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Report on
Land Capability, Salinity & Contamination Investigation
Volume 1 - Introduction

Vineyard Precinct
North West Priority Growth Area

Prepared for
Mott MacDonald Pty Ltd

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Executive Summary

1. Introduction

This report provides the results of the Land Capability, Salinity and Contamination Investigation for the Vineyard Precinct of the North West Priority Growth Area (the Precinct). The investigation has been conducted to support the current rezoning process, which is proposed to be conducted in a staged manner. The rezoning will allow for urban development, including residential and employment related development.

2. Summary of Land Capability Investigation Geotechnical Results

2.1 Geology

A review of available geology maps for the Precinct (Penrith 1:100 000 Geological Series Sheet 1) indicates that the Precinct is underlain rocks of the Wianamatta Group (Ashfield Shale, Minchinbury Sandstone and Bringelly Shale) as well as by Quaternary and Tertiary age sediments (associated with recent and ancient watercourses).

In summary, the underlying geology and lateral extent of the formations and associated soils comprise;

- Ashfield Shale (mapping unit Rwa) underlies much of the mid-slope parts of the Precinct, and this formation typically comprises shale, laminite and dark grey siltstone sometimes with a relatively deep, clay soil profile.
- the more elevated ridge line along the northern boundary area, as well as the north-western part of the Precinct are mapped as being underlain by Bringelly Shale (mapping unit Rwb). This formation typically comprises shale, carbonaceous claystone, laminite, and coal in parts.
- recent sediments (mapping unit Qal) underlie the central, lower portions of the Precinct, generally associated with Killarney Chain of Ponds, a watercourse which flows approximately from south-east to the north-west. Older Tertiary age sediments (mapping unit – Londonderry Clay Tl) are present at the north-western boundary.

The Minchinbury Sandstone separates the Ashfield and Bringelly Shale formations and is a thin, typically less than 3 m thick, persistent quartz-lithic sandstone.

2.2 Soil Associations

The Soil Landscape map (Penrith 1:100 000 Sheet) indicates that the Precinct includes three soil landscape groups which include the Blacktown, Berkshire Park and South Creek groups.

The South Creek (sc) group occupies the lower flood plains, valley flats and drainage depressions. The soils are fluvial, often very deep layered sediments overlying residual/relict soils or bedrock. The topography is typically flat to gently sloping (slopes of <5%) with the soils comprising brown, red and yellow brown, clays, silty and sandy clays. These soils are typically of low fertility, highly erodible, with some stream bank and gully erosion, and are moderately reactive in some areas.

The Blacktown (bt) soil group is a residual soil landscape which characterises the mid-slope topography formed on the Wianamatta Group shales. These areas, including the northern part of the Precinct, have local relief to 30 m and slopes usually less than 5%, but up to 10%. There are rounded crests and ridges with gently inclined slopes. The mapping indicates multiple soil horizons that range from shallow red-brown podzolic soils comprising mostly clayey soils on crests and upper slopes, with deep brown to yellow clay soils on mid to lower slopes and in areas of poor drainage. These soils are typically of low fertility, are moderately to highly reactive, highly plastic and generally have a low wet strength.

The north-western part of the Precinct is mapped as being the Berkshire Park (bp) group which is typically characterised by gently undulating, low rises with clay and sandy clay soils, often mottled with ironstone nodules. The soils may be subject to gully, rill and sheet erosion and where drainage is poor, waterlogging, impermeable subsoils and low fertility.

2.3 Fieldwork Results

Subsurface conditions encountered during the geotechnical investigation confirmed the presence of the mapped soil types and rock formations.

The boreholes (Bores 1 to 5), drilled using a geotechnical drilling rig for the installation of groundwater monitoring wells, generally on the lower creek line parts of the Precinct, typically encountered clays and sandy clays with some ironstone gravel to the full depth of investigation (6 m).

The remaining bores and test pits typically encountered stiff to hard residual clays and silty clays (away from the creek lines) grading into weathered bedrock of shale and siltstone at depths ranging from 0.5 m to about 2.5 m. The soil depths were greater towards the creek lines where alluvial sediments were present and in some mid-slope areas, particularly overlying the Ashfield Shale.

Groundwater was encountered in the deeper bores (Bores 1 to 5) at about 4 m to 5.5 m depth with subsequent monitoring indicating water levels between 0.8 m and 2.2 m below surface level (on 10/4/2014).

The shallower push tube bores generally did not encounter groundwater, although seepage was noted at some locations. The test pits did not encounter any groundwater and were backfilled on completion, which precluded long term monitoring of groundwater levels.

2.4 Geotechnical Laboratory Results

Geotechnical laboratory test results undertaken on soil samples collected from the Precinct indicated conditions as typically anticipated for the mapped and encountered geology and soil types.

In summary, the soils were generally found to be/have;

- medium to high plasticity (with moderate linear shrinkage),
- medium and high reactivity (i.e. medium and high potential for soil volume change due to variation and seasonal changes of soil moisture content);

- moderate (and one low) CBR values (4%, 9% and 2%);
- a predisposition to erosion in some areas;
- sodic to highly sodic;
- predominantly non-saline to slightly saline, becoming moderately saline in places; and
- predominantly non-aggressive to concrete and steel, becoming mildly aggressive to concrete in places.

2.5 Geotechnical Issues and Constraints

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

- No evidence of significant hillside/slope instability was observed within the Precinct. There were a number of examples of minor creek bank collapse/erosion in the lower areas of the Precinct, however, it is considered that such instability does not impose significant constraints on the proposed site development under the current Masterplan.
- 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. Minor sheet and rill erosion was observed with some gully erosion towards the lower creek line, generally in line with the soil dispersion results (Emerson Class Number);
- Highly sodic and sodic soils appear widespread and will require management to reduce dispersion, erosion and to improve drainage;
- Some mild aggressivity to concrete was indicated by the test results, however the indicated aggressivity levels are considered manageable, subject to appropriate design and construction considerations;
- With respect to residential foundation design (to AS 2870 – 2011 "Residential Slabs and Footings") the undisturbed subsurface profiles at most locations are typical of Class M (moderately reactive) and Class H (highly reactive) sites. Further delineation between Class H1 and Class H2 sites would need to be made for any subsequent construction certificate issue or prior to linen release. It is noted that disturbed ground, such as existing dam walls, including where existing filling is present (such as on the north-eastern side of the northern end of Windsor Road and adjoining Old Hawkesbury Road), would warrant an alternative classification of Class P (Problem site).
- CBR values indicate that appropriate assessment, design and road construction methods will be required as some poor quality materials and subgrades are present.

3. Summary of Salinity Investigation Results

Disturbed and undisturbed samples of filling, soil and weathered rock were obtained by excavation of test pits and using a hydraulic push tube, to depths of investigation of 3 m or prior refusal. Locations were selected for reasonably representative sampling of the primary geological units and landforms, although the lower slopes were more closely sampled than ridge areas due to the typically higher risks of salinity and aggressivity in these areas. Samples were taken at/near surface and at 0.5 m depth intervals to termination or refusal depth and an initial batch of samples, from locations reaching the greatest depths, were tested in a NATA-accredited laboratory for salinity and related parameters.

Vertical soil salinity profiles and vertical soil aggressivity profiles were constructed from the test results from the initial batch in order to determine if a particular depth zone or zones presented a more significant salinity-related risk to proposed land use or structures. Elevated salinities and aggressivities were indicated in the 1.0 m to 1.5 m depth zone, resulting in testing of a second batch of samples taken predominantly from this zone.

All salinity-related laboratory results are presented in the Summary Table (attached) and these results were analysed in two depth zones by calculation of Bulk pH values and Bulk Electrical Conductivity values (ECe) in two depth zones defined as the:

- Foundation Zone (0 – 1.5 m below ground level (bgl)); and the
- Piling Zone (0 – 3 m bgl).

Drawings S5 to S8 present interpolated and contoured pH and ECe values for these depth zones, highlighting those areas classified as mildly aggressive to concrete and moderately to very saline, where management methods will need to be applied during bulk earthworks and construction. These classifications will require refinement by further sampling and testing to cover areas presently untested due to access restrictions or restrictions due to underground services and when cut/fill designs are available to confirm the likely depths of impact of the development.

4. Summary of Contamination Investigation Results

4.1 Land Uses

The contamination investigation identified that:

- The majority of the Vineyard Precinct is currently used for rural residential purposes, including low intensity agriculture and minor commercial activities;
- Other land uses include market gardens, poultry sheds, low and medium to high-risk commercial, including a disused service station;
- Historical land uses have generally been residential and agricultural, including market gardens, orchards and poultry production.

Drawings **C1 to C5, Appendix A** provide a visual representation of current and historical land use types.

4.2 Field and Laboratory Results

4.2.1 Observations of Environmental Concern

Land uses which can be indicative of contamination are summarised in Section 4.1.

Potential issues of environmental concern not related to specific land uses generally include:

- Filling with soil of unknown origin, which could potentially include contaminants. Extensive filling was observed in a number of locations in the Precinct, particularly along sections of the Killarney Chain of Ponds and its tributaries. Drawing C6 shows some of the areas considered to have an elevated risk of being impacted by extensive filling.

  Filling is also present at the Precinct in dam walls, however, this usually comprises local cut-and-fill with a lower potential for contamination.

  Filling is also likely to be present along some local drainage lines, and where cut and fill has occurred in localised areas.
- Asbestos. Asbestos cement from the demolition or degradation of buildings is likely to be present on some properties within the Precinct. No obvious signs of asbestos cement were observed at the ground surface but may be present in unobserved areas.
- Migration of contamination from other sites. Two active service stations are present immediately up-gradient of the Precinct across Windsor Road (shaded red on Drawing C5). These service stations could potentially impact properties within the Precinct through migration of contaminants through surface water run-off and groundwater.

4.2.2 Soil Results

Selected soil samples were tested for a variety of heavy metals and metals to provide data on background levels of metals in soils in the Precinct for use in future assessments.

Preliminary environmental investigation levels have been calculated for selected metals in accordance with NEPC (2013)[1] and these are suitable for initial screening for future investigations.

4.2.3 Groundwater Results

Groundwater samples were recovered from the five groundwater monitoring wells (Wells 1 to 5) installed in Bores 1 to 5. All groundwater analyte concentrations were within the investigation levels[2] with the exception of manganese. This is, however, considered to be naturally occurring and not to present a limitation on residential rezoning or development.

Low concentrations of the organochlorine pesticide dieldrin were detected in three samples, however the two most down-gradient wells did not have detectable concentrations of dieldrin. These results were within the investigation level, but are indicative of the use and presence of dieldrin in the groundwater catchment. The highest result was recorded in Well 5, located at the up-gradient site boundary, indicating a potential off-site source. The other two detectable results came from the next two wells down-gradient from Well 5 (Wells 3 and 4). Well 4 is located relatively close and down-stream of market gardens, and Well 3 is in immediate proximity to market gardens.

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[1] National Environment Protection Council (NEPC) *National Environment Protection (Assessment of Site Contamination) Measure 1999* (as amended 2013)

[2] Australian and New Zealand Environment and Conservation Council (ANZECC) / Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000). 95% Level or Protection thresholds for freshwater

4.3 Overall Risks and Constraints from Contamination

The risk of contamination over the Precinct is generally considered to be low to moderate, although more elevated risk is associated with some commercial properties (i.e. sites where DSI is recommended, refer to Drawing C7). The main constraints for residential redevelopment of the Precinct from contamination issues are expected to be additional costs and time associated with the development process. With the exception of the property discussed below these risks are not considered to be significant enough to prevent rezoning or redevelopment of the Precinct for residential purposes.

The potential for contamination at the following property is considered to present a significant potential constraint for residential redevelopment:

- The disused service station located at 405-419 Windsor Road (shown on Drawing C8).

  Observations of the area of the former service station indicated that the former underground petroleum storage systems (UPSS) and bowsers were still present. An oily sheen was observed at the ground surface during an inspection during rainfall. General observations of the service station and the remainder of the property (much of which had been extensively filled) indicated that previous management practices at the service station were unlikely to have met current standards. Contaminants of concern include petroleum compounds, lead, chlorinated solvents, polycyclic aromatic hydrocarbons and the pH of the medium. Other contaminants which may be present, particularly given the extensive filling at the site include heavy metals, asbestos, phenols, pesticides, polychlorinated biphenyls.

  It is recommended that a Detailed Site Investigation be undertaken for this site, and that the contaminated land assessment and management process be subject to a Site Audit.

  The potential for contamination at and down-gradient of the disused service station may constrain residential development in the short to medium term (several years or more), particularly if significant groundwater contamination is present.

4.4 Recommendations for Minimum Investigation

Drawing C7 provides a visual representation of the recommended categories for further contamination investigation to be undertaken on each property prior to redevelopment. The minimum initial investigation scope for each category is detailed below. Additional investigation and/ or remediation and/ or management are expected to be required for some properties depending on the recommendations of the initial investigation, or to meet Council specific requirements.

Category 1 – Site Inspection

- Detailed site inspection for signs of concern;
- Hazardous Building Materials Survey of any buildings built during or before 2003;
- Implementation of the recommendations from the above; and
- Unexpected Finds Protocol (see below).

Category 2 – Preliminary Site Investigation (PSI)

- PSI, including a detailed review of site history;
- Hazardous Building Materials Survey of any buildings built during or before 2003;
- Implementation of the recommendations from the above; and
- Unexpected Finds Protocol (see below).

Category 3 – PSI with Limited Sampling

- PSI with limited sampling aimed at targeting any areas of potential chemical use and filling;
- Hazardous Building Materials Survey of any buildings built during or before 2003;
- Implementation of the recommendations from the above; and
- Unexpected Finds Protocol (see below).

Category 4 – Detailed Site Investigation (DSI)

- Preliminary and Detailed Site Investigation, including detailed site history review, and intrusive sampling, analysis and reporting in accordance with NSW EPA guidelines;
- Hazardous Building Materials Survey of any buildings built during or before 2003;
- Implementation of the recommendations from the above; and
- Unexpected Finds Protocol (see below).

Category 5 – DSI and Site Audit

- Preliminary and Detailed Site Investigation, including detailed site history review, and intrusive sampling, analysis and reporting in accordance with NSW EPA guidelines;
- Contaminated Land Site Audit by a NSW EPA accredited Site Auditor;
- Hazardous Building Materials Survey of any buildings built during or before 2003;
- Implementation of the recommendations from the above; and
- Unexpected Finds Protocol (see below).

An Unexpected Finds Protocol should be included in all site management plans for redevelopment works setting out the steps to be taken to ensure that any signs of potential environmental concern are appropriately identified and managed.

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Appendix G: CSIRO Guide to Home Owners on Foundation Maintenance and Footing Performance

AGS, Australian Geoguides LR1 to LR9

Volume 1 – Methodology and Field Results
Report on Land Capability, Salinity and Contamination Investigation
Vineyard Precinct, North West Priority Growth Area

1. Introduction

This report provides the results of the Land Capability, Salinity and Contamination Investigation for the Vineyard Precinct of the North West Priority Growth Area (the Precinct). The investigation has been conducted to support the current rezoning process. The rezoning will allow for urban development, including residential and employment related development. Full reporting is currently underway and will be provided in due course.

Details of the work undertaken and the results obtained are presented in this report, which is provided in three volumes, as follows:

- Volume 1 – Executive Summary, Background, Methodology and Fieldwork Results
- Volume 2 – Geotechnical and Salinity Results, Recommendations and Preliminary Soil, Water and Salinity Management Plans
- Volume 3 – Contamination Investigation Results and Recommendations

2. Study Area

The Vineyard Precinct:

- Is located at the northern end of the North West Priority Growth Area, wholly within the Hawkesbury Local Government Area (LGA);
- Comprises 590 ha in total and lies north west in orientation; it is located south of the Hawkesbury River and directly either side of Windsor Road and is immediately surrounded by Riverstone to the south, Box Hill to the south east and Riverstone West to the west. Beyond these precincts lie Marsden Park and Marden Park North to the south west, Alex Avenue to the south and Mulgrave to the direct north. The Vineyard Precinct location is shown in Figure 1.1; and
- Is currently zoned General Rural under the Hawkesbury Local Environmental Plan 1988.

The Vineyard Precinct includes part of the suburbs of Vineyard and Oakville. The land is subdivided into approximately 300 lots held by a variety of owners.

The Vineyard Precinct is located in the Hawkesbury Local Government Area (LGA) and is bounded by Commercial Road to the north, Boundary Road to the east and Windsor Road to the south.

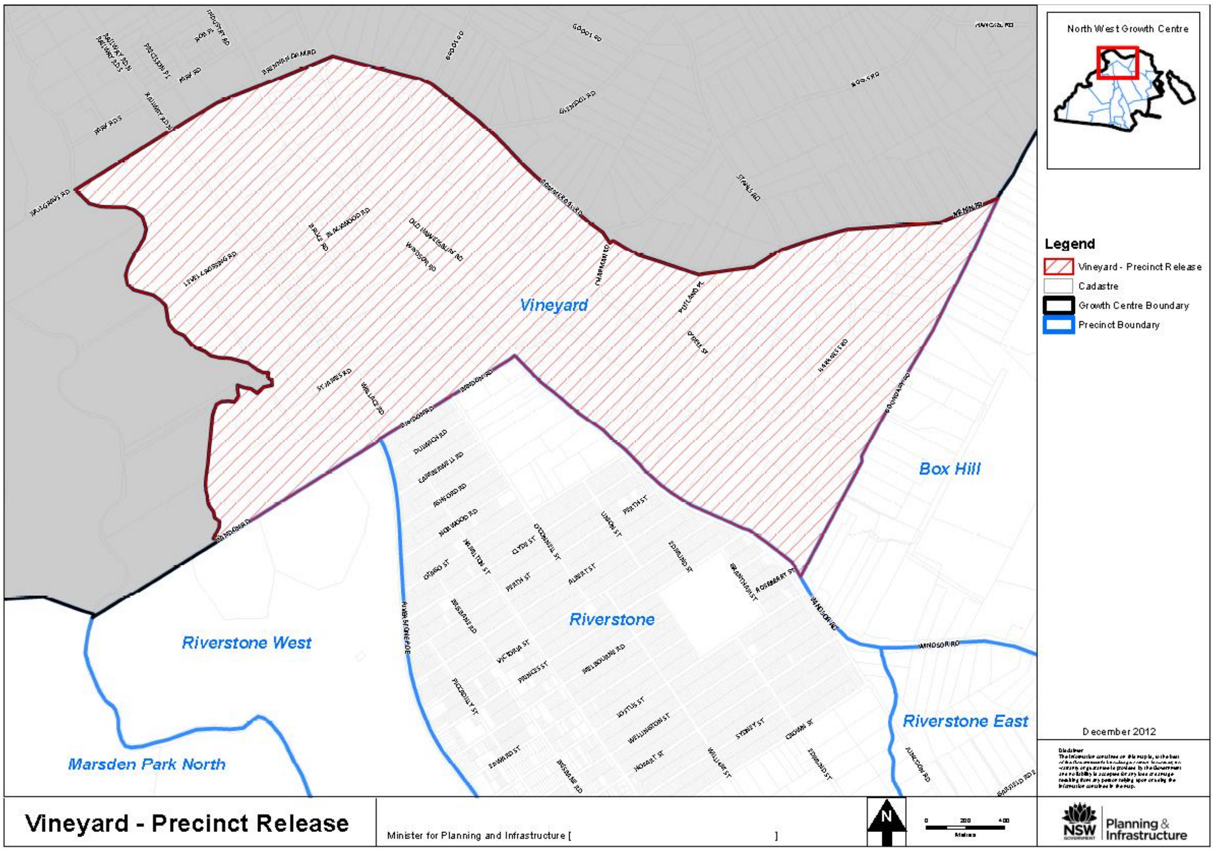

Figure 1.1 – Location

3. Proposed Development

This investigation is for the proposed future rezoning of the entire Vineyard Precinct for residential and ancillary land-uses.

Initially only Stage 1 of the Vineyard Precinct (refer to drawing in Volume 4) is proposed to be rezoned and is estimated by the NSW Department of Planning and Environment to accommodate up to 2,400 dwellings for 7,400 residents.

The rezoning timing for the remainder of the Precinct is expected to align with the future delivery of water, sewer and electricity services.

4. Scope of Works

The scope of works was as follows:

- Review of regional mapping for topography, geology and soils;
- Review of groundwater bores registered with the NSW Office of Water;

- Review of Council mapping for zoning;
- A search through the NSW EPA published records under the *Contaminated Land Management Act* (1997) and Protection of the Environment Operations Act (1997);
- Review of sites listed as potentially impacted by unexploded ordinance;
- A review of historical aerial photography for the area available through the Land Information Section of the Department of Planning (from years 1947, 1961, 1970, 1982, 1991, 2002, 2014). Digitised and geo-referencing the photography to allow preparation of drawings and extraction of geographic co-ordinates;
- Discussions with Council personnel, local residents and land owners (where possible) regarding local current and historical land use including of any large commercial operations and other information relevant to contamination potential (e.g. filling, spills, pesticide use, creek re-alignments);
- Research in the local studies sections of the Council libraries regarding history of the area and current and historic land use as necessary to follow up on other sources of information;
- Field mapping by an experienced environmental scientist and geologist based on drive over/ walkover of accessible areas;
- Drilling of 30 boreholes using push tube or auger methods. Logging of observed subsurface conditions and collection of soil samples at regular intervals. Preparation of logs of each sample location;
- Extending five of the test boreholes using auger methods to depths of approximately 6 m, and construction of groundwater piezometers (groundwater monitoring wells) in each bore;
- Excavation of six test pits using a backhoe. Logging of observed subsurface conditions and collection of soil samples at regular intervals. Preparation of logs of each sample location;
- Conducting Dynamic Cone Penetrometer (DCP) test at selected borehole location;
- Analysis of samples at a NATA accredited laboratory for:
  - soil texture (57 tests);
  - Electrical conductivity (EC1:5, 57 tests);
  - pH (57 tests);
  - Exchangeable sodium potential (ESP, 13 tests);
  - Emerson Crumb Number (ECN - dispersibility, 6 tests);
  - Chlorides and sulphates (10 tests);
  - Moisture content, plasticity, linear shrinkage (6 tests);
  - Californian Bearing Ratio (3 tests);
  - Shrink-swell Index (3 tests);
  - Metals (17 total metals including priority heavy metals As, Cd, Cr, Cu, Pb, Hg, Ni, Zn and Fe, Mn, B, Ba, Be, Co, Mo, Se, Sn) (10 tests);
  - Cation Exchange Capacity (CEC) (13 tests);
- Development of groundwater monitoring wells by removal of 3 well volumes of water (or until dry).
- Undertake groundwater sampling approximately one week after the installation of groundwater monitoring wells. Record field measurements (including pH, EC, dissolved oxygen, REDOX);
- Field measurements of EC and pH from surface water at various accessible locations;

- Analyse of groundwater samples at a NATA accredited laboratory for:
  - Metals (17 total metals including priority heavy metals As, Cd, Cr, Cu, Pb, Hg, Ni, Zn and Fe, Mn, B, Ba, Be, Co, Mo, Se, Sn); (5 samples);
  - Total recoverable hydrocarbons (TRH) (5 samples);
  - Monocyclic Aromatic Hydrocarbons (Benzene, Toluene, Ethyl benzene and Xylene – BTEX) (5 samples);
  - Organochlorine and organophosphorous pesticides (OCP and OPP) (trace level, 5 samples);
  - Hardness (5 samples);
  - Polycyclic aromatic hydrocarbons (PAH) (5 samples);
  - Polychlorinated biphenyls (PCB) (trace level, 1 sample); and
  - Volatile organic compounds (VOC) (1 sample).
- Calculation of ECe from soil texture and EC values;
- Calculation of preliminary EILs from heavy metal, EC, pH and clay content values;
- Plotting the results as vertical soil salinity and pH profiles versus depth. Based on these results the most saline and aggressive horizon or depth zone will be identified;
- Assessment of the above to identify AECs and previous land uses. An assessment of each land parcel using a risk approach with respect to its contamination potential, and provision of comments regarding the need for further investigation and any potential limitations for the proposed rezoning or landuse;
- Provision of a salinity, aggressivity and contamination hazard maps;
- Provision of a preliminary salinity management plan;
- Provision of comments on objectives and criteria for controlling erosion and sedimentation; and
- Provision of this report.

5. Regional Topography, Geology, Soils and Water

5.1 Topography and Surface Water

The Precinct topography is characterised by ridges and valleys. Two north west-south east aligned ridges are present, located generally in alignment with the railway line and Commercial Road. In between these two ridges is a valley associated with the Killarney Chain of Ponds draining to the north west to the Hawkesbury River. The south western areas of the Precinct slope downwards to the south west into a valley associated with the (off-site) Eastern Creek, which also flows into the Hawkesbury River.

Various smaller local drainage line and depressions are present draining into the two main local water courses mentioned above. Both of these water courses are prone to flooding.

5.2 Geology

A review of available geology maps for the Precinct (Penrith 1:100 000 Geological Series Sheet 1) indicates that the Precinct is underlain rocks of the Wianamatta Group (Ashfield Shale, Minchinbury Sandstone and Bringelly Shale) as well as by Quaternary and Tertiary age sediments (associated with recent and ancient watercourses respectively).

The approximate geological boundaries, as shown on the geology map are shown on Drawing G1, Appendix A.

In summary, the underlying geology and lateral extent of the formations and associated soils comprise;

- Ashfield Shale (mapping unit Rwa) underlies much of the mid-slope parts of the Precinct, and this formation typically comprises shale, laminite and dark grey siltstone sometimes with a relatively deep, clay soil profile.
- the more elevated ridge line along the north eastern boundary area, as well as the western part of the Precinct are mapped as being underlain by Bringelly Shale (mapping unit Rwb). This formation typically comprises shale, carbonaceous claystone, laminite, and coal in parts.
- recent sediments (mapping unit Qal) underlie the central, lower portions of the Precinct, generally associated with Killarney Chain of Ponds, a watercourse which flows approximately from south east to the north west.
- older sediments (mapping unit – Londonderry Clay Tl) are present at the north-western boundary.

The Minchinbury Sandstone separates the Ashfield and Bringelly Shale formations and is a thin (typically less than 3 m thick) persistent quartz-lithic sandstone.

5.3 Soil Landscapes

Reference to the Soil Landscapes of Penrith 1:100 000 Sheet indicates that the site includes three soil landscape groups which include the Blacktown, Berkshire Park and South Creek groups. The approximate soil landscape boundaries, as shown on the soil landscape maps, are shown on Drawing G2, Appendix A.

The South Creek (sc) group occupies the lower flood plains, valley flats and drainage depressions. The soils are fluvial, often very deep layered sediments overlying residual/relict soils or bedrock. The topography is typically flat to gently sloping (slopes of <5%) with the soils comprising brown, red and yellow brown, clays, silty and sandy clays. These soils are typically of low fertility, highly erodible, with some stream bank and gully erosion, and are moderately reactive in some areas.

The Blacktown (bt) soil group is a residual soil landscape which characterises the mid-slope topography formed on the Wianamatta Group shales. These areas, including the northern part of the Precinct, have local relief to 30 m and slopes usually less than 5%, but up to 10%. There are rounded crests and ridges with gently inclined slopes. The mapping indicates multiple soil horizons that range from shallow red-brown podzolic soils comprising mostly clayey soils on crests and upper slopes, with deep brown to yellow clay soils on mid to lower slopes and in areas of poor drainage. These soils are typically of low fertility, are moderately to highly reactive, highly plastic and generally have a low wet strength.

The north-western part of the Precinct is mapped as being the Berkshire Park (bp) group which is typically characterised by gently undulating, low rises with clay and sandy clay soils, often mottled with ironstone nodules. The soils may be subject to gully, rill and sheet erosion and where drainage is poor, waterlogging, impermeable subsoils and low fertility.

5.4 Salinity

Reference to the Map of Salinity Potential in Western Sydney, indicates that the Site is predominantly located in an area of *"Moderate salinity potential"* where *"saline areas may occur .... which have not yet been identified or may occur if risk factors change adversely"*. Soils along the Killarney Chain of Ponds and some associated drainage lines are in an area of *"High salinity potential"* where *"conditions are similar to areas of known salinity"*. These classifications are based on the landform and geology and it is noted that due to the resolution at the scale of the mapping, it is not possible to delineate the zone boundaries with precision.

Several references[3] describe some general features of the hydrogeology of western Sydney which are relevant to areas of the site which are underlain by shale. 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. Seasonal groundwater level changes of 1.0 m to 2.0 m can occur in a shallow regolith aquifer or a deeper shale aquifer due to natural influences.

The unweathered shale rock unit is effectively impermeable and the few bores drilled into the unweathered shales in the Sydney area are generally dry or yielding small flows of saline groundwater, typically with total dissolved salts (TDS) contents of 10,000 mg/L to 30,000 mg/L[4,5].

5.5 Hydrogeology and Groundwater Bore Database

Groundwater in the Precinct is expected to flow generally to the north, towards the Hawkesbury River and to include a shallow aquifer in the quaternary sediments with a deeper regional aquifer present in the underlying bedrock.

The NSW Government website NR Atlas was reviewed with respect to groundwater vulnerability and groundwater bores registered with the NSW Office of Water (NOW).

The mapping shows (Figure 1.2, below) that in general the groundwater aquifer is highly vulnerable near the creek lines, and of low vulnerability away from creek lines. The vulnerability level indicates the level of risk of aquifers to contamination and relates to physical characteristics of the location, such as the depth to the water table and soil type. The mapping indicates that groundwater in the sediments along the creek lines in the Precinct has an elevated level of risk to impact from potentially contaminating activities.

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[3] Including McNally, G. 2005. *Investigation of urban salinity – case studies from western Sydney*. UrbanSalt 2005 Conference Paper, Parramatta

[4] McNally, G.H. (2004) *Shale, salinity and groundwater in western Sydney*. Australian Geomechanics 39(3), September 2004, p109-123.

[5] Old, A.N. (1942) *The Wianamatta Shale waters of the Sydney district*. NSW Agricultural Gazette, May 1942, p215-221.

A number of groundwater bores are registered in and near the Precinct as shown on Figure 1.3, below. Many of the bores did not information available regarding their use or construction. Of the bores with information, uses included irrigation, domestic stock and monitoring bores. The reviewed bores included shallower bores (less than 15 m depth) and deeper bores (greater than 100 m depth).

These results indicate that groundwater is used as a resource in the region, including within the Precinct.

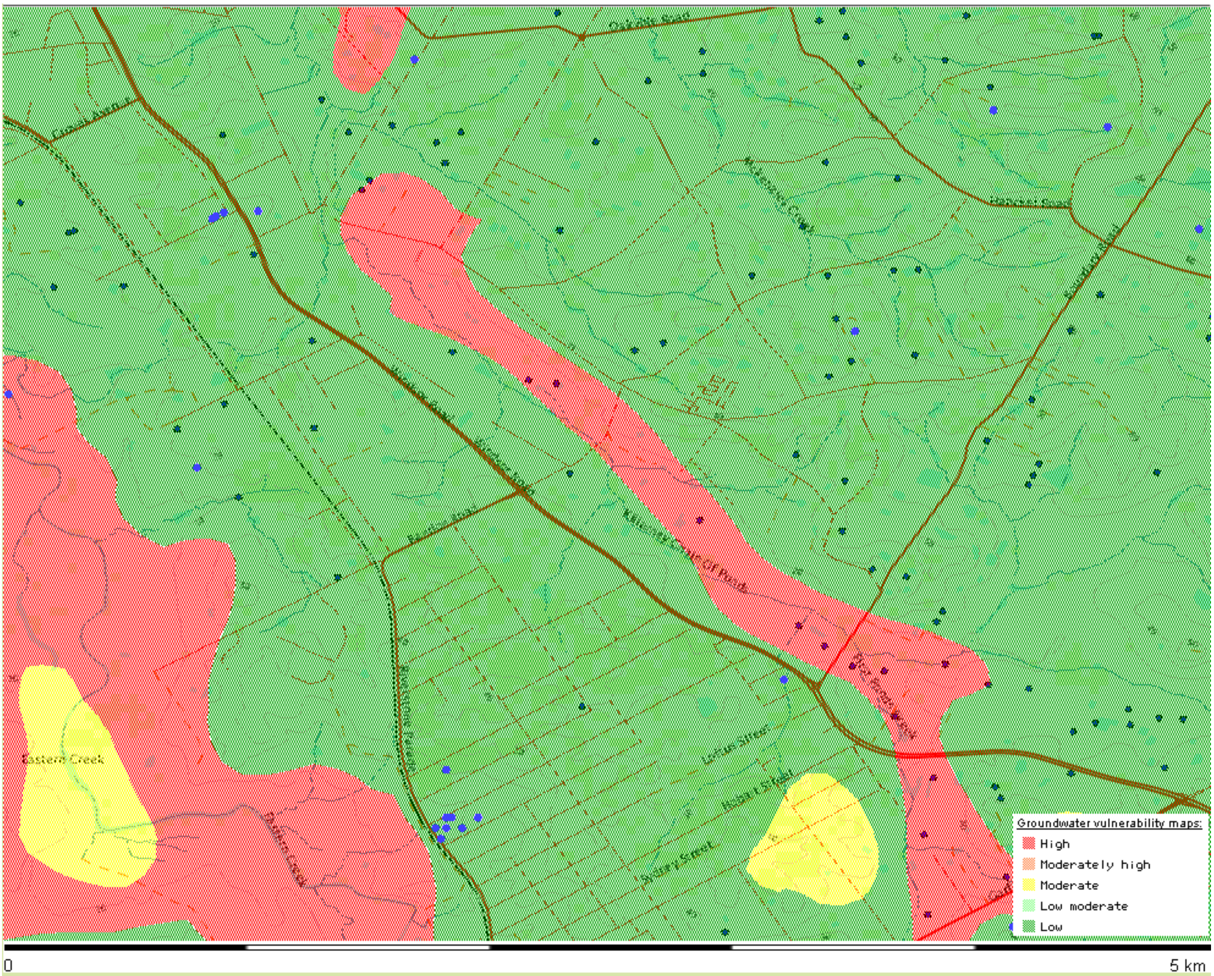

Figure 1.2 – Groundwater Vulnerability[6]

[6] Map created with the NSW Natural Resource Atlas – www.nratlas.nsw.gov.au <date>. Copyright © 2014 New South Wales Government. Map has been compiled from various sources and may contain errors or omissions. No representation is made as to its accuracy or suitability

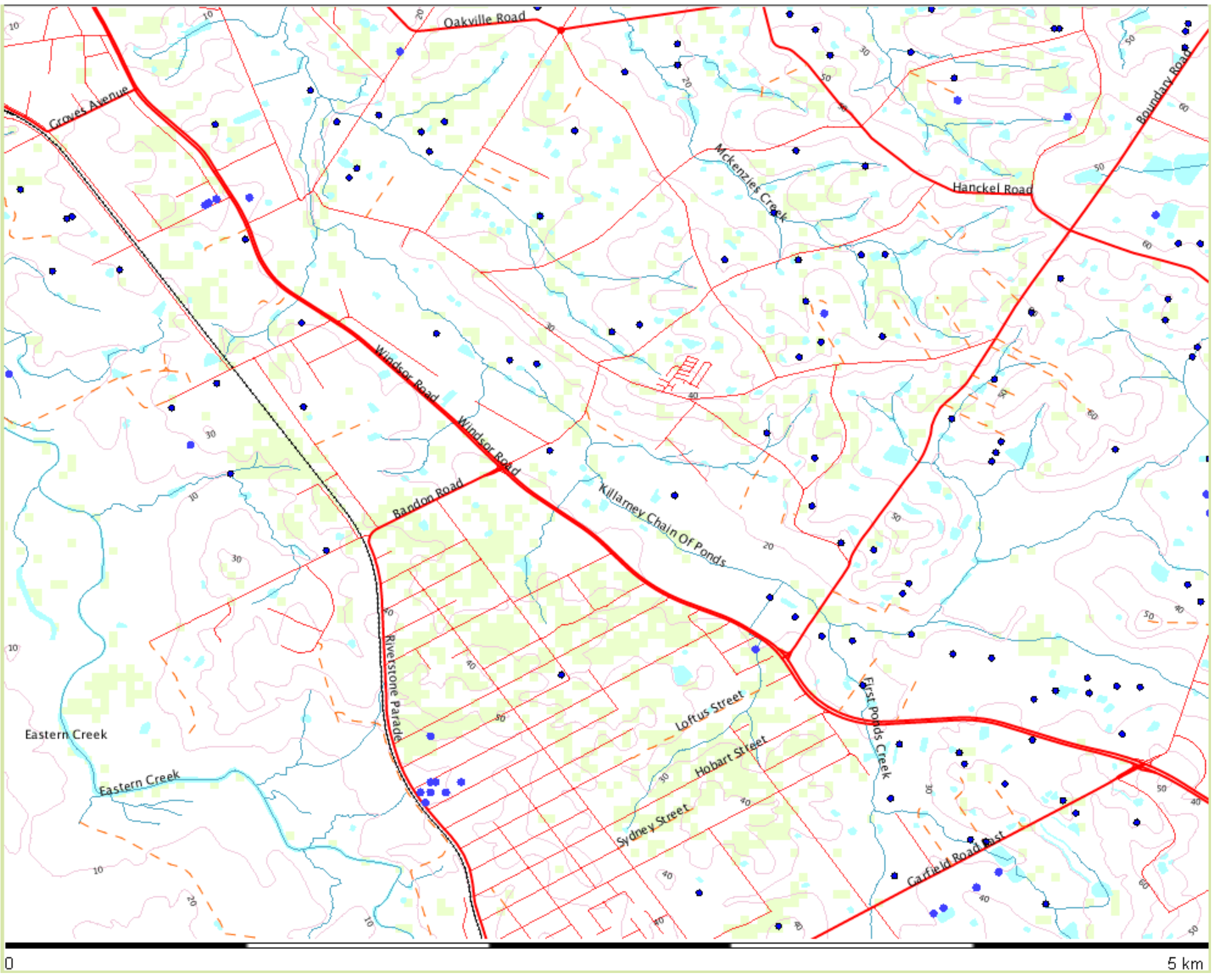

Figure 1.3 – Groundwater Bores Registered with NOW[7] (blue dots represent groundwater wells)

6. Methodology

6.1 Rationale

The purpose of the soil testing was to provide information on the soil types and likely salinity and geotechnical characteristics and limitations over the site. Test locations were selected based on the review of background information and the field mapping to target various landforms, geology and soils types to verify expected site conditions based on published mapping and surface features. Locations were modified to take into account access availability and underground services. Access to locations was also limited in some instances by localised flooding during fieldwork.

[7] Map created with the NSW Natural Resource Atlas – www.nratlas.nsw.gov.au <date>. Copyright © 2014 New South Wales Government. Map has been compiled from various sources and may contain errors or omissions. No representation is made as to its accuracy or suitability

Selected samples would be subjected to laboratory testing based on providing a coverage of the various geological and topographical units, and targeting depths of concern.

Given the large area, number of lots and landholders in the Precincts, the investigation aimed to assess broad scale issues which may impact the suitability of areas within the Precinct for rezoning. Localised/ lower risk issues may not be identified in all cases.

Given the purpose of the investigation, testing of soil for contamination was not considered to be an efficient method of investigation. Five groundwater monitoring wells were placed along drainage lines at the site to identify potential broad scale contamination.

6.2 Assessment Datum

The coordinates of the field tests and other pertinent features were determined by use of a portable dGPS receiver, which indicated a typical accuracy of about 1 m, however, this accuracy can be effected by tree cover and weather. Horizontal positioning was referenced to the Map Grid of Australia 1994 (MGA94), Zone 56 datum. Vertical positioning was referenced to reduced levels relative to AHD, with levels at test locations recorded to the nearest 0.5 m, as derived from survey contours on provided 1 m contour maps.

6.3 Field Work

6.3.1 Site Inspection

Site inspections were undertaken by an experienced engineering geologist and environmental scientist.

The inspections focused on issues relevant to the assessment including, but not limited to, topography and landform, land use, signs of slippage and erosion, indicators of filling.

6.3.2 Service Location and WHS

Prior to undertaking the intrusive investigations, DP conducted a Dial-Before-You-Dig search for buried services and undertook on-site services scanning at each test location using an electromagnetic scanner.

DP's standard Work Health and Safety procedures were followed for all works, including preparation and implementation of Safe Work Method Statements.

6.3.3 Soil Sampling

Test Pit Excavation and Soil Recovery

- Test pits were excavated using a backhoe to a nominal depth of 2 m or into the top of bedrock (if encountered above 2 m); and

- Soil for sampling was recovered directly from the excavator bucket and placed into plastic bags for transport to the laboratory;

Drill Rig and Soil Recovery

- Five boreholes were drilled to a nominal depth of 6 m using a conventional auger drilling rig;
- Twenty five boreholes were drilled to nominal depths of 2 to 3 m, or prior refusal, using a push tube drilling rig;
- Soil for sampling was recovered directly from the augers or push tube and placed into plastic bags for transport to the laboratory;

A log of materials encountered, other observations and samples collected would be prepared for each location.

6.3.4 DCP Tests

The dynamic cone penetrometer (DCP) test comprises driving a 16 mm diameter steel rod, tipped with a 20 mm diameter cone, into the soil using a 9 kg hammer dropping through a standard distance of 510 mm. The number of blows required to drive the rod each 150 mm is recorded and used to estimate the consistency of the soils. Testing was carried out at a number of borehole locations and the results were incorporated onto the Borehole log sheets.

6.3.5 Well Construction and Groundwater

Groundwater monitoring wells were installed in the five 6 m deep boreholes, and details of their construction is provided on the borehole logs.

The groundwater investigation targeted the shallow (perched) aquifer. The wells were installed using acid washed PVC casing and with screens over the expected full depth of the water column. Bentonite seals were used in the construction to prevent surface water entering the well. A lockable road box was used to finish each well.

Wells were developed at least one week prior to sampling by removal of a minimum of three borehole volumes of water.

Groundwater samples were collected by an environmental engineer/ scientist using low flow sampling techniques, following stabilisation of field parameters collected during well micropurging to ensure that representative samples were collected.

6.3.6 Surface Water

EC and pH readings were collected from five sample locations as shown on Drawing 1, Appendix A.

The readings were collected in the field using a calibrated meter.

6.4 Laboratory Analysis

Laboratory analysis was conducted by NATA accredited laboratories. Details of the methodologies are provided in the laboratory reports in Appendix F.

Samples were selected for analysis to provide site coverage over the range of materials and conditions encountered.

6.5 Interpretation of Results

The results were interpreted in accordance with relevant Australian Standards and guidance as detailed below.

Geotechnical

- Standards Australia 2011, AS 2870 – 2011 *Residential Slabs and Footings*.
- Standards Australia 1996, AS 1726 – 1993 *Geotechnical Site Investigations.*

Salinity

- Standards Australia 2009, AS 2159 – 2009 *Piling Design and Installation*.
- Standards Australia 1996, AS 2870 – 1996 *Residential Slabs and Footings*.
- Standards Australia 1996, AS 3798 – 2007 Guidelines on Earthworks for Commercial and Residential Developments.
- Standards Australia 2000, AS 1547 – 2000 *On-Site Domestic Waste Water Management*.
- Standards Australia 2009 (and subsequent amendments), AS 3600 – 2009 *Concrete Structures*.
- Cement, Concrete and Aggregates, Australia 2005, Guide to Residential Slabs and Footings in a Saline Environment, Introduction to Urban Salinity.
- Department of Natural Resources (DNR) 2002, *Broad Scale Resources for Urban Salinity Assessment Sydney* (now managed by DPI).
- DNR 2002, *Indicators of Urban Salinity* (now managed by DPI).
- DNR 2002, Site Investigations for Urban Salinity (now managed by DPI).
- DNR 2003, *Building in a Saline Environment* (now managed by DPI).
- DNR 2003, *Roads and Salinity* (now managed by DPI).
- DNR 2004, *Urban Salinity Processes* (now managed by DPI).
- DNR 2004, *Waterwise Parks and Gardens* (now managed by DPI).
- (Rebecca Nicholson for) WSROC, DNR and natural Heritage Trust (amended January 2004) *Western Sydney Salinity Code of Practice*.

Contamination

- National Environment Protection Council (NEPC) *National Environment Protection (Assessment of Site Contamination) Measure 1999 (as amended 2013).*
- State Environmental Planning Policy No. 55–Remediation of Land (1998) under the *Environmental Planning and Assessment Act* (NSW) 1979 (SEPP55).

7. Field Work Results

7.1 Site Observations

Field observations are provided in the discussion sections for geotechnical, salinity and contamination issues respectively.

7.2 Subsurface Conditions – Soils and Bedrock

Subsurface conditions encountered during the investigation confirmed the presence of the mapped soil types and rock formations. The observations are recorded on the borehole and test pits logs, provided in Appendix B.

The boreholes (Bores 1 to 5), drilled using a geotechnical drilling rig for the installation of groundwater monitoring wells, generally on the lower creek line parts of the Precinct, typically encountered clays and sandy clays with some ironstone gravel to the full depth of investigation (6 m).

The remaining bores and test pits typically encountered stiff to hard residual clays and silty clays (away from the creek lines) grading into weathered bedrock of shale and siltstone at depths ranging from 0.5 m to about 2.5 m. The soil depths were greater towards the creek lines where alluvial sediments were present and in some mid-slope areas, particularly overlying the Ashfield Shale.

7.3 Groundwater and Surface Water Field Parameters

Groundwater was encountered in the deeper bores (Bores 1 to 5) at about 4 m to 5.5 m depth during drilling with subsequent monitoring indicating water levels ranging from 0.8 m and 2.2 m below surface level (on 10/4/2014) with the recorded data presented in Table 1.1 below. These boreholes generally targeted the creek lines, where groundwater is expected to be shallowest.

The shallower push tube bores generally did not encounter groundwater, although seepage was noted at some locations. The test pits did not encounter any groundwater and were backfilled on completion, which precluded long term monitoring of groundwater levels.

Table 1.1: Summary of Groundwater Levels/Depth Measurements

Borehole	Surface Level	Groundwater Level 10/04/2014	
	m AHD	m bgl	m AHD
1	10.4	0.8	9.6
2	13.5	1.27	12.23
3	12.3	0.8	11.5
4	31.6	2.2	29.4
5	35.7	1.81	33.89

Field parameters for the surface and groundwater are provided in Tables 1.2 and 1.3 below. Groundwater field sheets are provided in Appendix C. Sample locations for where the surface water samples were collected are as shown on Drawing 1, Appendix A.

Table 1.2: Summary of Monitoring Results for Groundwater (undertaken 10/04/2014)

Borehole	Temperature	DO	EC	pH	Redox	Salinity
	°C	mg/L	µS/cm	pH units	mV	ppt
1	20.8	2.07	32,646	6.08	83.7	20.42
2	21.6	0.58	34,148	6.18	95.4	21.47
3	19.6	2.95	25,428	5.58	99.10	15.52
4	19.70	1.50	2,600	7.33	102.2	1.73
5	22.4	1.02	21,822	5.86	160.0	13.13

Table 1.3: Summary of Monitoring Results for Surface Water (undertaken 1/04/2014)

Parameter	Temperature	pH	EC	Salinity	DO		ORP	Comments
Units	°C	pH units	µS/cm	ppt	%	mg/L	mV	
Brennans Dam Rd (SW1)	21.6	6.6	620	0.32	62	5.45	85.2	Near MW1
Old Hawkesbury Rd (SW2)	22.3	7.2	550	0.28	48.6	4.08	42.9	Near MW3, reedy
Chapman Rd (SW3)	21.8	7.0	880	0.46	66.1	5.69	99.9	Near MW4
Boundary Rd (SW4)	22.3	7.1	990	0.52	65.5	4.89	11.4	Near MW5, reedy
Bandon Rd (SW5)	22.8	7.3	478	0.24	69.1	6.24	92.7	Near Sydney Water STP

8. References

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9. Limitations

Douglas Partners (DP) has prepared this report for this project at Vineyard Precinct, North West Priority Growth Area in accordance with DP's proposal SYD140003, dated 21 January 2014 and acceptance received from Mr Chris Avis of Mott MacDonald dated 20 March 2014. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of Mott MacDonald and NSW Government Department of Planning and Infrastructure (DP&I) for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions on the site only at the specific sampling locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of human influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across the site between and beyond the sampling locations as well as site accessibility.

This report must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP.

Douglas Partners Pty Ltd