch to the analytical testing laboratory under *Chain-of-Custody* conditions.

7.2 Surface water Sampling Locations

No surface water was flowing off site at the time of the investigation, nor had it in the recent past according to communications with the custodians. The only surface water currently on site is in dams located across the site. Seven dams across the properties were selected for sampling based upon their size and size of the catchment they intercept. Sampling locations are shown on Drawing 3.

Samples were preserved in appropriate laboratory provided sampling media. Water samples to be analysed for metals were filtered using a 0.45-micron filter before preservation using nitric acid. Samples were cooled on ice prior to dispatch to the laboratory under *Chain-of-Custody* conditions.

8. FIELD WORK RESULTS

8.1 Geotechnical Site Observations

The geotechnical site observations made during inspections of the site are summarised below and are further detailed on Drawings 4 – 6.

- gully erosion locally entrenches the colluvial, residual or alluvial soils within the bases of creek lines (see Drawing 4). Erosion depths ranged from <0.3 m to 1.5 m.
- coal washery filling (now mostly grass covered), some 70 m by 50 m in plan dimensions is present (at approximately E293585, N6232630), adjacent to the south-western boundary of the site in an area apparently developed for use by a pony club.
- building rubble, including concrete, brick, metal and bituminous pavement fragments extend over an approximately 100 m by 50 m area (at approximately E293660, N6233750) adjacent to the southern boundary of the Camden Valley Golf Course.
- minor volumes of building rubble have also been used to backfill erosion channels in the south-eastern corner of the site and at Mapping References Point 7 (see Drawing 4).

- bare, hard-setting soil patches are present in several gully floor areas within the Camden Valley Golf Course (see Drawing 4) and may indicate salt scalding, sodic soil conditions or simply excessive trafficking.
- there are only isolated, very minor rock outcrops within the site and these are associated with an unnamed sandstone member within the south-eastern corner of the site. Bedrock exposures of interbedded shale, siltstone and fine grained sandstone are, however, present at shallow depth (typically at depths in the range 0.5 m to 1 m) within road cuttings of the Camden Valley Way, the private access road, dam excavations (Mapping Reference Points 3 and 15) and an abandoned quarry (at approximately E294630, N6231895) adjacent to the southern site boundary (see Drawing 5).
- possible soil creep or shallow slumping was noted in three gully heads or steeper slope (about 8^{o} – 10^{o}) locations below a resistant un-named sandstone member within the south-eastern corner of the site (see Drawing 5). Re-contouring of the hillside at one location suggests land management practices to reduce gully erosion which may trigger shallow instability.
- salt efflorescence is present within the banks and bases of the erosion gullies developed along the course of South Creek and also about the margins of dams and drainage lines within the Camden Valley Golf Course (see Drawing 6). Salt tolerant vegetation (Casuarina and Melaleuca species) is also present along the course of South Creek.
- areas of possible surface ponding, seepage or waterlogging, with consequent salinity risks, were noted in the vicinity of dams constructed across the floor of South Creek within the eastern section of the site.

8.2 Subsurface Investigation

Details of the subsurface conditions encountered in the test pits are given in the test pit logs included as Appendix G. The logs should be read in conjunction with the accompanying notes that define classifications methods and descriptive terms.

Relatively uniform conditions were encountered underlying most of the site with the residual soils a result of weathering of the underlying Bringelly Shale. Sandstone was encountered in the more elevated parts of the site which confirmed the geological mapping. Whilst some variability in the overall stratigraphy was encountered in the 123 test pits excavated on the site, the general succession of strata can be broadly summarised as follows:

TOPSOIL: brown silty clay/clayey silt to depths of 0.1 – 0.4 m.

CLAY: stiff to hard (but predominantly very stiff to hard) clay, silty clay and gravelly silty clay to depths of 1.2 m to in excess of 3 m (limit of investigation).

BEDROCK: variably extremely low to medium strength shale (66 test pits) and highly weathered extremely low to low strength sandstone (16 test pits). Rock was not encountered in 41 of the 123 test pits excavated on the site to the 3.3 m limit of investigation.

Slightly variable conditions were encountered in Pit 8 and Pit 58 where filling (silty clay, cobbles and some rubble) was encountered to depths of 1.7 m and 0.7 m respectively.

Free groundwater was only encountered in Pits 102, 115 and D2 during excavation at a depths of 2.2 – 3.0 m. Groundwater was not encountered in the remaining pits which were backfilled immediately following logging and sampling, thus precluding longer term monitoring of groundwater levels.

8.3 Groundwater and Surface water Investigation

Electrical conductivity and pH were measured in the field during monitoring of surface and groundwater. Depth to groundwater was also recorded from the surface. The following table provides the results of field work (refer Drawing 3 for sample locations):

Table 2 – Groundwater and Surface Water Investigation

Location	Sample	Type	Depth (BGL)	pH	EC μS/cm
1	-	GW	Dry	-	-
2	40741/3	GW	1.5 m	7.1	18,000
3	40741/4	GW	2.0 m	7.0	22,000
4	40741/5	GW	2.8 m	-	-
5	40741/16	GW	Submerged	-	-
1	40741/1	SW	-	6.6	140
2	40741/14	SW	-	7.7	120

3	40741/13	SW	-	7.7	1,700
4	40741/12	SW	-	7.6	1,100
5	40741/7	SW	-	7.8	480
6	40741/6	SW	-	7.9	400
7	40741/15	SW	-	7.4	110
8	40741/11	SW	-	7.7	610
9	40741/10	SW	-	7.2	830
10	40741/8	SW	-	7.7	720
11	40741/9	SW	-	8.6	540

GW – Groundwater SW – Surface water

9. LABORATORY TESTING

9.1 Soil Samples

Selected samples from the test pits were tested in the laboratory for measurement of field moisture content, Atterberg limits, linear shrinkage from the liquid limit condition and Emerson Class Number.

The detailed test report sheets are given in Appendix H and indicate that the soils tested are at about (or slightly dry of) the plastic limit which can be considered as being an approximation of the equilibrium moisture content of the soil. The soils are also of intermediate to high plasticity with measured liquid limits within the range 41 – 72%. As such, the clays would be susceptible to shrinkage and swelling movements with changes in soil moisture content.

The results of the Emerson crumb tests indicate that seven of the seventeen samples tested were dispersive (ECN values of 1 and 2) with the remainder being non-dispersive (ECN of 4). Five of the seven dispersive results were from test pits near the western site boundary with the remaining two samples (Pits 49 and 110) towards the eastern and north eastern limit of the site.

The mechanical testing data is summarised in Table 3. Discussion of the results and implications for the proposed development are given in Section 9.3.3.

Table 3 – Results of Laboratory Testing (Mechanical Properties)

Pit No.	Depth (m)	FMC (%)	PL (%)	LL (%)	PI (%)	LS (%)	ECN	Material
2	0.5	15.0					4	Silty Clay
4	1.0	17.5					2	Silty Clay
6	0.5	14.5	11	47	36	12	1	Silty Clay
31	0.5	18.3					4	Silty Clay
36	0.5	15.9	20	58	38	11.0	4	Silty Clay
41	1.0	12.1					4	Sandy Clay
47	0.5	13.4					4	Silty Clay
49	1.0	12.9					1	Silty Clay
65	0.5	24.0					4	Silty Clay
73	0.5	20.5	24	72	48	18.0	4	Silty Clay
89	0.5	15.7	15	57	42	13.5	4	Silty Clay
90	1.0	14.4					2	Silty Clay
110	1.0	15.1					2	Silty Clay
111	1.1	11.4					4	Silty Clay
115	1.0	21.3					2	Silty Clay
116	1.0	17.0					4	Silty Clay
120	0.5	14.9	12	41	29	15.5	1	Silty Clay

Where FMC = Field moisture content; PL = Plastic limit
LL = Liquid limit; PI = Plasticity index
LS = Linear shrinkage; ECN = Emerson Class No.

9.2 Groundwater and Surface Water Samples

Groundwater (GW) and surface water (SW) samples collected from the site were analysed at the laboratory for a wide range of common chemical contaminants including:

- 8 heavy metals;
- polycyclic aromatic hydrocarbons;
- Total Recoverable hydrocarbons;
- Benzene Toluene, Ethylbenzene and Xylene;
- Polychlorinated Biphenyls; and
- OC and OP pesticides.

All analytes returned results below the practical quantitation limit of the laboratory, except for heavy metals which are summarised together with relevant guideline criteria in the table below. Details of the other test results are included in Appendix I.

Table 4 – Analytical Results for Heavy Metals in Water (Results in µg/L)

Location & Type	Sample	As	Cd	Cr*	Cu	Pb	Hg	Ni	Zn
2 / GW	40741/2	<1	**0.3**	<5	**<5**	<1	<0.1	<5	**63**
3 / GW	40741/4	<1	**0.4**	<5	**<5**	1.1	<0.1	5.4	**51**
4 / GW	40741/5	-	-	-	-	-	-	-	-
1 / SW	40741/1	1.4	<0.1	<1	**2.7**	<1	<0.1	**27**	**12**
2 / SW	40741/14	2.1	<0.1	<1	**4.5**	**3.9**	<0.1	1.8	**9.5**
3 / SW	40741/13	<1	<0.1	<5	**<5**	3.3	<0.1	<5	**8.2**
4 / SW	40741/12	<1	<0.1	<5	**<5**	**4.0**	<0.1	<5	**11**
5 / SW	40741/7	2.4	<0.1	<1	**3.8**	**5.1**	<0.1	2.2	6.1
6 / SW	40741/6	2.3	<0.1	<1	**3.6**	**8.0**	<0.1	1.6	4.3
7 / SW	40741/15	2.7	<0.1	<1	**3.5**	**7.4**	<0.1	1.8	**11**
8 / SW	40741/11	3.9	<0.1	<1	**1.8**	1.2	<0.1	1.3	2.9
9 / SW	40741/10	1.7	<0.1	<5	**<5**	2.7	<0.1	<5	**8.9**
10 / SW	40741/8	3.9	<0.1	<1	**2.2**	**4.9**	<0.1	2.5	5.3
11 / SW	40741/9	3.8	<0.1	<1	**1.6**	<1	<0.1	1.4	2.9
	Guideline 1	**24**	**0.2**	**7.7**	**1.4**	**3.4**	**0.6**	**11**	**8.0**

Guideline 1 ANZECC 2000 Guidelines Trigger Values for freshwater with 95% level of protection.

Shaded Indicates an exceedence of the guideline value

* Assumed to be Cr(III), as Cr(VI) is unstable in most natural environments. (Marine Water guideline used in the absence of Freshwater Criteria)

Table 4a – Analytical Results for Surface Water TRH and BTEX (µg/L)

Location & Type	TRH				Benzene	Toluene	Ethylbenzene	Total Xylenes
	C_6-C_9	C_{10}-C_{14}	C_{15}-C_{28}	C_{29}-C_{40}				
2 / GW	<10	<50	<100	<100	<1.0	<1.0	<1.0	<3.0
3 / GW	<10	<50	<100	<100	<1.0	<1.0	<1.0	<3.0
4 / GW	<10	<50	<100	<100	<1.0	<1.0	<1.0	<3.0
1 / SW	<10	<50	<100	<100	<1.0	<1.0	<1.0	<3.0
2 / SW	<10	<50	<100	<100	<1.0	<1.0	<1.0	<3.0
3 / SW	<10	<50	<100	<100	<1.0	<1.0	<1.0	<3.0

Location & Type	TRH				Benzene	Toluene	Ethylbenzene	Total Xylenes
	C_6-C_9	C_{10}-C_{14}	C_{15}-C_{28}	C_{29}-C_{40}				
4 / SW	<10	<50	<100	<100	<1.0	<1.0	<1.0	<3.0
5 / SW	<10	<50	<100	<100	<1.0	<1.0	<1.0	<3.0
6 / SW	<10	<50	**290**	<100	<1.0	<1.0	<1.0	<3.0
7 / SW	<10	<50	**120**	<100	<1.0	<1.0	<1.0	<3.0
8 / SW	<10	<50	<100	<100	<1.0	<1.0	<1.0	<3.0
9 / SW	<10	<50	<100	<100	<1.0	<1.0	<1.0	<3.0
10 / SW	<10	<50	**290**	<100	<1.0	<1.0	<1.0	<3.0
11 / SW	<10	<50	**140**	<100	<1.0	<1.0	<1.0	<3.0
Groundwater Quality Criteria								
Guideline 1	7.0*				950	180*	8*	550
Guideline 2	ND	600			30	1000	150	70

1 ANZECC, 2000, Australian Water Quality Guidelines for Fresh & Marine Waters, 95% level of protection of fresh and marine species.

2 Dutch Intervention Guidelines sourced from *Environmental Quality Objectives in the Netherlands (1999*).

* Low reliability trigger values used from section 8.3.7 of ANZECC, 2000 Guidelines.

ND Not Defined.

10. SALINITY DATA

10.1 Analysis and Presentation

Soil salinity is often assessed with respect to electrical conductivity of a 1:5 soil:water extract (EC 1:5). This value can be converted to ECe (electrical conductivity of a saturated extract) by multiplication by a factor dependent of soil texture ranging from 6 for shale to 17 for sand. Richards (1954, Ref. 9) and Hazelton and Murphy (1992, Ref. 10) classify soil salinity on the basis of ECe, and describe the implications of the salinity classes on agriculture as follows:

Table 5 – Soil Salinity Classification

Class	ECe (dS/m)	Implication
Non Saline	<2	Salinity effects mostly negligible
Slightly Saline	2 – 4	Yields of sensitive crops affected
Moderately Saline	4 – 8	Yields of many crops affected
Very Saline	8 – 16	Only tolerant crops yield satisfactorily
Highly Saline	>16	Only a few very tolerant crops yield satisfactorily

Salinity measurements on 145 samples from 101 test pits throughout the Turner Road Precinct are distributed throughout the salinity classes as shown in detail in Table 7a (Appendix J) and statistically in Table 7 below.

Table 7 – Distribution of Test Pit Sample Salinities

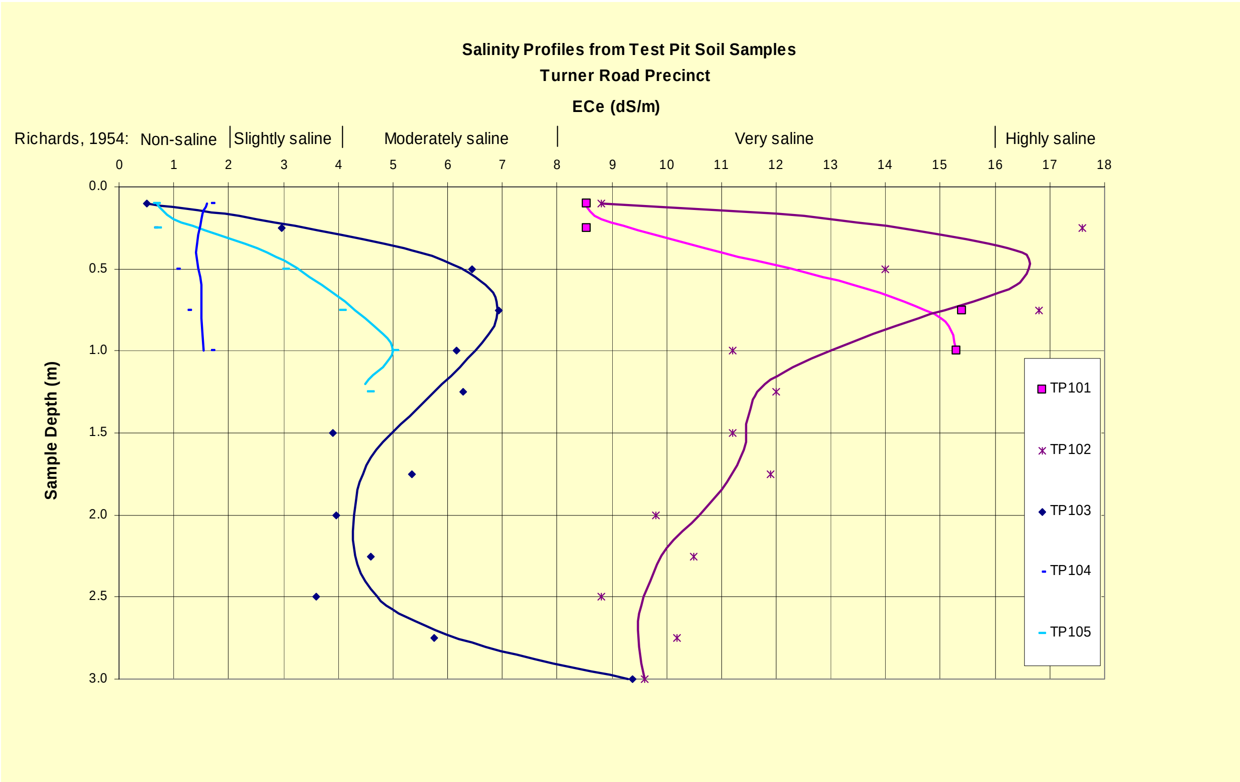
Class	ECe (dS/m)	% of Measurements
Non Saline	<2	26
Slightly Saline	2 – 4	23
Moderately Saline	4 – 8	34
Very Saline	8 – 16	15
Highly Saline	>16	2

The implication of these results, to the extent that the 145 test pit samples are representative of the study area, is that non-saline to very saline conditions can be expected throughout the study area, with only minor occurrences of highly saline conditions. These results are derived from salinity measurements in soils to depths of up to 3 m but with 74% of samples obtained at a depth of 1 m, for reasons described below.

At five test pits (selected as "control test pits" from EM profiling results to cover the full range of apparent conductivities), soil samples were taken at a depth of 0.1 m then at 0.25 m depth intervals to a maximum of 3 m or to rock level, enabling the construction of vertical soil salinity profiles (Figure 1 below).

From these profiles it is inferred that in some areas (e.g. TP 104) soils remain non-saline throughout the tested depth range. At the remaining control test pit locations, salinities generally reach maxima in the 0.5 m to 1 m depth zone, decreasing below 1 m but possibly rising again immediately above rock level. In order to assess the most saline soil horizon, follow-up test pits were sampled for salinity tests at depths of 0.5 m to 0.7 m (23 tests) and 0.9 m to 1.0 m (80 tests). In addition, salinity test results from a depth of 1 m were selected for correlation with EM results (below), since the horizon of maximum salinity (around 1 m) was inferred to have produced the bulk of the EM response.

Figure 1 – Vertical Soil Salinity Profiles



11.2 Salinity Data From Electromagnetic Measurements

On completion of EM31 profiling, field data were corrected for the measured conductivity response of the ATV and were filtered with a moving average operator to reduce the noise induced by irregular ATV motion (changes in height of the coils above the ground conductor). Details of these corrections and subsequent processing steps are presented in Appendix C.

The histogram (Figure 2) and Table 8 below show that of the 90,500 corrected and filtered apparent conductivity measurements over the study area, 92% fall in the non-saline to slightly saline classes of Chhabra (1996, Ref 8), with <8% in the moderately saline class and <1% in the very to extremely saline classes. This represents an apparent shift towards lower salinity classes by comparison with the classifications from test pit sample salinities alone (Table 7 above), as a result of the difference in classification schemes. This highlights the need for "calibration" of the conductivity data to conform with the classification scheme of Richards (1954, Ref. 9), currently accepted by authorities such as DIPNR for use in urban salinity management.

Figure 2 – Distribution of Apparent Conductivities from EM 31 Profiling

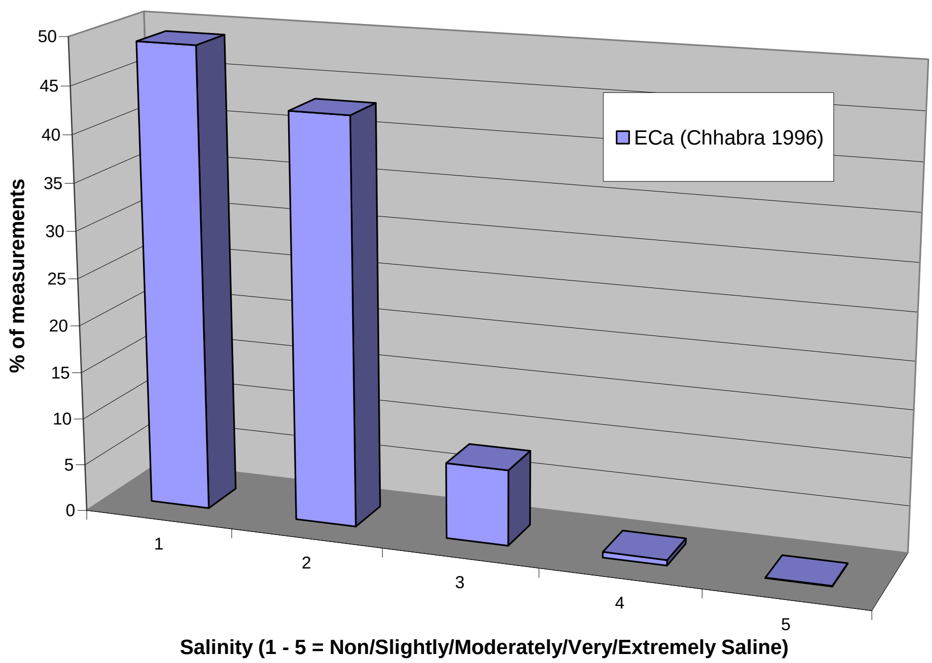
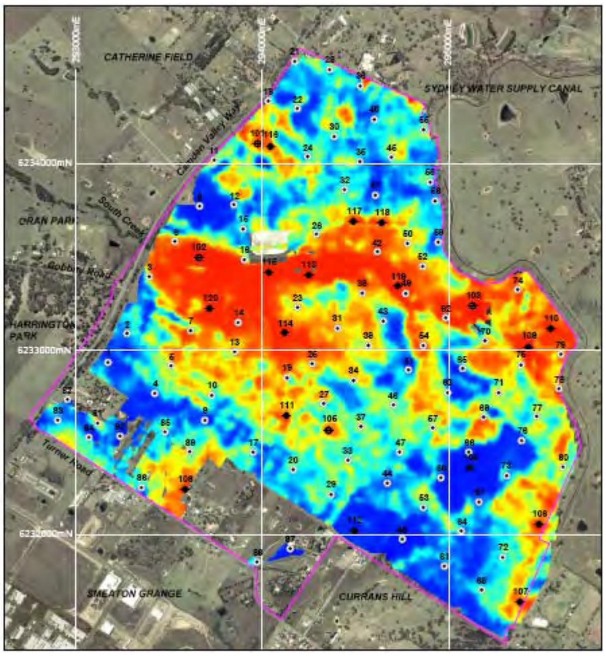


Table 8 – Distribution of Apparent Conductivities from EM 31 Profiling

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	48.7	43.0	7.5	0.6	0.05

Apparent conductivity data were added to the GIS database for interpolation onto a regular grid throughout the area surveyed. Drawing 14 (Appendix A and thumbnail image below) presents the apparent conductivity image with a continuous colour spectral scale in mS/m. Areas of most interest are those coloured bright red. Using the classifications of Chhabra (1996, Ref 8), these colours may indicate moderately saline to extremely saline ground conditions.



Apparent Conductivity (see Drawing 14, Appendix A)

To achieve a consistent classification from both test pit samples and EM profiling data, a form of calibration of the latter was carried out as described in Appendix C. A line-of-best-fit to an ECe/ECa scattergram provided a factor of 5.97 by which to multiply apparent conductivities (in dS/m) to estimate ECe values throughout the EM31 data set. The histogram (Figure 3) and Table 9 below show that of the re-scaled data points, 70% fall in the non-saline to slightly saline classes of Richards (1954, Ref. 9), 28% fall in the moderately saline class and <2% fall in the very saline to highly saline classes.

Figure 3 – Distribution of Apparent Salinities

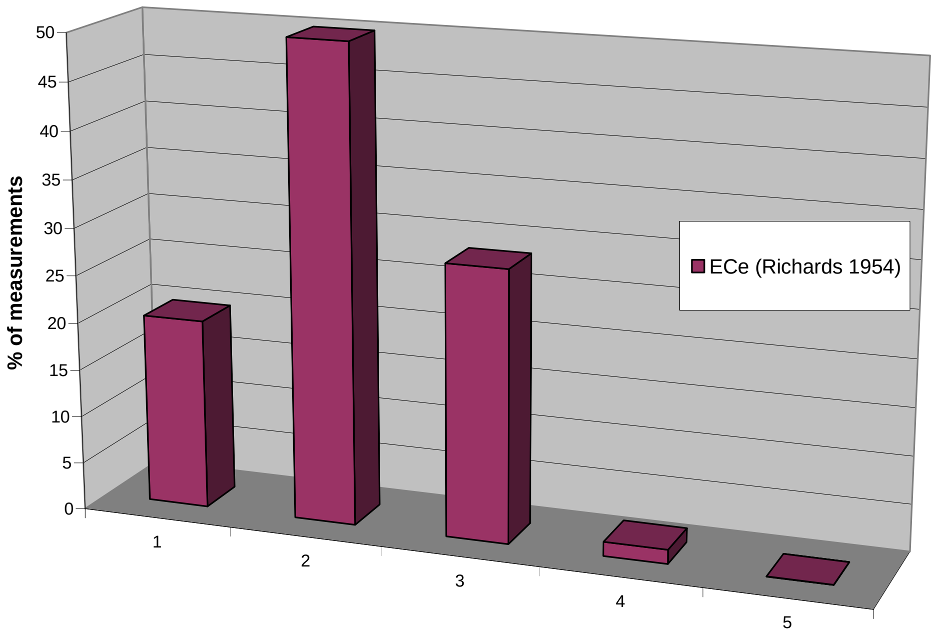


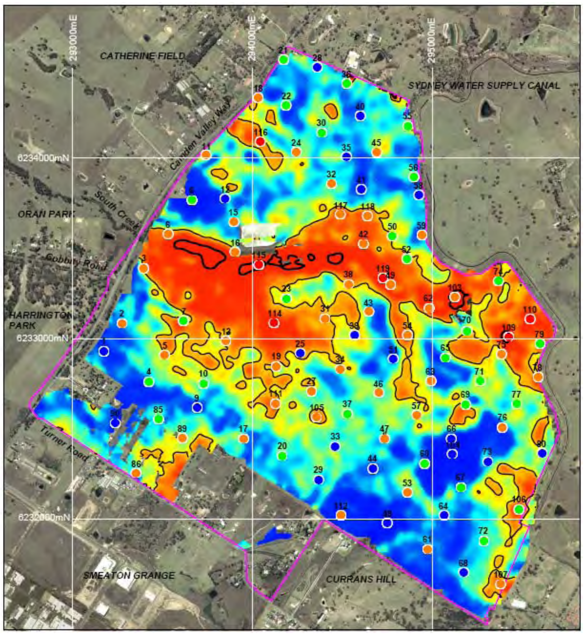
Table 9 – Distribution of Apparent Salinities

ECe Range (mS/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	20.0	50.0	28.5	1.5	0.0

The scale factor was applied to all EM data for presentation as an apparent salinity image (Drawing 15 Appendix A and thumbnail image below) with a continuous colour spectral scale in dS/m, based on the Richards classification scheme.

Contours were added to the image in Drawing 15, corresponding to the 4 dS/m and 8 dS/m boundaries of the salinity classes of Richards, providing a direct subdivision of the study area into non-saline and slightly saline classes (<4 dS/m), moderately saline class (4 – 8 dS/m) and very saline class (>8 dS/m). No highly saline areas were inferred.

Areas inferred to be moderately saline or very saline generally occur along the South Creek drainage system but extend into low lying drainage areas and around dams within the golf course north of South Creek and to some areas south of South Creek and close to Turner Road.



Apparent Salinity (see Drawing 15, Appendix A)

11. DISCUSSION

11.1 Slope Instability

Thick residual soil profiles of the Blacktown Soil Landscape can be prone to slope instability due to slumping and soil creep, particularly on steep south-facing slopes underlain by shale. The high clay content of these soils results in poor drainage, and therefore reduced cohesion during periods of high rainfall or where natural drainage has been disturbed by development. Instability due to slumping is typically associated with thick soils and slopes in excess of 11º - 20º (or greater than a 20% gradient - Ref. 5).

No evidence of deep-seated hillslope instability (landslip) has been noted within the site. Observed or inferred slope instability is restricted to surficial soil creep and possible shallow ancient slumping of residual soils developed in over-steepened gully head or steeper ridge slope locations below the mapped or interpreted un-named sandstone member within the south-eastern corner of the site (see Drawing 5). It is considered that potential soil creep or shallow slump instability impose only minor to moderate constraints (i.e. able to be addressed by good engineering practices for hillside development including site specific investigation and engineering of structures).

Other than erosion-triggered slumping of a material (probably less than 1 m^3 at any event) from the low height banks of the gullies within the site, there does not appear to be a significant risk of stream bank instability. It is considered that stream bank instability impose only minor constraints (i.e. able to be addressed by good engineering practices) on the proposed site development.

An assessment of the areas of geotechnical constraints is shown in Drawing 7.

11.2 Erosion Potential

Soils of the Blacktown Soil Landscape are typically of moderate erodibility (K values of 0.02 – 0.04). The more sodic or saline soils of the Blacktown soil landscape can have high erodibility and the erosion hazard for this landscape is estimated as moderate to very high (Ref. 1). Similarly, the erodibility of the soils of the South Creek Soil Landscape is classed as high and the erosion hazard is potentially very high to extreme. Laboratory results of soil tests indicate that the soils tested are moderately to highly susceptible to dispersion.

It is considered that the erosion hazard within the areas proposed for development would be within usually accepted limits which could be managed by good engineering and land management practices which will also be required to address flood hazard and localised waterlogging limitations of soils along the course of South Creek. These hazards are considered to impose only minor constraints to development.

It is anticipated that the treatment of the existing gullies as part of an overall site development would include:

- filling using select materials (i.e. non – dispersive or erodible) placed under controlled conditions;
- provision of temporary surface cover (e.g. pegged matting) during the period of valley floor revegetation;
- channel lining in sections of rapid change in gully floor grade;
- piping of flow where appropriate;
- the re-establishment of a zone of tree cover along gully banks.

11.3 Soil Salinity, Aggressivity and Sodicity

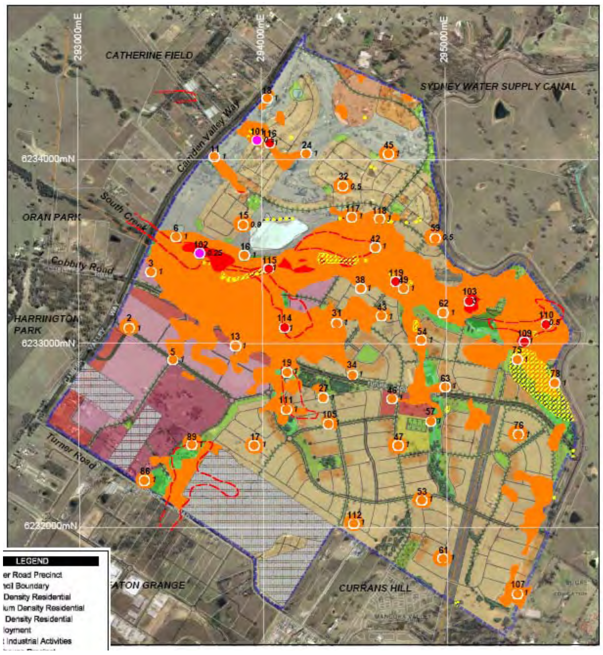
11.3.1 Assessment of Salinity Constraints

Three methods of assessment of soil salinity were employed to ground-truth the salinity potential map of DIPNR (2003, Ref. 6):

- Visible indicators of salinity mapped during a geological inspection;
- ECe estimates derived from 145 laboratory tests of soil samples from 101 test pits; and
- ECa (apparent conductivity) data obtained at 90,500 measurement stations.

No single method of assessment is sufficient due to spatial sampling and other limitations, however a joint assessment can provide a practical means of defining areas where there is a risk that urban development will be affected by soil salinity, or will adversely affect the salinity of the environment.

To better assess the constraints that saline soils may place on the proposed development, a number of mappable features were overlain on the aerial photograph of the site to produce a Salinity Constraints map (Drawing 16 Appendix A and thumbnail image below).



Salinity Constraints (see Appendix A, Drawing 16)

These features included:

- the Indicative Layout Plan (ILP) dated 7 February 2007;
- zones of "known salt" i.e. surface salt observed or inferred from airphoto interpretation (DIPNR 2003, Ref. 6);
- locations of salinity indicators observed by DP;
- locations of test pits where salinity estimates (ECe) from samples at any sample depth, exceeded 4 dS/m (i.e. moderately to highly saline soil anywhere within the soil profile);
- constraint regions based on 4 dS/m and 8 dS/m ECe contours. The ECe values (termed apparent salinities herein) were derived, as detailed in Appendix C, by correlation of apparent conductivities (ECa) from EM profiling, with ECe estimates from laboratory testing of soil samples. Correlation was carried out with samples from a depth of 1 m, since soil at this general depth was considered (from vertical salinity profiles) to be contributing most of the EM31 response.

For a conservative approach in some areas, the constraint regions were inferred to extend across minor saddles in the calculated ECe contours. Similarly, a number of test pits indicating moderate salinity (at some depth within the soil profile), lie outside the main constraint region but are shown with a "local" constraint region of unknown extent.

At this site, ground truthing has generally confirmed the salinity potential indicated by DIPNR. As indicated above (Section 11.2), the areas inferred to be moderately saline or very saline generally occur along the South Creek drainage system but extend into low lying drainage areas and around dams within the golf course north of South Creek and to some areas south of South Creek and close to Turner Road.

It is assumed that the development (represented by the ILP dated 7 February 2007) will not impact on the South Creek riparian corridor and that the very saline and highly saline soils identified in the riparian corridor will not be exposed, hence will not impact on the development. However, parts of the proposed development outside the riparian corridor may be constrained as indicated below. Where locations are given in relation to test pits, see Table 7a (Appendix J) for coordinates.

11.3.2 Possible Development Constraints due to Soil Salinity

Development may be constrained by the need to apply various levels of salinity management, as indicated below:

- Apply management strategies for highly saline soil at shallow depths (0.25 m to 0.5 m) locally around Test Pit 101 (within the northwestern low density residential area of the golf course) and at locations of salt efflorescence shown on Drawing 16;
- Apply management strategies for very saline soil at depths of the order of 1 m
  - Around Test Pit 116 (within the northwestern low density residential area of the golf course)
  - Within the golf course itself north of and close to Test Pit 102;
  - Locally within the employment area southwest of Test Pit 115; and
  - Within the low density residential zones around Test Pits 103 and 110 (either side of sports parks in the northeast of the Precinct).
- Apply management strategies for moderately saline soil at depths of the order of 1 m
  - Within several low density residential lots southeast of the golf course, on both sides of the east-west power line easement) and east of the sports park;

- Within several low density residential lots between the eastern forks of the riparian corridor and along the southeastern Precinct boundary;
- Within the Primary School and adjacent commercial/retail lots and Badgally Road ;
- Within low density and medium density residential lots and park land in the centre of the Precinct (around Test Pit 31);
- Within low density and medium density residential lots adjacent to Turner Road (south of Test Pit 89);
- Locally at a number of locations on the golf course and within the low density and medium density residential areas of the golf course;
- Locally at a number of locations within the southern low density residential area;
- Along Badgally Road west of the riparian corridor and within several adjacent commercial/retail lots and employment lots; and
- Locally within the industrial and other employment areas.

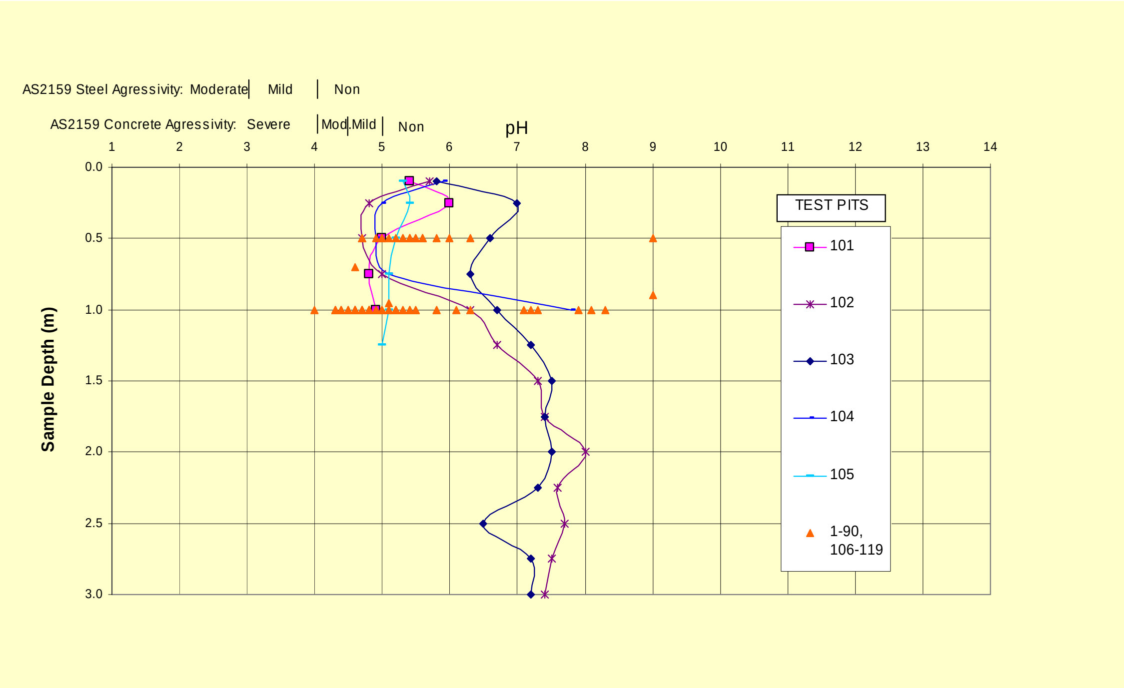
11.3.3 Assessment of Aggressivity Constraints

The aggressivity of the soil to concrete and steel was assessed primarily by measurement of the pH of 150 soil samples from 101 test pits, for classification of the soils according to the criteria of Australian Standard AS2159. Samples were taken at 0.25 m depth intervals from Test Pits 101 to 105 (control test pits) and primarily from a depth of 1 m at other test pits. From 17 of the 101 test pits, 22 soil samples were also tested for chloride and sulphate concentrations, as a complementary check on aggressivity.

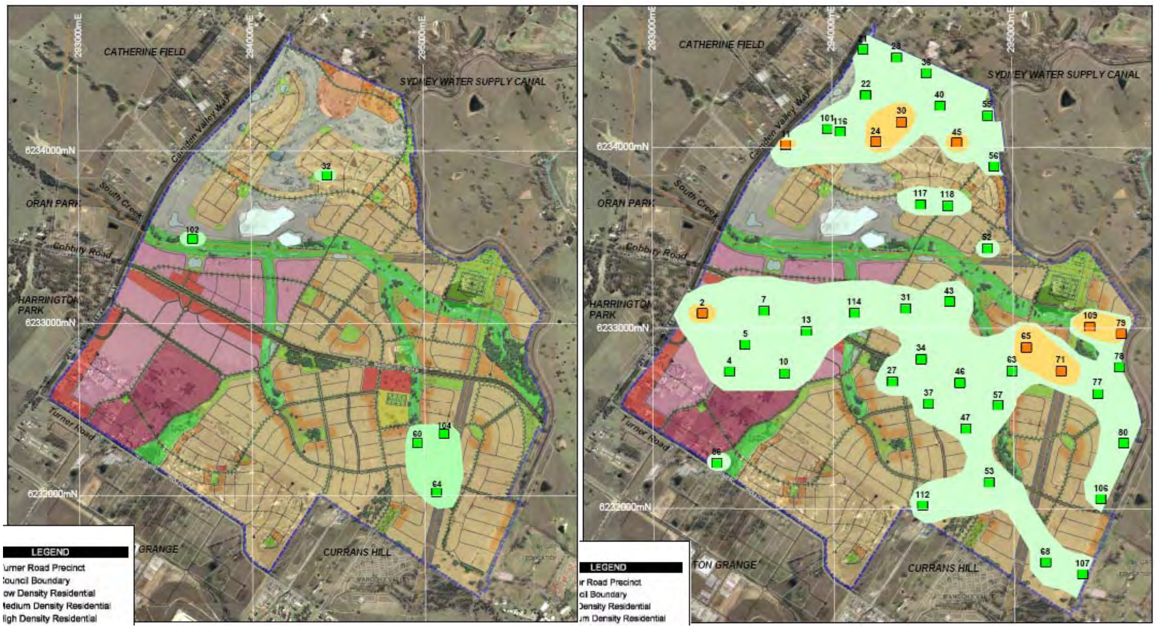
Laboratory results and classifications are presented in Table 7a (Appendix J) and indicate non-aggressivity to steel at all tested locations and depths except at Test Pit 79 (mildly aggressive at a depth of 1 m).

Aggressivity to concrete varied from non-aggressive to moderately aggressive as indicated by the pH profiles and scattergram of Figure 4, with a tendency for greatest aggressivity in the 0.25 m to 1.0 m depth range.

Figure 4 – pH Profiles



Drawings 17 and 18 (Appendix A and thumbnail images below) show the lateral distributions of aggressivity to concrete at depths of 0.5 m and 1 m respectively. Because of the number and widespread distribution of test pits from which aggressivity classifications were made, approximate boundaries of mildly aggressive and moderately aggressive zones could not be inferred, so that these drawings do not represent aggressivity constraint maps (discussed in 12.3.4 below).



L & R: Aggressivity to concrete at 0.5m and 1m depths (See Drawings 17 and 18, Appendix A)

11.3.4 Possible Development Constraints due to Soil Aggressivity

Salinity management plans should include strategies for management of the often-associated property of aggressivity to concrete. From Drawings 17 and 18, it is inferred that development may be constrained by the need to apply strategies to combat aggressivity, as indicated below:

- Apply management strategies for mild aggressivity to concrete at depths of the order of 0.5 m
  - Within several low density residential lots and the power line easement southeast of the Primary School;
  - Locally around Test Pit 102 in the low density residential area to the east of the golf course.
- Apply management strategies for moderate aggressivity to concrete at depths of the order of 1 m
  - Within sections of the golf course and low density residential areas to the east of the golf course;

  - Within the eastern part of the sports park and low density residential lots east of the sports park;
  - Within low density and medium density residential areas in the fork of the riparian corridor, south of the sports park; and
  - Locally around Test Pit 2, within employment land adjacent to Camden Valley Way and south of Badgally Road.
- Apply management strategies for mild aggressivity to concrete at depths of the order of 1 m
  - Within the northern half of the golf course, within low, medium and high density residential areas and the clubhouse in the north of the golf course and within low density residential areas east of the golf course;
  - Within broad zones south of the main riparian corridor, extending from west to east across the Precinct and into the southeastern corner, encompassing low to medium density residential areas, park land, Primary School, commercial/retail areas and part of the light industrial area.

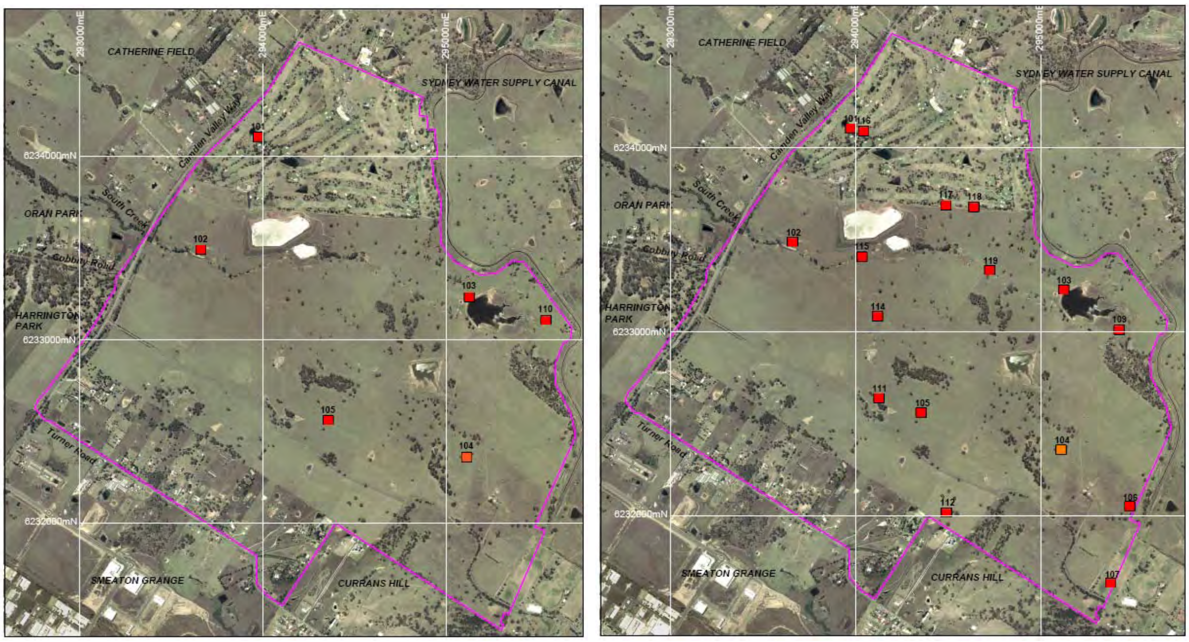
It should be noted that the soils within the lower slopes around South Creek are characterised by moderately saline to highly saline soil but are inferred to be non-aggressive to concrete, possibly due to lithological differences in the vicinity of South Creek.

11.3.5 Assessment of Sodicity Constraints

The sodicity of the soil (proportion of exchangeable sodium cations as a percentage of total exchangeable cations) can be elevated due to salt content and can affect properties such as dispersion, erodibility and permeability. Sodicity was assessed by measurement of the exchangeable sodium capacity and total cation exchange capacity of 32 soil samples from 22 test pits, for classification of the soil as non-sodic (<5% sodicity), sodic (5-15% sodicity) or highly sodic (>15% sodicity). Samples were taken from a depth of 0.5 m in 11 test pits and from a depth of 1 m in 10 of these test pits and in a further 11 test pits.

Laboratory results and classifications are presented in Table 7a (Appendix J) and indicate highly sodic conditions at both depths in all but one tested location. At Test Pit 104, sodic conditions were indicated at both depths.

Drawings 19 and 20 (Appendix A and thumbnail images below) show the lateral distributions of sodicity at depths of 0.5 m and 1 m respectively. The relatively small number and sparse distribution of test pits from which sodicity measurements were made, prevents the interpretation of detailed sodicity constraint zones. However on the basis of these measurements, it is considered likely that sodic to highly sodic conditions exist throughout the Precinct and that salinity management plans should include strategies for management of this associated property.



L & R: Sodicity at 0.5m and 1m depths (See Drawings 19 and 20, Appendix A)

11.3.6 Salinity, Aggressivity and Sodicity Management Strategies

Development must be planned to mitigate against the effects of any potential salinisation that could occur and efforts should be made to prevent or restrict changes to the water balance that will result in rises in groundwater levels, bringing more saline water closer to the ground surface.

Efforts need to be directed at all levels of the development process including site design, vegetation, landscaping, building and infrastructure construction.

The following strategies are based on the assumptions that development will proceed in general according to the ILP dated 7 February 2007 and that earthworks will in general be confined to the depths of investigation of the test pits employed for direct soil sampling and laboratory testing (i.e. up to 3 m). Zones of deeper excavation may require modifications to the management strategies, based on further sampling and testing to the maximum depth of excavation.

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.

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 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 should rural construction methods be used.
- Surface drains should generally be provided along the top of all batters 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 regrading within the development footprint, a minimum surface slope of 1V:40H is suggested in order to improve surface drainage and reduce ponding and waterlogging, which can lead to evaporation and salinisation. Consideration should also be given to regrading of natural slopes outside the development footprint within salinity risk zones, where this will improve overall drainage without creating additional erosion hazards.
- 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.
- Where a capping layer of topsoil, sandy material or crushed rock cannot be placed to reduce the potential for dispersive behaviour of the sodic to highly sodic soils, consideration should be given to mixing of gypsum into filling and placement on exposed slopes to improve soil structure and reduce the potential for scour.
- Salt tolerant grasses and trees should be considered if re-planting close to creeks 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.

Building and Infrastructure Construction

The extent of measures adopted during construction, in particular the concrete, masonry and steel requirements, should depend on the particular level of salinity or aggressivity at the actual site. In general, for the construction of buildings or infrastructure (buried services) on moderately or more saline sites, the following guidelines are suggested:

- To manage soil from specific building sites or services alignments within the moderate salinity constraint regions or moderate aggressivity constraint regions of Drawings 16 and 18 (Appendix A), use of a bedding layer of sand (say 100 mm minimum) followed by a membrane of thick plastic is recommended under concrete slabs to act as a moisture barrier and drainage layer to restrict capillary rise under the slab.

- Higher than normal strength concrete (say 32MPa) or sulphate resistant cement may need to be considered in very saline constraint regions in order to reduce the risk of reinforcement corrosion in concrete slabs. A minimum of 65 mm of concrete cover on slab reinforcement, proper compaction and curing of concrete are also suggested to produce a dense low permeability concrete.
- 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 saline or aggressive soils and reduce the potential cut and fill on site which could alter subsurface flows.
- Other measures that can be considered to improve the durability of concrete in saline environments include reducing the water to cement ratio (hence increasing strength), minimising cracks and joints in plumbing on or near the concrete, reducing turbulence of any water flowing over the concrete.
- 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 brickwork 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.
- Service connections and stormwater runoffs should be checked to avoid leaking pipes which may affect off site areas further down slope and increase groundwater recharge resulting in increases in groundwater levels.

- Within very saline constraint regions, particularly in the vicinity of Test Pit 109 in the east of the Precinct (where this is coincident with a moderately aggressive region), consideration should be given to use of higher grade (more resistant) materials in all underground service lines.

11.4 Soil Contamination Potential

11.4.1 Potential Areas of Environmental Concern

Sixty two areas were identified in the course of site history investigations as Potential Areas of Environmental Concern (PAEC) (logs in Appendix D give locations). Each PAEC was logged on a PAEC Identification & Inspection Log. These logs are included for reference in Appendix D. The logs contain detailed information regarding the investigations and analysis undertaken for the assessment. Table 9 below lists the identified PAEC which includes an "outcome" as not all nominated PAEC became AEC.

Table 9 – Identified Potential Areas of Environmental Concern

PAEC #	Description	Identified from	Inspection Type	Outcome
1	Onsite waste water treatment facility (type unknown)	Council Records	Interview / site walkover	Not AEC
2	Onsite waste water treatment facility (type unknown)	Council Records	Interview/ site walkover	Not AEC
3	Obstruction to natural watercourse using unknown filling materials	Council Records	Walkover	AEC
4	Obstruction to natural watercourse using unknown filling materials	Council Records	Linked to PAEC 3	
5	Biocycle waste water treatment system involving irrigation of land within property with the treated water	Council Records		Not AEC
6	Illegal activity – spray painting business	Council Records		AEC
7	Corrugated iron sheds (horse stables) in rusted dilapidated condition	Council Records	Site walkover	AEC
8	Use as a Truck Depot	Council records	Site walkover	AEC
9	Illegal application of septic tank effluent on ground surface	Council Records	Council records	Not AEC
10	UST (unknown fuel) and oil storage on-site	Council Records	Linked to PAEC 11	
11	Approval for chemical and machinery store room; sedimentation ponds; earthworks to form golf course	Aerials/ Property attributes	Interview / site walkover	AEC
12	St Gregory's College (agricultural college); Approval for a laundry	Property attributes	Interview / site walkover	Not AEC
13	Approval for a veterinary clinic	Property attributes	Interview / site walkover	Not AEC
14	Approval for a proposed irrigation dam and a resited building (timber/fibro)	Property attributes	Interview / site walkover	Not AEC
15	One large and one medium sized dam	Aerials	Interview / site walkover	Not AEC

16	Rural Buildings (asbestos) and possibly market gardens	Aerials	Interview / site walkover	AEC
17	Dam	Aerials	Interview / site walkover	Not AEC
18	Creek crossing and dam (fill)	Aerials	Interview / site walkover	Not AEC
19	Dam	Aerials	Interview / site walkover	Not AEC
20	Dam	Aerials	Interview / site walkover	Not AEC
21	Dam	Aerials	Interview / site walkover	Not AEC
22	Unidentified land disturbance	Aerials	Interview / site walkover	Not AEC
23	Land disturbance (College Rodeo Ground)	Aerials	Interview / site walkover	Not AEC
24	Dam	Aerials	Interview / site walkover	Not AEC
25	Unidentified disturbance (earthworks)	Aerials	Interview / site walkover	AEC
26	Dairy Building	Aerials	Walkover	AEC
27	Small scale sewage treatment plant	NSW EPA website		Not AEC
28	Above and below ground storage tanks, Marist Bros St Gregory's College	WorkCover Search	Interview / site walkover (tanks may be outside precinct boundary)	Not AEC
29	Dam	Aerials	Interview / site walkover	Not AEC
30	Dam and shed like structures. Possible market gardening	Aerials	Site walkover	AEC
31	Buildings, possibly storage for Golf Course	Aerials	Site walkover	See AEC 11
32	Dam	Aerials	Interview / site walkover	Not AEC
33	Rectangular shaped dam and shed like structures	Aerials	Site walkover	AEC
34	Dam	Aerials	Interview / site walkover	Not AEC
35	Dam	Aerials	Interview / site walkover	Not AEC
36	Dam, possibly in-filled and shed type structures	Aerials	Interview / site walkover	Not AEC
37	Dam	Aerials	Interview / site walkover	Not AEC
38	Dam	Aerials	Interview / site walkover	Not AEC
39	Dam	Aerials	Interview / site walkover	Not AEC
40	Dam, possibly in-filled, and shed like structures. Possible past use for market gardening	Aerials	Site walkover	AEC
41	Dam, possibly in-filled, and shed like structures. Possible past use for market gardening	Aerials	Site walkover	AEC
42	Dam and shed type structure	Aerials	Site walkover	AEC
43	Dam and possible past use for market gardening	Aerials	Site walkover	AEC
44	Dam – possibly associated with PAEC 43	Aerials	Interview / site walkover	Not AEC
45	Dam, possibly in-filled, and shed like structures	Aerials	Site walkover	AEC
46	Dam and shed like structures	Aerials	Site walkover	AEC
47	Dam, possibly in-filled, and possible past use for market gardening	Aerials	Site walkover	AEC
48	Dam, possible past use for market gardening	Aerials	Site walkover	AEC
49	Dam	Aerials	Interview	Not AEC
50	Possible in filled dam or ground disturbance	Aerials	Interview	Not AEC
51	Possible in filled dam or ground disturbance	Aerials	Site walkover	AEC
52	Ground disturbance	Aerials		AEC
53	Possible land use for cultivation	Aerials	Interview / site walkover	Not AEC
54	Ground disturbance	Aerials	Site walkover	Not AEC
55	Ground disturbance with road leading to it (1984 aerial composite)	Aerials	Site walkover	Not AEC
56	Filled Gully	Aerials	Walkover	AEC

57	Ground disturbance	Aerials	Site walkover	AEC
58	Possible asbestos pipe system	Interviews	Interview	AEC
59	Filled gully	Interviews	Interview	AEC
60	Filled silage pit	Interviews	Interview	AEC
61	Filled gully	Interviews	Interview	AEC
62	Filled dam	Interviews	Interview	AEC
63	Filled gully	Interviews	Interview	AEC
64	Uncontrolled backfill	Interviews	Interview	AEC

11.4.2 Areas of Environmental Concern (AEC)

The site history and inspection indicated that the site had mainly been used for agricultural recreational and rural residential purposes. Following investigation of each PAEC and on the basis of these findings, the identified areas of environmental concern (AEC) are summarised in Table 10 together with an assessment of the potential contamination associated with each AEC. The location of each of the AEC is shown on Drawing 21, Appendix A.

Table 10 – Summary of Identified Areas of Environmental Concern

AEC#	PAEC #	Description	Property	Contaminants	Level of Assessment
1	3	Unknown fill	Lot 19 DP 28024	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	Full
2	6	Illegal spray painting	Lot 27 DP 28024	Heavy metals, TRH, BTEX, VOCs	Full
3	7	Dilapidated buildings	Lot 14 DP 28042	Heavy metals, TRH, BTEX, OCP, OPP, , PAH, Asb	Full
4	8	Illegal land use	Lot 1 DP 589609	Heavy metals, TRH, BTEX, OCP, OPP, PAH,	Full
5	11, 31	Fuel and chemical storage	Camden Valley Golf Resort	Heavy metals, TRH, BTEX, OCP, OPP, PAH,	Full
6	16,64	Dairy operations and demolished dwellings	Camden Valley Golf Resort	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	Full
7	25	Unknown land disturbance	St Gregory's	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	Limited
8	26	Structure	St Gregory's	Lead paint, Asb	Hazmat
9	30	Structures and possible market garden	Lot 22 DP 28024	Heavy metals, TRH, BTEX, OCP, OPP, , PAH, Asb	Full
10	33	Fill material	Lot 5 DP 654863	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	Full
11	52	Fill material	St Gregory's Collage	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	Full
12	56	Fill material	NSW Clubs Land	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	Full
13	57	Fill material	NSW Clubs Land	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	Full
14	58	Possible asbestos pipe system	St Gregory's Collage	Asbestos	Hazardous
15	59	Fill material	St Gregory's College	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	Full

AEC#	PAEC #	Description	Property	Contaminants	Level of Assessment
16	60	Filled silage pit	St Gregory's Collage	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	Full
17	61	Fill material	St Gregory's College	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	Full
18	62	Fill material	St Gregory's College	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	Full
19	63	Fill material	Golf Course	Heavy metals, TRH, BTEX, OCP, OPP, PCB, PAH, Asb	Full
20		Asbestos Pipe System	Golfcourse	Asbestos	Hazardous

Notes:
Heavy metals = As, Cd, Cr, Cu, Pb, Hg, Ni, Zn
BTEX = Benzene, Toluene, Ethylbenzene, Xylene
OCP = Organochlorine pesticides
PCB = Polycyclic Biphenyls
TRH = Total Recoverable Hydrocarbons
PAH = Polycyclic aromatic hydrocarbons
OPP = Organophosphorus pesticides
Asb = Asbestos

Only limited access to the Turner Road properties was available during the timeframe of the assessment, several owners were either reluctant to provide access or unavailable. PAEC and subsequent AECs have been logged on the basis of site history information and inspections made from the boundary. Whilst the overall risk is deemed to be low based on the rural residential use of the site, further investigation is recommended for all sites. The additional investigation should incorporate hazardous building material assessments of all buildings and site inspections of the premises for current contaminating practices (ie fuel tanks, chemical stores). This assessment must be taken with the landowners and tenants full agreement and knowledge. The assessment should be undertaken prior to the demolition of any structures in this area.

11.5 Groundwater and Surface Water Investigation

Water was found in the main north-south running catchment incorporating the majority of Lakeside (GW1, refer Drawing 3). It appears that a significant shallow groundwater system is non-existent in the residual clay landscape. The only significant shallow groundwater system is held within the alluvial sediments at the base of the major north south running valley.

pH levels measured in groundwater and surface water samples collected were all measured as slightly alkaline of neutral and within the range of pH7 - pH8. Electrical conductivity (EC) in the groundwater was up to two orders of magnitude higher than the stored water in the nearby dams.

Chemical contaminants within water samples submitted for testing were all generally within the relevant guideline criteria the only exception being metals. Copper and zinc levels were elevated above the guideline however this is expected for waters from the western Sydney region with a dominant shale geology. In general no indication of contamination was found and the results supported the low potential findings of the contamination assessment.

11.6 Geotechnical Considerations

Development of the site, geotechnically, should be relatively straightforward with comments on site preparation, earthworks, foundations, likely lot classifications, maintenance, drainage and preliminary pavement thickness designs given in the following sections.

The investigation completed to date has also indicated localised areas that will require attention, such as removal of existing fill both on the general site and within localised gullies (refer Drawing 3) together with likely extensive stripping requirements within the existing golf course. Remedial works required for redevelopment of the existing dam located near the southern (lower) limit of the existing golf course will depend on whether or not the dam is to be retained or possibly reduced in size.

11.6.1 Site Preparation and Earthworks

Site preparation necessary for development (which would include building and road pavement construction) should allow for the removal of topsoils and other deleterious materials such as existing filling and all topsoils.

In areas that require filling, the stripped surfaces should be proof rolled in the presence of a geotechnical engineer. Any areas exhibiting significant deflections under proof rolling should be appropriately treated by over-excavation and replacement with low plasticity filling placed in near horizontal layers no thicker than 250 mm compacted thickness. Each layer should be compacted to a minimum dry density ratio of 98% relative to standard compaction with placement moisture contents maintained within 2% of standard optimum. The upper 0.5 m in areas of pavement construction should achieve a minimum dry density ratio of 100% relative to standard compaction.

All formed batters (in both cut and fill) should be constructed no steeper than 3:1 (horizontal:vertical) and appropriately vegetated to reduce the effects of erosion. The construction of toe and spoon drains is recommended as a means of controlling surface flows.

To validate site classifications, sufficient field inspections and in-situ testing of future earthworks should be undertaken in order to satisfy the requirements of a Level 1 inspection and testing service as defined in AS 3798 – 1996 (Ref. 12).

11.6.2 Site Classification

Classification of residential lots within the site should comply with the requirements of AS 2870 – 1996 *"Residential Slabs and Footings"* (Ref. 11). Based on the limited work for the current investigation, the subsurface profiles at most locations are as would be expected for Class M (moderately reactive) and Class H (highly reactive) sites. Some Class P areas may result should relatively deep uncontrolled filling be left in place (refer Pit 8) or in the event that waterlogging and saturation of the low-lying occurs (refer Section 9.1). Additional testing will be required at the appropriate time for validation purposes.

11.6.3 Footings

All footing systems for residential type structures should be designed and constructed in accordance with AS 2870 – 1996 (Ref. 11) for the appropriate classification. Whilst conventional high level footing systems would be appropriate for M or H sites, suitable foundation systems for Class P lots could include (depending on the depth of suitable founding stratum and the presence of groundwater) backhoe excavated blockdowns, pier and beam, screw piles or possibly driven timber piles and mini piles founding on the underlying stiff clays or weathered rock.

Footings for all other structures should be based on the results of specific geotechnical investigations. As a guide, preliminary design could be based on maximum allowable bearing pressures of 150 kPa for stiff to very stiff clays and 800 kPa for highly weathered rock.

11.6.4 Site Maintenance and Drainage

The developed lots should be maintained in accordance with the CSIRO publication *"Guide to Home Owners on Foundation Maintenance and Footing Performance"*, a copy of which is included in Appendix J. Whilst it must be accepted that minor cracking in most structures is inevitable, the guide describes suggested site maintenance practices aimed at minimising foundation movement to keep cracking within acceptable limits.

Adequate surface drainage should be installed and maintained at the site. All collected stormwater, groundwater and roof runoff should be discharged into the stormwater disposal system.

11.6.5 Pavements

Whilst detailed design of pavements will obviously be undertaken at the development/ construction stage, Table 11 summarises a range of pavement thickness designs. These designs are based on the procedures given in APRG – SR 21 (Ref. 13) (Aust Roads Pavement Research Group) for a range of traffic loadings and subgrade CBR (California Bearing Ratio) values and are provided to give an indication of the range of pavement thickness that can be expected. Whilst the site clays would probably have soaked CBR values of 3 – 4%, field testing and direct measurement of remoulded samples by laboratory methods will be necessary at the appropriate time.

Table 11 – Preliminary Pavement Thickness Design

Traffic Loading (ESA)	Total Pavement Thickness (mm)			
	CBR < 3%	CBR 3%	CBR 4%	CBR 5%
5×10^4	440 (590)	440	370	320
1×10^5	470 (625)	470	395	340
1×10^6	550 (700)	550	470	390

Bracketed figures in Table indicate total boxing depth, taking into account 150 mm of subgrade replacement with granular material with CBR ≥ 20%.

The pavements should be placed and compacted in layers no thicker than 150 mm with control exercised over placement moisture contents. If layer thicknesses greater than 150 mm are proposed, it may be necessary to test the top and bottom of the layer to ensure that the minimum level of compaction has been achieved through the layer.

Suggested material quality and compaction requirements are given in Table 12.

Table 12 – Materials and Compaction

Layer	Material Quality	Minimum Compaction
Wearing Course	To conform to APRG requirements	To conform to APRG requirements
Base Course	To conform to APRG requirements Soaked CBR ≥ 80%, PI ≤ 6% or Council requirements	Minimum dry density ratio of 98% Modified (AS 1289 Test 5.2.1)
Sub-base Course	To conform to APRG requirements Soaked CBR ≥ 50%, PI ≤ 12% or Council requirements	Minimum dry density ratio of 98% Modified (AS 1289 Test 5.2.1)
Subgrade		Minimum dry density ratio of 100% Standard (AS 1289 Test 5.1.1)

Where PI = plasticity index

Whilst the use of lesser quality pavement materials than that detailed in Table 12 may be feasible, some compromise in either performance and/or pavement life must be anticipated and accepted. It is also suggested that advice be sought from Council if lesser quality pavement materials are proposed.

Surface and subsoil drainage should be installed and maintained to protect the pavement and subgrade. The subsoil drains should be located at a minimum of 0.5 m depth below the excavation level. Guidelines on the arrangement of subsoil drainage are given on Page 20 of ARRB – SR41 (Ref. 14).

11.7 Soil and Water Management Plan

The main existing limitations to development of the Turner Road Precinct are considered to be the concentration of soil salinity about some creek lines, together with minor areas of gully erosion. Soil and water management is an integral part of the development process and should adopt a preventative rather than a reactive approach to the site limitations, such that the work can proceed without undue pollution of receiving streams.

Once consent is given, a detailed soil and water management plan (SWMP) developed in accordance with Reference 15 will be required and should be incorporated into the engineering design of the development methods for:

- minimising water pollution due to erosion of soils or the development of saline conditions;
- reducing or managing salinity to provide acceptable conditions for building and revegetation works;
- minimisation of soil erosion during and after construction;
- maximising the re-use of materials on site;

The following provides a conceptual SWMP with the objectives of controlling site works:

General Instructions: These conditions include methods to ensure compliance with the SWMP, specially:

- the SWMP will be read with the engineering plans and site specific instructions issued in relation to the development;
- contractors must ensure that all soil and water management works are undertaken as instructed in the specification and constructed in accordance with Reference 12;
- all subcontractors will be informed by the Superintendent of their responsibilities in minimising the potential for soil erosion and pollution of down-slope areas.

Land Disturbance: These conditions provide methods to minimise soil erosion, the exposure of potentially or known saline subsoils and direction of overland drainage into areas of potential slope instability, specifically:

- the erosion hazard will be kept as low as possible by limiting of construction area size at any one time and clearly defining the area by barrier fencing upslope and sediment fencing down slope (to be installed before the commencement of construction activities);
- access areas will be clearly defined and limited in size while being considerate of the needs of efficient work areas. All site workers will clearly recognise these boundaries;

- the prohibition of entry into areas outside physical works except for essential management works;
- restriction of work in creek lines during periods of rainfall, with programming of works in these areas to be within periods of anticipated lower rainfall;
- the programming of development road works and major excavations to minimise the time of soil exposure, and to coincide with periods of anticipated lower rainfall;
- placement of topsoils and subsoils in separate stockpiles (where required) with appropriate sediment fencing and dimensions selected to minimise the surface area of soils exposed to rainfall and hence erosion and leaching of saline materials;
- the creation of larger lots on steeper slope sections to permit the more sensitive development of the individual site;
- orientation of access roads and services to minimise the requirements of excavation and possible retaining structures;
- where excavation of filling of batters is required, the construction of these at a low as practical gradient with a maximum 3:1 (H:V) in the clay soil profiles;
- the placement of excavated soils in filled areas in the sequence of excavation (i.e. to place potentially saline or sodic subsoils below a capping of non-saline material);
- during windy conditions, large, unprotected areas will be kept moist by sprinkling with water to keep dust under control. In the event that water is not available in sufficient quantities, soil binders and/or dust retardants must be used or the surface left in a cloddy state that resists removal by wind;
- the inclusion of techniques such as spray coating or a secured protective turf overlay on cut and fill batters to minimise erosion;
- where vegetation cover is not adequate to control erosion, the improvement of soil resistance to erosion by the addition of lime and gypsum (the proportion to be determined by site specific testing);
- maintenance including watering of lands established with grass cover until an effective cover has been established. Where there has been inadequate vegetation establishment, further application of seed should be carried out. During establishment, trafficking of the treated areas should be minimised;

- the design of stormwater drainage including lined catch drains at the crest of cut slopes, stormwater pipes and dissipators as required to minimise concentrated runoff and to provide controlled discharge of the collected runoff;
- the sampling and analysis of groundwater samples from monitoring bores installed prior to construction in order to assess impacts on groundwater quality.

Pollution Control: These conditions provide measures to protect downstream areas for water-borne pollution, specifically:

- the installation of sediment fences to intercept the coarser sediment fraction as near as possible to their source;
- ensuring that stockpiles are not located within hazard areas including areas of likely high velocity flow such as waterways, paved areas and driveways;
- the installation of sediment basins down-slope of areas to be disturbed, with the design based upon a design storm event;
- the inclusion of one or more depth indicators in the floor of the sediment basins to indicate the level at which design capacity occurs and when collected sediment will be removed;
- disposal of trapped materials from sediment basins to locations where further erosion and consequent pollution to down-slope lands and waterways will not occur;
- sampling and laboratory analysis of collected waters to ensure compliance with benchmark parameters prior to discharge.
- the treatment of collected waters by gypsum and settling of flocculated particles before any discharge occurs (unless the design storm event is exceeded);
- the removal of sediment basins (where not required as part of the on-going site management) only after the lands they are protecting are stabilised.

Site Inspection and Maintenance: These conditions provide for self and external auditing of the performance of construction and pollution protection measures, together with appropriate maintenance of erosion and sedimentation structures, specifically:

- a self auditing program against an established checklist to be completed by the site manager at least weekly, immediately before site closure and immediately following rainfall events in excess of 5 mm in any one 24 hour period. The audit should include the recording of the condition of temporary sediment and water control devices, any maintenance requirements for these structures, volumes and disposal sites of material removed from sediment retention systems. A copy of the audit should be provided to the project superintendent.

- provision for periodic inspection of records and site conditions by an external, suitably qualified person, for oversight of soil and water management works. The person will be responsible for ensuring that the SWMP is being implemented correctly, repairs are being undertaken as required and modifications to the SWMP are made if and when necessary. A short written report will be provided at appropriate intervals and will confirm that the works have been carried out according to the approved plans.

11.8 Mine Subsidence

The area is not underlain by any registered mines and is not within BHP's current 30 year mining plan. That said, there are significant coal resources underlying the site that are likely to be mined at some point in the future. Such mining operations will lead to subsidence, and related damage to buildings and infrastructure. Further investigation and correspondence with the relevant authorities is recommended.

12. FURTHER INVESTIGATION

Further investigation will be required as conceptual design/planning progresses together with additional work during the construction phase. Specific investigation would include but not necessarily be limited to:

- Detailed environmental investigation (comprising subsurface sampling and laboratory testing) in the nominated areas of environmental concern (AEC), primarily in those areas which lie within the proposed "development footprint". The purpose of this work would be to quantify the level of contamination (if any) and delineate contaminated areas in order to facilitate the preparation of remediation action plans (RAP).

- Additional hazardous building material assessments should be undertaken of all buildings in the Turner Road sector and in buildings in the golfcourse that are to be demolished/renovated. A site walkover should also be undertaken at all Turner Road properties to confirm the low potential for contamination previously assessed.
- Remediation and validation monitoring of areas subject to an RAP, to render such areas appropriate for the proposed land use, from the contamination viewpoint.
- Additional investigation should be undertaken in development areas which are to be excavated deeper than 3 m or into rock at shallower depth, where direct sampling and testing of salinity has not been carried out. Salinity management strategies herein should be modified or extended following additional investigation by deep test pitting and/or drilling, sampling and testing for soil and water pH, electrical conductivity, TDS, sodicity, sulphates and chlorides.
- Installation of groundwater bores well in advance of construction and monitoring/sampling/analysis before, during and after construction, to assess changes in groundwater quality, electrical conductivity and level as a result of the development. The bores would be strategically located on a catchment basis near creek lines.
- Routine inspections and earthworks monitoring during construction.
- Detailed geotechnical investigations on a stage-by-stage basis for determination of pavement thickness designs and lot classifications.
- Further investigation into the potential for future coal mining and correspondence with the relevant authorities regarding subsidence and any foreseen restrictions on the development.

13. SUMMARY OF LAND CAPABILITY FOR SITE DEVELOPMENT

Based on the results of the assessment thus far compiled, the following summary points are noted:

- No evidence of hillslope instability was observed within the site. It is considered that hillslope and stream bank instability do not impose significant constraints on the proposed site development.
- The presence of erosive soils on site should not present significant constraints to development provided they are well managed during earthworks and site preparation stages. Gully erosion already present on site should be remediated during site works as discussed earlier in Section 11.2.
- Development will be constrained by moderately saline soils over a significant portion of the Precinct however very saline soils are generally confined to the riparian corridor of South Creek and should have minor impact on the development if the development does not impact on this corridor.
- Although mild aggressivity to concrete is widespread in the far north and central section of the Precinct, constraint regions due to moderately aggressive soils are limited in area.
- Highly sodic to sodic soils appear widespread and will require management to reduce dispersion, erosion and to improve drainage.
- Based on the extensive site history review, inspection/field mapping and groundwater, surface water and sediment investigation, the overall potential for contamination at the subject site is considered to be low.
- Twenty separate AECs were identified across the site. As the land has been proposed for development, it is recommended that field-based investigations be carried out in each of the identified AEC to confirm the suitability for the intended landuse. Appropriate scopes of work and sample quality plans should be prepared for each AEC prior to commencement of fieldwork. It is considered unlikely that any of the identified AEC will present a major constraint to development.

14. LIMITATIONS

DP's assessment is necessarily based upon the result of a site history search and site inspections that were set out in the original proposal. Neither DP, nor any other reputable consultant, can provide unqualified warranties nor does DP assume any liability for site conditions not observed, or accessible during the time of the investigations (ie areas under or within buildings, thickly wooded areas, overgrown areas). Despite all reasonable care and diligence, site characteristics may change at any time in response to variations in natural conditions, chemical reactions and other events, e.g. groundwater movement and or spillages of contaminating substances. These changes may occur subsequent to DP's investigations and assessment.

This report and associated documentation have been prepared solely for the use of the Growth Centres Commission. Any reliance assumed by third parties on this report shall be at such parties' own risk. Any ensuing liability resulting from use of the report by third parties cannot be transferred to DP.

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