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REPORT ON PRELIMINARY CONTAMINATION ASSESSMENT

PROPOSED DEVELOPMENT 245 MARION STREET LEICHHARDT

Prepared for
P & C CONSULTING PTY LTD

NOVEMBER 1999
PROJECT No. 28594

Douglas Partners Pty Ltd
ACN 053 980 117
96 Hermitage Road
West Ryde NSW 2114
Australia

PO Box 472
West Ryde NSW 1685
Phone (02) 9809 0666
Fax (02) 9809 4095
e-mail douglasp@douglaspartners.com.au

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REPORT ON PRELIMINARY CONTAMINATION ASSESSMENT
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EXECUTIVE SUMMARY

A preliminary contamination assessment carried out at the above site by Douglas Partners Pty Ltd (DP) in October and November, 1999. The work was requested by the client, P & C Consulting Pty Ltd to determine the concentration and extent of potential contamination and the suitability of the site for the proposed commercial land use.

The site comprises Lot 1 DP 507525, located in a combined industrial/commercial and residential area of Leichhardt, and is rectangular in shape, with an area of 5189 m^2. The site runs between Marion Street to the south and Walter Street to the north. There is industrial and residential development to the east, and residential development also to the north. At the time of the investigation, the site was predominantly occupied by a single storey car repair workshop with associated offices at the front of the site. Site inspection indicated that there was a series of above ground storage tanks (AST) located in a concrete bund in the north west corner of the workshop. A grease trap was observed on the outside north west corner of the workshop. Observation of site plans also indicated an electrical substation in the south west corner of the site. At the rear of the site were a number of single storey buildings used as offices.

The contamination assessment comprised the drilling of test bores and installation of standpipe monitoring wells, followed by laboratory analysis of soil samples collected. Out of a total of 16 samples collected from the site, 14 soil samples and one duplicate soil sample were analysed at a NATA registered laboratory for a range of analytes, including heavy metals, polycyclic aromatic hydrocarbons (PAH), total recoverable hydrocarbons (TRH), and monoaromatic hydrocarbons (BTEX).

The results of the assessment indicated that:

- there is no evidence of elevated levels of heavy metals or BTEX in the soils or filling in exceedence of the guidelines for industrial sites;
- there are elevated levels of benzo(a)pyrene, total PAH, and TRH in up to three samples representing the filling materials;

It is considered that the filling materials indicating exceedences are unsuitable for the intended commercial/industrial landuse. The site requires remediation to remove the unsuitable materials prior to being considered suitable for the proposed use. The remediation could involve:

- removal of the contaminated filling material,
- validation of the remaining substrate to ensure complete removal of the contaminated filling material, and
- classification of the excavated material and approval for disposal off site to an appropriately licensed landfill by a licensed contractor.

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REPORT ON PRELIMINARY CONTAMINATION ASSESSMENT
245 MARION STREET
LEICHHARDT

1. INTRODUCTION

This report details the results of a preliminary contamination assessment carried out at the above site by Douglas Partners Pty Ltd (DP) in October and November, 1999. The work was requested by the client, P & C Consulting Pty Ltd.

The construction of a commercial development is proposed, and a preliminary contamination assessment was carried out to assess the concentration and extent of potential contamination and the suitability of the site for the proposed commercial land use.

The preliminary contamination assessment comprised the drilling of test bores and installation of standpipe monitoring wells, followed by laboratory analysis of soil samples collected. Details of the field work and laboratory findings are given in the report, together with comments relating to remedial requirements to facilitate the proposed commercial use of the site.

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2. SITE DESCRIPTION AND GEOLOGY

The site comprises Lot 1 DP 507525, located in a mixed industrial/commercial and residential area of Leichhardt, and is rectangular in shape, with an area of 5189 m^2. The site slopes gently to the north, with an overall crossfall of around 2 m. The site runs between Marion Street to the south and Walter Street to the north. There is industrial and residential development to the east, and residential development also to the north. A nearby railway line is situated to the west of the site, and runs adjacent to the Hawthorne Canal, previously known as Long Cove Creek.

At the time of the investigation, the site was predominantly occupied by a single storey car repair workshop with associated offices at the front of the site. Site inspection indicated that there was a series of above ground storage tanks (AST) located in a concrete bund in the north western corner of the workshop. A grease trap was observed on the outside north western corner of the workshop. A review of the available site plans following on site observations also indicated an electrical substation in the south western corner of the site. At the rear of the site were a number of single storey buildings used as offices.

A site plan is included as Drawing 1 (Appendix A).

Reference to the Sydney 1:100 000 Geological Series Sheet indicates that the site is located near the border of Hawkesbury Sandstone of the Wianamatta group, and an area affected by man-made filling. The Hawkesbury Sandstone comprises medium to coarse grained quartz sandstone, with minor shale and laminite lenses. Field work for the current investigation confirmed the presence of filling, comprising sand, clay, and some gravel, with some ash and slag materials, underlain by natural sands and sandstone.

Groundwater was detected in Bore 2 at 2.4 m depth, and Bore 5 encountered wet samples from 2.0 m depth. It is considered that groundwater levels are generally below 2.4 m.

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3. SITE HISTORY

To investigate the previous land uses of the site, a title deed search was conducted for Lot 1 DP507525. A summary of the property owners for the past 100 years is outlined below:

Part of Lot 1:	
28 February 1887	Peter Cunningham
14 March 1903	Margaret Cunningham
Part of Lot 1:	
25 September 1917	The Railway Commissioners for New South Wales
Part of Lot 1:	
17 July 1919	The Railway Commissioners for New South Wales
Part of Lot 1:	
13 December 1918	Minister for Public Works
30 April 1931	The Railway Commissioners for New South Wales
Whole of Lot 1:	
7 February 1946	His Most Gracious Majesty King George the Sixth.
26 August 1994	P & C Consulting Pty Ltd.

A review of the title deed search indicated plans dated 1942 and 1964 that showed the south west corner of the site comprising reclaimed land, bounded by the original high water mark of Long Cove Creek. As the creek has since been filled in this area, it is considered probable that substantial filling is located in the south west corner of the site.

The review of the title deed search further indicated that the electrical substation is located on land leased to Sydney Electricity and that the lease expires on 31 August 2044.

The information from the title deed search suggests that the site has been owned by the Rail Authority and was probably used for industrial purposes and that filling has been placed on the site. A copy of the title deed search is included in Appendix D.

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4. POTENTIAL FOR CONTAMINATION

On the basis of the site history, the range of potential contaminants may include:-

- heavy metals contaminants present in filling used to level or reclaim the site, or from contaminating landuse activities, such as the car repair garage;
- polycyclic aromatic hydrocarbons (PAH) present in filling or waste oil, and
- total recoverable (TRH) and monoaromatic (BTEX) hydrocarbons resulting from previous spillages originating from garage activities.

5. SCOPE OF WORK

Following the site history and title deed search, field work was undertaken to collect subsoil samples for laboratory analysis. To meet NSW EPA Contaminated Sites Sampling Design Guidelines, a total of 12 sampling locations are required for a site area of approximately 0.45 ha. This sampling density is designed to enable characterisation for sensitive site uses (ie. child care centres) to achieve 95% upper confidence level (UCL) in the detection of contamination 'hotspots' of specified diameters. Given that the site is intended for less sensitive, commercial use, a reduced sampling density has been adopted. A total of six test bores, two in the area of the AST, were undertaken.

The test bores were drilled using a bobcat with auger attachment, working under the supervision of an experienced engineer. Concrete coring was required for all six locations. Sampling and identification were from the cuttings returned by the auger blade. The test bores were drilled to maximum depths of 1.3-3.0 m. Soil/fill samples (including duplicates) were collected at depths of 0.5 m, 1.5 m, and at bore completion. A total of 16 soil/fill samples (including one sample for QA/QC purposes) were collected over the site.

The locations of the test bores are given in Drawing 1 (Appendix A).

Environmental sampling was performed according to standard operating procedures outlined in the DP *Field Procedures Manual.* All sampling data were recorded on DP chain of custody sheets, and the general field work procedure consisted of the following:

- one duplicate sample for QA/QC purposes was collected;
- Sampling equipment was decontaminated using a 3% solution of phosphate free detergent (Decon 90) and distilled water prior to collecting each sample;
- Samples were transferred into laboratory-prepared glass jars, and capped immediately. The sample containers were labelled with individual and unique identification, including project number, test bore number and sample depth.
- The samples were then placed into a cooled, insulated and sealed container for transport to the laboratory.

Two standpipe monitoring wells were installed in the bores where groundwater was encountered (Bores 3 and 4). The groundwater was encountered at a depth of 2.4-2.5 m.

Australian Environmental Laboratories, a laboratory certified by the National Association of Testing Authorities (NATA), was employed to conduct sample analysis for heavy metals, TRH, BTEX, and PAH. The laboratory is required to carry out routine in-house QC procedures to ensure accuracy, precision, and analytical repeatability. A total of 14 soils (including one duplicate) were analysed.
Test bore reports were prepared, describing the physical characteristics of the soil encountered, sample depths and locations.

6. FIELD WORK RESULTS

The results of the field work are given in detail in Appendix B, together with notes defining classification methods and descriptive terms.

Bores 1 and 2 were taken to auger refusal on probable bedrock at depths of 2.0 m and 2.5 m. Bores 3 and 4 were taken to target depths of 2.5-3.0 m. Bores 5 and 6 were discontinued in filling at depths of 1.3 m and 2.2 m, due to auger refusal on wire cable, in both bores.

The field work encountered relatively uniform conditions over the site, with pavements and filling, overlying clays, and sandstone.

Filling Materials

Concrete pavements, generally 150 mm thick, were encountered in all bores. The underlying filling materials comprised mostly orange sandy clays, crushed sandstone, dark brown sandy clays, silty clays, and gravelly silty sands. Some ash was encountered in Bore 1 at 0.5 m depth, and some slag was encountered in Bore 6 at 1.5 m depth. Filling was encountered in all bores and extended from depths of 0.8 to beyond 2.5 m.

Sandy Clays and Clayey Sands

Mostly soft, orange and grey sandy clays, and white, light grey, and yellow clayey sands were encountered in Bores 1-3 to depths of 2.0-3.0 m. These materials were underlain by probable sandstone bedrock at depths of 2.0 m and 2.5 m in Bore 1 and Bore 2.

Groundwater

Free groundwater was only encountered at two locations, Bores 3 and 4. It is considered that groundwater levels are around 2.5 m depth. Standpipe monitoring wells were installed at two locations, however, no groundwater samples have been collected at the time of the current report.

7. SELECTION OF GUIDELINE CRITERIA FOR CONTAMINATION ASSESSMENT

The contamination assessment has been undertaken in accordance with the following guidelines:

- NSW EPA, 1995, *Contaminated Sites: Sampling Design Guidelines*
- NSW EPA, 1998, *Contaminated Sites: Guidelines for the NSW Site Auditor Scheme*
- NSW EPA, 1994, *Contaminated Sites: Guidelines for Assessing Service Station Sites*
- NSW EPA, 1999, *Environmental Guidelines: Assessment, Classification, and Management of Liquid and Non-Liquid Wastes.*

For commercial or industrial development, the NSW EPA have provided site assessment criteria detailed in *Contaminated Sites: Guidelines for the NSW Site Auditor Scheme*. The guidelines are based on the National Environmental Health Forum (NEHF) guidelines (1996), Exposure Setting Column F- Commercial or Industrial. The EPA guidelines are considered suitable for the assessment of this site for the proposed development.

It should be noted that the guidelines for the Site Auditor Scheme do not provide threshold levels for TRH or BTEX. As a result, the guidelines in: NSW EPA, 1994, *Contaminated Sites: Guidelines for Assessing Service Station Sites* have been adopted.

It should be noted that any soil to be removed from site either as part of proposed development or as a result of remediation works should be classified in accordance with *Environmental Guidelines: Assessment, Classification, and Management of Liquid and Non-Liquid Wastes* (NSW EPA, 1999), and be disposed of at an appropriately licensed waste facility.

8. LABORATORY TESTING

Out of a total of 16 samples collected from the site, 14 soil samples and one duplicate soil sample were analysed at a NATA registered laboratory for a range of analytes, including heavy metals, polycyclic aromatic hydrocarbons (PAH), total recoverable hydrocarbons (TRH), and monoaromatic hydrocarbons (BTEX). Results of the laboratory analyses are summarised in Tables 1 to 3. Laboratory reports are provided in Appendix C.

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Table 1 - Results of Analysis for Heavy Metals

Sample	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	Nickel (mg/kg)	Zinc (mg/kg)
Filling								
B1/0.5	<5	<1	18	50	130	0.16	47	150
B2/0.5	<5	<1	10	220	22	0.06	9	110
B3/0.5	8	1	14	100	290	0.16	9	270
B3/1.5	13	1	20	840	190	0.56	32	910
B4/0.5	5	<1	9	210	550	1	14	240
B4/2.5	-	<1	16	140	160	-	6	410
B5/0.5	6	<1	7	200	100	0.14	11	210
B6/0.5	-	<1	12	230	750	-	11	770
B6/1.5	7	<1	9	440	120	0.14	25	160
Z10-B4/0.5	-	<1	8	180	380	-	11	170
In situ soil								
B1/1.5	<5	<1	9	<3	21	<0.05	<4	19
B2/1.5	<5	<1	16	16	24	0.07	<4	37
B3/3.0	9	1	16	360	620	0.24	16	890
Guideline 1	**500**	**100**	**500**	**5000**	**1500**	**75**	**3000**	**35000**
Guideline 2	**10**	**2**	**10**	**-**	**10**	**0.4**	**4**	**-**
Guideline 3	**100**	**20**	**100**	**-**	**100**	**4**	**40**	**-**
Guideline 4	**400**	**80**	**400**	**-**	**400**	**16**	**160**	**-**

Guideline 1 NSW EPA, 1998, *Contaminated Sites: Guidelines for the NSW Site Auditor Scheme - Column 4: Commercial or Industrial.*

Guideline 2 NSW EPA, 1999, *Environmental Guidelines: Assessment, Classification, and Management of Liquid and Non-Liquid Wastes - Inert Waste Criteria CT1 (without TCLP)*

Guideline 3 NSW EPA, 1999, *Environmental Guidelines: Assessment, Classification, and Management of Liquid and Non-Liquid Wastes - Solid Waste Criteria CT2 (without TCLP)*

Guideline 4 NSW EPA, 1999, *Environmental Guidelines: Assessment, Classification, and Management of Liquid and Non-Liquid Wastes - Industrial Waste Criteria CT3 (without TCLP)*

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Table 2 - Results of Analysis for PAH

Sample	B(a)P (mg/kg)	Total PAH (mg/kg)
Filling		
B1/0.5	0.61	6.65
B3/1.5	**5.7**	63.34
B4/2.5	**16**	**164.1**
B6/1.5	**62**	**731.5**
95% UCL	**54**	**633**
In situ soil		
B3/3.0	2.5	30.68
Guideline 1	**5**	**100**
Guideline 2	**0.08**	**200**
Guideline 3	**0.8**	**200**
Guideline 4	**3.2**	**800**

Guideline 1	NSW EPA, 1998, *Contaminated Sites: Guidelines for the NSW Site Auditor Scheme - Column 4: Commercial or Industrial.*
Guideline 2	NSW EPA, 1999, *Environmental Guidelines: Assessment, Classification, and Management of Liquid and Non-Liquid Wastes - Inert Waste CT1 and SCC1*
Guideline 3	NSW EPA, 1999, *Environmental Guidelines: Assessment, Classification, and Management of Liquid and Non-Liquid Wastes - Solid Waste CT2 and SCC2*
Guideline 4	NSW EPA, 1999, *Environmental Guidelines: Assessment, Classification, and Management of Liquid and Non-Liquid Wastes - Industrial Waste CT3 and SCC3*
95% UCL	95% Upper Confidence Level in the detection of contamination 'hotspots' of specified diameters

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Table 3 - Results of Analysis for TRH and BTEX

Sample	TRH C6-C9 (mg/kg)	TRH C10-C14 (mg/kg)	TRH C15-C28 (mg/kg)	TRH C29-C40 (mg/kg)	Benzene (mg/kg)	Toluene (mg/kg)	Ethyl Benzene (mg/kg)	Xylene (mg/kg)
Filling								
B1/0.5	<20	<20	<50	<50	<0.5	<0.5	<0.5	<1.5
B3/0.5	<20	<20	360	360	<0.5	<0.5	<0.5	<1.5
B4/2.5	<20	<20	530	280	<0.5	<0.5	<0.5	<1.5
B6/1.5	<20	<20	**4000**	**3600**	<0.5	<0.5	<0.5	<1.5
In situ soil								
B3/3.0	<20	<20	68	73	<0.5	<0.5	<0.5	<1.5
Guideline 1	**65**	**1000**			**1**	**1.4**	**3.1**	**14**
Guideline 2	**650**	**5000**			**1**	**28.8**	**60**	**100**
Guideline 3	**650**	**10000**			**10**	**288**	**600**	**1000**

Guideline 1 NSW EPA, 1994, *Contaminated Sites: Guidelines for Assessing Service Station Sites*
Guideline 2 NSW EPA, 1999, *Environmental Guidelines: Assessment, Classification, and Management of Liquid and Non-Liquid Wastes - Inert Waste CT1 and SCC1*
Guideline 3 NSW EPA, 1999, *Environmental Guidelines: Assessment, Classification, and Management of Liquid and Non-Liquid Wastes - Solid Waste CT2 and SCC2*
95% UCL 95% Upper Confidence Level in the detection of contamination 'hotspots' of specified diameters

Due to the substantially elevated TRH levels detected in sample B6/1.5, which is in excess of one order of magnitude above the TRH levels of other samples, calculation of 95% UCL averages for the filling material is not considered appropriate.

8.1 QA/QC Procedures and Results

Quality assurance/quality control procedures comprised an integral part of this contamination assessment, and included both field and laboratory QA/QC procedures.

8.1.1 Field QC Procedures

The field QC comprised duplicate sampling, and approximately 10% additional samples were obtained during the course of sampling. Of a total of 16 test samples obtained from the subject site, one of these was a duplicate sample (Z10=B4/0.5). The duplicate, Z10, was analysed for heavy metals and the comparative results of analysis are included in Table 1.

The results indicate a generally acceptable consistency between the sample and the duplicate. The results indicated an RPD of between 0-37%. In general, a relative percentage difference (RPD) of ±30% is generally considered acceptable by NSW EPA. A review of the analytical results indicates that the RPD values of lead (37%) and zinc (34%) exceeded the guideline value. In view of the relatively low levels of lead and zinc contaminants detected, in comparison with the criteria levels, the RPD values will not compromise the assessment results.

8.1.2 Laboratory QA/QC Procedures

The analytical laboratory is certified by the National Association of Testing Authorities (NATA) and required to conduct in-house QA/QC procedures. These are normally incorporated into every analytical run and include the following:-

Reagent Blank

A reagent blank sample is prepared and analysed at the beginning of every analytical run, following calibration of the analytical apparatus. The laboratory results for reagent blanks for soil analyses indicated concentrations of all analytes to be below respective laboratory practical quantitation (detection) limits. These results are included in the laboratory report in Appendix C.

Spike/Recovery

Spike/recovery samples are prepared by adding a known amount of a particular analyte or analytes prior to analysis, and then treated in exactly the same manner as all other samples. The recovery results indicate the proportion of the known concentration of the target analyte, which is detected during analysis. A range of 70-130% is generally considered acceptable by laboratory quality control.

The spike/recovery results for this range of analyses fall within the range of 70-130%. On this basis, the analytical results obtained are considered to be acceptable. The laboratory report is provided in Appendix C.

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9. PROPOSED DEVELOPMENT

Details of the proposed development are not known at this stage, however, it is anticipated that the site will be used for industrial use.

10. COMMENTS

10.1 Heavy Metals

The laboratory results for heavy metals are included in Table 1.

The results indicate that concentrations of all heavy metals are below the NSW EPA guidelines for commercial or industrial sites. On this basis, the potential impacts due to heavy metals, with respect to the proposed commercial/industrial development are minimal, and the site is assessed to be not impacted by heavy metals.

10.2 PAH

The laboratory results for polycyclic aromatic hydrocarbons are included in Table 2.

The results indicate exceedences of guideline levels in filling materials in Bores 3, 4, and 6. Given that a sample from the natural clays was tested for PAH and indicated no elevated levels, it is anticipated that the contamination is limited to the filling materials, in particular the slag material identified at B6/1.5, and does not extend to the underlying natural clays. The 95% UCL for benzo(a)pyrene and total PAH also exceeded guideline levels. As a result, it is considered that the filling material at these locations is not suitable for the intended commercial/industrial use.

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10.3 TRH and BTEX

The laboratory results for TRH and BTEX are included in Table 3.

The results indicate that concentrations of all BTEX are below the NSW EPA guidelines for service station sites (also the guidelines for industrial/commercial sites) and as a result, the potential for contamination of the site with BTEX is considered to be minimal. There was, however, an exceedence of the guidelines for TRH in a sample of filling material at B6/1.5. A review of the analytical findings indicates that the TRH levels at sample B6/1.5 are substantially higher than the TRH levels detected at other locations. As a result, it is considered that the filling material in the vicinity of Bore 6 should be considered as a localised hotspot. The material is not suitable for the intended commercial/industrial use.

10.4 Classification for Waste Disposal

Whilst the extent of any proposed excavation is not known at this stage, the results of laboratory analysis were assessed to provide a preliminary classification for disposal to landfill. The results of the preliminary assessment indicated that:

- there are concentrations of lead in some of the filling and natural samples which exceed the screening criteria for Industrial Waste (without conducting leachability testing), and
- there are concentrations of benzo(a)pyrene and Total PAH in some of the filling and natural samples which exceed the screening criteria for Industrial Waste (without conducting leachability testing).

On the basis of the above results, and without leachability tests to complete the waste classification, the material is potentially classifiable as Hazardous Waste, which requires treatment on site prior to being acceptable for disposal to landfill. It should be noted that this a preliminary classification only, and following additional investigation including TCLP tests to characterise the materials, a more favourable classification may be available to some, or all, of the materials.

It should be noted, however, that the concentration levels of benzo(a)pyrene substantially exceeded the total concentration criteria for Industrial Waste. It is therefore considered that the PAH contaminants would need to be treated by micro-encapsulation prior to disposal. The NSW EPA's consent on the treatment process is also required.

10.4 Summary of Contamination Assessment

The results of the assessment indicated that:

- there is no evidence of elevated levels of heavy metals or BTEX in the soils or filling in exceedence of the guidelines for industrial sites;
- there are elevated levels of benzo(a)pyrene, total PAH, and TRH in up to three samples representing the filling materials;

It is considered that the filling materials indicating exceedences are unsuitable for the intended commercial/industrial landuse. The site requires remediation to remove the unsuitable materials prior to being considered suitable for the proposed use. The remediation could involve:

- removal of the contaminated filling material,
- validation of the remaining substrate to ensure complete removal of the contaminated filling material, and
- classification of the excavated material and approval for disposal off site to an appropriately licensed landfill by a licensed contractor.

It is further noted that the elevated level of TRH in one of the samples from near the AST may indicate contamination from the AST. It is recommended that upon removal of the AST and the concrete bund, that the underlying filling materials be inspected to assess whether there are any signs of obvious contamination from the AST.

It is anticipated that the area occupied by the substation in the south west corner of the site will not be part of any development until the completion of the lease in 2011. In the event that this area is to be part of proposed development, it is recommended that assessment be undertaken

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in this area to verify the presence, or otherwise, of contaminants associated with electrical substations, namely polychlorinated biphenyls (PCB).

11. LIMITATIONS TO THIS REPORT

Douglas Partners (DP) have performed investigation and consulting services for this project in accordance with current professional and industry standards for environmental site assessments. The scope of the site assessment activities were limited to those detailed in the proposal dated 27 August 1999.

DP's assessment is necessarily based on the result of a limited program of sample screening and chemical testing which were set out in the proposal.

This report and associated documentation and the information herein have been prepared solely for the use of P & C Consulting Pty Ltd, based on the understood intentions for site use at the time, and any reliance assumed by third parties on this report shall be at such parties' own risk.

DOUGLAS PARTNERS PTY LTD

Reviewed by

Roberta Lindbeck
Geotechnical Engineer

Ronnie Tong
Manager Environmental Services

APPENDIX A
Notes Relating to this Report
Drawing 1 – Site Plan

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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 (MPa) = (0.4 to 0.6) N (blows per 300 mm)

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

q_c = (12 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.