



Douglas Partners

Geotechnics • Environment • Groundwater

Integrated Practical Solutions

GROUNDWATER MONITORING PLAN

**PROPOSED INDUSTRIAL SUBDIVISION
TOMAGO ROAD, TOMAGO**

Prepared for

ADW JOHNSON PTY LTD

on behalf of

WEPL INVESTMENTS PTY LTD

Project 39920.02

JANUARY 2010



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Project No: 39920.02

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29 January 2010

**GROUNDWATER MONITORING PLAN
PROPOSED INDUSTRIAL SUBDIVISION
TOMAGO ROAD
TOMAGO**

1. INTRODUCTION

This Groundwater Monitoring Plan (GMP) has been prepared for the proposed industrial subdivision at Tomago Road, Tomago, New South Wales. Stage 1 of the industrial subdivision comprises the proposed WesTrac Facility. The work was undertaken at the request of ADW Johnson Pty Ltd on behalf of WEPL Investments Pty Ltd.

The Department of Planning (DoP) has granted Project Approval for the proposed industrial subdivision at Tomago (including the WesTrac Facility). “Condition 13” of the approval requires the preparation of a “Groundwater Monitoring Program”. The specific requirements of Condition 13 and the relevant section of this report are shown in Table 1.

Table 1 - Report Sections Addressing Condition 13 of DoP Approval

Requirements for Groundwater Monitoring Plan	Report Section
Be prepared in consultation with the DWE.	4.1
Include details of a program to monitor groundwater levels and quality.	4.2 & 4.3
The groundwater levels and quality impact assessment criteria.	4.4
Procedures for reporting the monitoring results against the criteria.	4.5
Contingency measures to address exceedances.	4.6
A description of how the effectiveness of actions and measures would be monitored over time.	4.7

Following recent restructuring of state government agencies, the DWE (Department of Water and Energy) is now the Office of Water within the Department of Environment Climate Change and Water (DECCW).

2. BACKGROUND

2.1 Site Description

The proposed industrial subdivision site is located on the southern side of Tomago Road, Tomago, approximately 8 km south-west of Raymond Terrace, and approximately 12 km north-west of Newcastle. The site details are summarised in Table 2.

Table 2 - Site Details

Address:	197 - 325 Tomago Road, Tomago
Lot/DP:	Lot 161 DP 774440; Lot 1 DP 1003492; Lot 1 DP 597372 and Lot 513 DP585256
Local Government Area:	Port Stephens
Zoning:	IN1 - General Industrial
Total Site Area:	Approximately 116 ha (herein referred to as 'the site')
Stage 1 Site Area (WesTrac):	Approximately 23 ha (herein referred to as 'the Stage 1 site')
Elevation:	0.5 m AHD to 8.5 m AHD
Geological Setting:	Quaternary Alluvium

The Hunter River (North Arm) is located to the south-west and south of the site, varying in distance from about 1.6 km to 2.4 km. Fullerton Cove is located about 2 km east-south-east of the site. The Tomago Sandbeds are situated immediately north of the site and include an extensive water-extraction borefield operated by the Hunter Water Corporation (HWC).

2.2 Previous Reports

The relevant reports in relation to the proposed development and geotechnical / hydrogeological conditions for the site and surrounding areas are summarised in Table 3.

Table 3 - Relevant Reports for the Site and Surrounds

Date	Title	Author
Jul 1990	Prediction of Maximum Water Levels at Tomago Aluminium	Douglas Partners Pty Ltd
1983 -2000	Annual Reviews of Mineral Sands Mining at Tomago	Douglas Partners Pty Ltd
Jul 2001	Preliminary Geotechnical Investigation Proposed Steel Mill and Port Development, Tomago, New South Wales, Australia	Earth & Rock Engineering Pty Ltd
Dec 2001	Stage 2 Geotechnical Investigation Proposed Steel Mill, Tomago, New South Wales, Australia	Earth & Rock Engineering Pty Ltd
Aug 2006	Proposed Industrial Development, 197 - 325 Tomago Road, Tomago, NSW, Preliminary Geotechnical / Due Diligence Assessment	Coffey Geosciences Pty Ltd
Nov 2007	Proposed Westrac Industrial Development - Tomago - Geotechnical Assessment	Coffey Geotechnics Pty Ltd
Jul 2008	Geotechnical Review, Proposed Westrac Facility, Tomago Road, Tomago	Douglas Partners Pty Ltd
Aug 2008	Proposed Industrial Development - Tomago Hydrogeological Investigation	Coffey Geotechnics Pty Ltd
Jul 2009	Major Project Assessment: Redlake Enterprises Industrial Estate	NSW Department of Planning

DP has not independently confirmed the accuracy or completeness of the above reports where prepared by others and has taken the information presented at face value.

2.3 Topography and Geology

The site topography and regional geology is described in Refs 2 and 3. The main features are:

- The southern part of the site comprises flat water-logged terrain with a typical elevation of 0.5 to 1.0 AHD;
- The northern part of the Stage 1 site is dominated by a low sand dune formation with a maximum elevation of RL 8.5 AHD;

- The site vegetation is mainly grassland and low scrub, with just a few mature trees located on the dune;
- The soil profile comprises alluvial / estuarine sediments (deposited under water), with some aeolian (wind-blown) sand deposits. The resulting upper soil profile consists of very soft to stiff silty clay, clay and sandy clay soils, overlying very loose to medium dense clayey sand;
- The upper soils are underlain by medium dense sand and stiff to hard clay strata. The depth to bedrock has not been established, but exceeds 18 m.

Groundwater was encountered at depths ranging from just above ground surface to 6 m in the boreholes (Ref 3), however it is noted that many observations corresponded to reduced levels below AHD and are unlikely to represent stabilised water levels.

2.4 Hydrogeology

The north-western parts of the site are underlain by relatively permeable sands associated with the Tomago Sandbeds with the remainder of the site comprising relatively low permeability, primarily clayey soils, becoming sandier with depth.

Groundwater flow on the site is to the south and south-east, with recharge coming from the sand beds to the north as well as surface infiltration on the site and discharge occurring into the wetland areas to the south.

Limited existing groundwater quality data indicates the following:

- The groundwater has high salinity which exceed drinking water guidelines with especially high salinity on the southern parts of the site;
- Ammonia concentrations at several locations exceed ANZECC criteria.

No testing for metals or hydrocarbons has been undertaken to date.

2.5 Potential Development Impacts

The following potential effects of the development on groundwater have been identified (Ref 3):

- Lowering of water table leading to oxidation of acid sulphate soils;
- Surface contamination from construction and site usage leaching into water table; and
- Leaching of contamination or suspended solids from filling. DP considers that this is an unlikely scenario.

Previous studies by Douglas Partners (Refs 10 -12) and others (Ref 3) indicate that the site is located down-gradient of HWC extraction bores within the Tomago Sandbeds and therefore infiltration at the development site would not flow towards the HWC borefield.

3. REGULATORY SETTING

The legislation and guidelines that are considered most relevant to the environmental management of the Tomago Industrial subdivision are listed in Table 4.

Table 4 - Environmental Legislation and Guidelines

Legislation / Guideline	Relevance / Applicability
Protection of the Environment Operations Act (1997) [known as POEO Act]	Key overarching legislation that enables the NSW Government to set out explicit policies for protection of the environment, including granting and administering Environmental Protection Licences (EPL).
Contaminated Land Management Act (as amended 2009) [known as CLM Act]	NSW Legislation for management of contaminated sites. New amendments to this act came into force on 1 July 2009.
DECC Guidelines for the Assessment and Management of Groundwater (March 2007)	These guidelines are relevant for groundwater contamination in NSW. They stipulate the use of ANZECC groundwater investigation levels (GILs) for 95% protection of aquatic ecosystems.
National Environment Protection Council, National Environment Protection Measures (NEPM, December 1999)	The NEPMs outline <i>national</i> objectives for protecting or managing particular aspects of the environment. These may be a combination of goals, guidelines, standards or protocols.
EPA (now DECC) Guidelines for Consultants Reporting on Contaminated Sites, November 1997	Sets out the minimum requirements / standards for consultant reports on contamination assessments.

The NSW government policy for the management of groundwater resources in the state (Ref 1) lists nine management principles:

1. *All groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained.*
2. *Town water supplies should be afforded special protection against contamination.*
3. *Groundwater pollution should be prevented so that future remediation is not required.*
4. *For new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource.*
5. *A groundwater pumper shall bear the responsibility for environmental damage or degradation caused by using groundwaters that are incompatible with soil, vegetation or receiving waters.*
6. *Groundwater dependent ecosystems will be afforded protection.*
7. *Groundwater quality protection should be integrated with the management of groundwater quantity.*
8. *The cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource.*
9. *Where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored.*

The Commonwealth Government administers the Environment Protection and Biodiversity Conservation Act (EPBC Act), and it is noted that the development will need to meet the conditions of approval for the project.

4. MANAGEMENT STRATEGY

4.1 Consultation with Department of Water and Energy

The Department of Water and Energy (DWE) is now the Office of Water within the Department of Environment Climate Change and Water (DECCW).

The plan presented herein was discussed with Mr John Williams of the Office of Water on 21 October 2009. The matters discussed and agreed included the following:

- General parameters types and the frequency of sampling and testing.
- The use of suitable percentiles for setting trigger levels from background monitoring, where background concentrations are greater than ANZECC/drinking water criteria. Mr Williams indicated that with this approach, if an exceedance occurred it would be sensible to allow for re-testing to check if the exceedance was an aberration. This was included into the plan.
- A review of the monitoring plan after 5 years. Mr Williams suggested that the main concern would be an initial spike in concentrations within the first five years of construction and after this it may well be possible to drop many of the parameters and continue to monitor only key indicator parameters.

4.2 Groundwater Monitoring Network

The groundwater quality will be monitored using a network of 11 wells, comprising five existing wells and six new wells. Three of the new wells would be located immediately south of the Stage 1 development to provide early warning of any off-site contamination, including one well adjacent to the effluent treatment plant. The three wells close to the northern boundary are up-gradient of the site and will provide “background” water quality with respect to groundwater flowing into the site.

The five existing wells have screen intervals ranging from 0.00/0.85 m to 3.00/3.85 m within the upper sandy strata (silty sand, clayey sand, silty clay). The new wells will be screened at a similar depth range.

The well locations are shown on the attached Drawing 1. All wells will be licensed with DWE.

4.3 Groundwater Monitoring Program

4.3.1 Groundwater Quality Parameters

The parameters to be measured fall into three categories as shown in Table 5 below.

Table 5 - Groundwater Quality Parameters

Category 1 Parameters	Category 2 Parameters	Category 3 Parameters
pH Electrical Conductivity (EC) Total Suspended Solids (TSS)	Cations: Calcium (Ca) Iron (Fe) Potassium (K) Magnesium (Mg) Sodium (Na) Anions: Chloride (Cl) Sulphate (SO ₄) Ammonia (NH ₃) Bicarbonate (HCO ₃) Carbonate (CO ₃) Nitrite (NO ₂) Nitrate (NO ₃) Total Kjeldahl Nitrogen (TKN) Total Phosphorous (PO ₄) Fluoride (F)	Heavy Metals: Arsenic (As) Cadmium (Cd) Chromium (Cr) Copper (Cu) Lead (Pb) Manganese (Mn) Mercury (Hg) Molybdenum (Mo) Nickel (Ni) Zinc (Zn) Total Recoverable Hydrocarbons (TRH) Polycyclic Aromatic Hydrocarbons (PAH) BTEX: Benzene Toluene Ethly benzene Xylene; Pesticides (OCP/OPP) Polychlorinated Biphenyl (PCB) Hydrogen Cyanide (HCN) Phenols

4.3.2 Sampling and Testing Protocols

The sampling will be undertaken in accordance with standard industry practice, including:

- Purging of at least 5 well volumes or until pH and EC readings are constant;
- Filtering and preservation of samples;
- Chain of custody documentation;
- Duplicate samples on at least 10% of samples.

Laboratory testing will be undertaken at a NATA-accredited chemical laboratory and Practical Quantification Limits (PQLs) will be no greater than half of the relevant criteria for each parameter.

4.3.3 Baseline Monitoring (Prior to Construction of Stage 1)

At least three quarterly rounds will be undertaken to establish baseline groundwater quality prior to construction of Stage 1. The monitoring will comprise Category 1, 2 and 3 parameters (see Table 4) at a suitable interval to provide at least three rounds, with a maximum period of 3 months between rounds.

Groundwater level monitoring will comprise water level measurements in each well on the basis of the following:

- Continual groundwater monitoring using data logger recording at 1 hour intervals in three selected wells (MW3, MW4 & MW10);
- Monthly recording of water levels in all of the wells;
- Measurement of water levels in all wells within 24 hours of more than 50 mm of rainfall within a 24 hour period.

4.3.4 Ongoing Monitoring (During and Following Stage 1 Construction)

Ongoing monitoring for Stage 1 will comprise Wells MW1, MW2, MW3, MW4, MW6, MW9, MW10 and MW11 for the following parameters:

- Category 1 Parameters on a 3 monthly basis;
- Category 2 Parameters on a 6 monthly basis;
- Category 3 Parameters on a 12 monthly basis;
- Groundwater level gauging on a 3 monthly basis.

4.3.5 Monitoring for Future Stages

The monitoring program for future stages will comprise the addition of Wells MW5, MW7 and MW8 for a nominal baseline period of two years prior to construction, with a minimum of three rounds. Once future stage construction starts, it may be appropriate to remove Wells MW9 to MW11 from the program and replace them by new wells located to suit the future staging of the development. A tentative program has been prepared for future stages (see below), however the program will be reviewed and revised as necessary during the regular annual reviews.

4.3.6 Monitoring Summary

The groundwater monitoring program is summarised in Table 6 below.

Table 6 – Summary of Monitoring Program

Parameters	Initial Baseline Period (Baseline 1)	During and following Stage 1 Construction	Two Years Prior to Future Stages (Baseline 2)	During and Following Future Stages Construction
Wells to be Monitored	MW1 to MW11 (all wells)	MW1 MW2 MW3 MW4 MW6 MW9 MW10 & MW11	MW5 MW7 & MW8	MW1 to MW8, plus new wells as required ^(Note 3)
Water Levels	Monthly ^(Note 1)	3 Monthly	3 Monthly ^(Note 2)	3 Monthly
Category 1 Parameters	3 Monthly (max), min of 3 rounds	3 Monthly	6 Monthly (max), min of 3 rounds	3 Monthly
Category 2 Parameters	3 Monthly (max), min of 3 rounds	6 Monthly	6 Monthly (max), min of 3 rounds	6 Monthly
Category 3 Parameters	3 Monthly (max), min of 3 rounds	12 Monthly	12 Monthly (max), min of 2 rounds	12 Monthly
Reporting	On completion	12 Monthly	On completion	12 Monthly
Monitoring Program Review	On Completion	5 Yearly	On Completion	5 Yearly

Notes to Table 6:

1. Plus hourly water level monitoring by datalogger in Wells MW3, MW4 and MW10 over 3 months.
2. Plus hourly water level monitoring by datalogger in Wells MW2, MW3 and MW5 over 3 months.
3. Wells MW9 and MW10 may be discontinued / relocated to suit new Stages.
4. Baseline 2 and Future Stage monitoring is tentative - to be reviewed after Stage 1 completed.

4.4 Assessment Criteria

4.4.1 Groundwater Levels

Groundwater levels will fluctuate with variations in climatic conditions and therefore comparison will need to be made with the background fluctuations as well as with climatic conditions. The ongoing results of monitoring will be reviewed on an annual basis for variations in groundwater levels which are inconsistent with rainfall trends (measured at Williamstown Meteorological Station) and/or outside the range of measured background fluctuations.

4.4.2 Groundwater Quality

In general the most sensitive beneficial use for groundwater below the site will be the downstream tidal wetland areas to the south (ANZECC ecosystem criteria, Ref 4), however for some parameters drinking water beneficial use (NHMRC, Ref 5) will be the more critical. It is recognised, however, that groundwater in the region can have background levels of various parameters, in particular metals, with concentrations higher than the ANZECC Marine Criteria or parameters such as salinity greater than the drinking water criteria. Therefore the baseline groundwater monitoring will be used to provide a statistical assessment of the background levels to allow adoption of appropriate assessment criteria.

The baseline data will be statistically assessed to determine the following for each parameter:

- UCL₉₅-mean (using methodology presented by USEPA, Refs 13 to 15);
- 80th Percentile.

If any parameter shows a particular trend across the site, such as relatively high total dissolved salts along the southern boundary, then the statistics for this parameter will be undertaken on representative sub-areas, otherwise the parameters will be assessed across the site as a whole.

The most sensitive beneficial use has been assessed based on the lowest concentration from the ANZECC 95% Fresh and Marine Criteria, as well as NHMRC Drinking Water and Irrigation uses. Although the available background data suggests that the water on site is not suitable for drinking, the Drinking Water Guidelines have been considered due to the close proximity to the Tomago Sandbeds. The identified criteria for the most sensitive beneficial use are listed in Table 7 below.

The baseline data will be considered in adoption of actual trigger levels for the site. Where there is no specific criteria for a certain parameter, or the background 80th percentile is higher than the criteria for the most sensitive beneficial use (for example sodium or chloride which can be expected to exceed the drinking water criteria) then the 80th percentile background concentration will be adopted as a trigger level. Otherwise the criteria for the most sensitive beneficial use will be adopted.

Table 7 – Groundwater Quality Criteria

Parameter	Most Sensitive Beneficial Use		Background Quality		Trigger Level
	Criteria (mg/L)	Corresponding Guideline	UCL ₉₅ -mean	80 th Percentile	Higher of Beneficial Use Criteria and 80 th Percentile of Background Quality
pH	6.5-805	ANZECC	TBC	TBC	TBC
Electrical Conductivity (uS/cm)	NC	NC	TBC	TBC	TBC
Hardness as CaCO ₃	200	Drinking	TBC	TBC	TBC
Turbidity (NTU)	0.5-10	ANZECC	TBC	TBC	TBC
Total Suspended Solids	NC	ANZECC	TBC	TBC	TBC
Anions					
Chloride (Cl)	250	Drinking	TBC	TBC	TBC
Ammonia (NH ₃) as N	0.5	Drinking	TBC	TBC	TBC
NO _x (NO ₂ ⁻ + NO ₃ ⁻)	0.015	ANZECC	TBC	TBC	TBC
Total Nitrogen as N	0.3	ANZECC	TBC	TBC	TBC
Sulphate (SO ₄ ²⁻)	500	Drinking	TBC	TBC	TBC
Total Phosphorus	0.025	ANZECC	TBC	TBC	TBC
Carbonate (CO ₃ ²⁻)	NC	NC	TBC	TBC	TBC
Bicarbonate (HCO ₃ ⁻)	NC	NC	TBC	TBC	TBC
Cations					
Ca	NC	NC	TBC	TBC	TBC
Fe ²⁺	0.3	Drinking	TBC	TBC	TBC
Mg	NC	NC	TBC	TBC	TBC
K	NC	NC	TBC	TBC	TBC
Na	180	Drinking	TBC	TBC	TBC
Heavy Metals			TBC	TBC	TBC
As	0.013	ANZECC	TBC	TBC	TBC
Cd	0.0002	ANZECC	TBC	TBC	TBC
Cr	0.001	ANZECC	TBC	TBC	TBC
Cu	0.0013	ANZECC	TBC	TBC	TBC
Mn	0.5	Drinking	TBC	TBC	TBC
Mo	0.05	Drinking	TBC	TBC	TBC
Ni	0.007	ANZECC	TBC	TBC	TBC
Pb	0.0034	ANZECC	TBC	TBC	TBC
Zn	0.008	ANZECC	TBC	TBC	TBC
Hg	0.00006	ANZECC	TBC	TBC	TBC
Total Cyanide	0.004	ANZECC	TBC	TBC	TBC
TRH					
C ₆ - C ₉	NC	NC	TBC	TBC	TBC
C ₁₀ - C ₁₄	NC	NC	TBC	TBC	TBC
C ₁₅ - C ₂₈	NC	NC	TBC	TBC	TBC

Table 7 – Groundwater Quality Criteria (continued)

Parameter	Most Sensitive Beneficial Use		Background Quality		Trigger Level
	Criteria (mg/L)	Corresponding Guideline	UCL ₉₅ -mean	80 th Upper Percentile	Higher of Beneficial Use Criteria and Upper 80 th Percentile of Background Quality
C ₂₉ - C ₃₆	NC	NC	TBC	TBC	TBC
BTEX					
Benzene	0.001	Drinking	TBC	TBC	TBC
Toluene	0.18	ANZECC	TBC	TBC	TBC
Ethyl Benzene	0.08	ANZECC	TBC	TBC	TBC
Xylene	0.2	ANZECC	TBC	TBC	TBC
PAHs					
Total PAH			TBC	TBC	TBC
Naphthalene	0.016	ANZECC	TBC	TBC	TBC
Acenaphthylene	NC	NC	TBC	TBC	TBC
Acenaphthene	NC	NC	TBC	TBC	TBC
Fluorene	NC	NC	TBC	TBC	TBC
Phenanthrene	0.0006	ANZECC	TBC	TBC	TBC
Anthracene	0.00001	ANZECC	TBC	TBC	TBC
Fluoranthene	0.001	ANZECC	TBC	TBC	TBC
Pyrene	NC	NC	TBC	TBC	TBC
Benzo[a]anthracene	NC	NC	TBC	TBC	TBC
Chrysene	NC	NC	TBC	TBC	TBC
Benzo[b,k]fluoranthene	NC	NC	TBC	TBC	TBC
Benzo[a]pyrene	0.00001	ANZECC	TBC	TBC	TBC
Indeno[123-cd]pyrene	NC	NC	TBC	TBC	TBC
Dibenzo[ah]anthracene	NC	NC	TBC	TBC	TBC
Benzo[ghi]perylene	NC	NC	TBC	TBC	TBC
OPPs	NC	NC	TBC	TBC	TBC
OCPs					
Total OCPs	NC	NC	TBC	TBC	TBC
Aldrin + Dieldrin	NC	NC	TBC	TBC	TBC
Chlordane	0.00003	ANZECC	TBC	TBC	TBC
DDT	0.000006	ANZECC	TBC	TBC	TBC
Heptachlor	0.00001	ANZECC	TBC	TBC	TBC
Total Phenols	0.32	ANZECC	TBC	TBC	TBC
Total PCBs	NC	ANZECC	TBC	TBC	TBC

Notes to Table 7:

NC – No current criteria

TBC – Criteria to be confirmed from results of baseline water quality testing.

ANZECC – Lowest of 95% Marine and Fresh criteria (Ref 4)

Drinking – NHMRC Health Based (Ref 5)

All parameters mg/L unless otherwise shown

4.5 Reporting Requirements

An annual report will be prepared which shall include the following:

- Time and date of sampling;
- Sampling methods, including well purging records;
- Sample Chain of Custody Documentation;
- Results of QA/QC protocols;
- Laboratory test methods and PQLs;
- Tabulated results of current round of testing;
- Plot of results over time to allow assessment of trends;
- Groundwater levels plotted against rainfall records;
- Comparison with groundwater quality trigger levels and assessment of trends in groundwater levels noting any exceedances of criteria.

4.6 Contingency Measures

4.6.1 Groundwater Levels

If a consistent trend in variations in groundwater level are recorded, then the potential implications of the long term variation should be assessed. The management strategy will depend on the nature of the groundwater variation and its expected effects.

If long term lowering of the water table were to occur and it was having adverse environmental effects, such as oxidising acid sulphate soils, then this can be managed by buffering the groundwater pH by injection of lime treated water.

4.6.2 Groundwater Quality

It is considered that the UCL₉₅-mean values could be used to indicate when monitored values are above average background levels, prompting review and closer scrutiny if levels are consistently above average. Exceedance of the adopted trigger levels would prompt further sampling and testing. This procedure is summarised in Table 8 below.

Table 8 - Actions Prompted by Monitoring Results

Event	Action
Consecutive results exceeds UCL ₉₅ -mean value	Review trend in parameter(s) concerned and note in monitoring report.
Result exceeds trigger level (80 th percentile)	Notify the following government agencies within 7 days: DEWHA, NSW DoP, NSW Parks & Wildlife Group-DECC Undertake additional round of sampling immediately and analysis for parameter(s) concerned.
Three consecutive results exceed the trigger level.	Investigate possibility of a contaminant plume and if necessary implement appropriate actions to mitigate contamination.

4.7 Monitoring Effectiveness of the Program

A review of the monitoring program will be undertaken a five yearly basis by a suitably qualified groundwater consultant to:

- Review land uses and potential contamination sources;
- Analyse trends in groundwater levels and quality;
- Assess effectiveness of existing monitoring program;
- Recommend any changes to provide an efficient and effective monitoring programme.

Parameters which have been established to be of minimal concern from the results of monitoring may be dropped from the program and others may be added if warranted from changes to site use.

5. LIMITATIONS

DP has performed investigation and consulting services for this project in general accordance with current professional and industry standards.

Whilst every effort has been made to ensure a representative programme of field and laboratory sampling and testing, conditions different to those identified during these tasks may exist. Therefore DP cannot provide unqualified warranties nor does DP assume any liability for site conditions not observed, or accessible during the time of the investigations.

Despite all reasonable care and diligence, the ground conditions encountered may not be representative of conditions between the locations sampled and investigated. In addition, site characteristics may change over time in response to variations in natural conditions, chemical reactions and other events, eg. groundwater movement and/or spillages of contaminating substances. These changes may occur subsequent to DP's investigations and assessment.

This report and associated documentation and the information herein have been prepared solely for the use of ADW Johnson Pty Ltd and WEPL Investments Pty Ltd. Any reliance assumed by other parties on this report shall be at such party's own risk. Any ensuing liability resulting from use of the report by other parties cannot be transferred to DP.

DOUGLAS PARTNERS PTY LTD

Reviewed by:

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NOTES RELATING TO THIS REPORT

Introduction

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

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

Description and Classification Methods

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

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

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

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

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

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

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

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

Sampling

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

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

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

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

Drilling Methods.

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

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

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

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

Continuous Spiral Flight Augers — the hole is advanced using 90—115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and in sands above the water

table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

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

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

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

Standard Penetration Tests

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

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

The test results are reported in the following form.

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

as 4, 6, 7
 N = 13

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

as 15, 30/40 mm.

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

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

Cone Penetrometer Testing and Interpretation

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

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

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

The information provided on the plotted results comprises: —

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

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

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

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

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

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

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

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

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

Hand Penetrometers

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

Two relatively similar tests are used.

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

Laboratory Testing

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

Bore Logs

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

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

Ground Water

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

- In low permeability soils, ground water although present, may enter the hole slowly or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be

the same at the time of construction as are indicated in the report.

- The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made.

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

Engineering Reports

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

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

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

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

Site Anomalies

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

Reproduction of Information for Contractual Purposes

Attention is drawn to the document "Guidelines for the Provision of Geotechnical Information in Tender Documents", published by the Institution of Engineers, Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section

is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. The Company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

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

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