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3 June 2021
Our ref: MT/C11805

Morris Property Group
50 Blackall Street
Barton ACT 2600

Attention: Matthew Hall

Dear Sir

NATIONAL CAPITAL MOTORS
BLOCKS 11 &12, SECTION 10 – BELCONNEN, ACT

GEOTECHNICAL INVESTIGATION REPORT

We are pleased to present our geotechnical investigation report for the upgrades of the National Capital Motors buildings located on Blocks 11 & 12, Section 10, Belconnen, ACT.

The report outlines the methods and results of exploration, describes site subsurface conditions and provides recommendations for building footing design, excavation conditions, preparation of subgrades, stability of cut and fill batters, provides indicative design CBR values, and site drainage advice.

Should you require any further information regarding this report, please do not hesitate to contact our office.

Yours faithfully
ACT Geotechnical Engineers Pty Ltd

Jeremy Murray
Director
Senior Geotechnical Engineer

MORRIS PROPERTY GROUP

NATIONAL CAPITAL MOTORS
BLOCKS 11 &12, SECTION 10 – BELCONNEN, ACT

GEOTECHNICAL INVESTIGATION REPORT

JUNE 2021

MORRIS PROPERTY GROUP

NATIONAL CAPITAL MOTORS
BLOCKS 11 &12, SECTION 10 – BELCONNEN, ACT

GEOTECHNICAL INVESTIGATION REPORT

TABLE OF CONTENTS

MORRIS PROPERTY GROUP

NATIONAL CAPITAL MOTORS
BLOCKS 11 &12, SECTION 10 – BELCONNEN, ACT

GEOTECHNICAL INVESTIGATION REPORT

1 INTRODUCTION

At the request of Matthew Hall of Morris Property Group (MPG), ACT Geotechnical Engineers Pty Ltd carried out a geotechnical investigation for the proposed upgrades of the National Capital Motors complex, located at Blocks 11 & 12 of Section 10, Belconnen, ACT.

The project involves the construction of a single-level car showroom with roof top parking, sales office, work shop and staff amenities building.. The aim of the investigation was to:

(i) Identify subsurface conditions including the extent and nature of any fill materials, soil strata, bedrock type and depth, and groundwater presence.

(ii) Advise on excavation conditions and suitability of excavated material for use as structural fill.

(iii) Provide site classification to AS2870 "Residential Slabs & Footings".

(iv) Advise on suitable footings systems, founding depths, allowable bearing pressures and design parameters for ground slabs.

(v) Provide guidelines for construction of controlled fill platforms.

(vi) Advise on stable batter slopes and temporary excavation support (shoring)

(vii) Provide Retaining wall design parameters.

(viii) Provide subgrade CBR value(s) for pavement design.

(ix) Drainage and other geotechnical advice.

2 SITE DESCRIPTION & GEOLOGY

The site is located at 11 and 15 Josephson Street, in Belconnen, ACT. The 6,828m^3, site is presently occupied by existing show rooms and work shop buildings, surrounded by concrete pavements, which will be partially demolished to make way for the proposed development. Figure 1 shows the site locality. Figure 2 is an overlain site plan showing the present site layout.

The 1:100,000 Canberra Geology map (Reference 1) documents the site to be covered by Silurian age Deakin Volcanics bedrock, comprising rhyodacitic ignimbrite and minor volcaniclastic and argillaceous sediments.

3 INVESTIGATION METHODS

To establish the subsurface conditions, an EZ36 mini excavator with a continuous flight auger attachment was used to drill boreholes, designated BH1 to BH5, on 27 May 2021. The subsurface profiles were logged in general accordance with AS1726-2017. The locations of the boreholes are shown on Figure 2, and the detailed logs are included in Appendix A.

Definitions of geotechnical engineering terms used in the report on the borehole logs, including a copy of the USCS chart, are provided in Appendix B.

4 INVESTIGATION RESULTS

4.1 Subsurface Conditions

The subsurface conditions of the proposed development were investigated by five (5) boreholes designated BH1 to BH5. The borehole logs in Appendix A can be referred to for more detail. Investigation boreholes found the subsurface profile to comprise:

Geological Profile	Typical Depth Interval	Description
PAVEMENT	0m to 0.1m/0.24m	CONCRETE
FILL	0.1/0.24 to 1.0/2.5m	Gravelly SAND, Sandy CLAY, Sandy SILT, Clayey SAND; fine to coarse sand, low to high plasticity clay, low plasticity silt, grey-brown, light brown, dark brown mottled light brown, dry to moist, loose to dense, firm to very stiff. Not encountered in BH2.
ALLUVIUM	1.3m/2.5m to 2.5m/6.5m	Sandy Silty CLAY, low to high plasticity, grey, fine to coarse sand, moist less than plastic limit, firm to stiff. Only encountered in BH1 and BH5.
RESIDUAL SOIL	0.1/1.0m/2.5m/4.7m/6.5m to 1.5m/2.8m/4.7m/>7.5m	Sandy CLAY, Clayey SAND; medium to high plasticity, fine to coarse sand, brown, dark brown, light grey mottled light red-brown, with light grey horizons, trace of fine gravel, dry to moist less than plastic limit, medium dense/very stiff.
EXTREMELY WEATHERED BEDROCK	0.4m/1.5m/2.8m/6.0m to >0.8m/1.6m/3.0m/6.5m	DACITE; extremely to highly weathered, light brown. Not encountered in BH5.

Table 1 – Depth to Refusal

Borehole No.	Depth of Fill	Depth to Auger Refusal	Termination Note
BH1	1.3m	3.0m	Refusal on bedrock
BH2	-	0.8m	Refusal on bedrock
BH3	1.0m	1.6m	Refusal on bedrock
BH4	2.2m	6.5m	Refusal on bedrock
BH5	2.5m	>7.5m	-

4.2 Groundwater

Groundwater was only encountered in BH4 at 4.5m depth and the rest of soils were most to dry. However, temporary, perched seepages could be encountered following rainfall within the more pervious soils.

5 DISCUSSION & RECOMMENDATIONS

5.1 Site Classification

Due to the presence of uncontrolled fill materials exceeding 0.4m depth, the site is designated as a Class "P" (problem) site in accordance with AS2870. If the fill is removed, or if footings are founded in the residual, alluvial soil or extremely weathered material below the fill, a Class "M" (moderately reactive) category can be used in design of new footings. The characteristic ground surface movement "ys", as defined by AS2870 for the range of normal soil moisture conditions is estimated to be between 20mm to 40mm for the encountered subsurface profile described in Section 4.

Should earthworks (cut or fill) be undertaken on the site, or other activities which may cause abnormal moisture conditions to impact the soils within or near the building envelope beyond those addressed herein, the site classification shall be reassessed.

5.2 Building Footings

As the site has been classified as Class P, footing design shall be undertaken in accordance with engineering principles, based upon the requirements on AS2870 and the characteristic ground surface movement estimate of 20mm to 40mm.

Footings including thickened sections of slabs must be founded below any topsoil, loose material and uncontrolled fill, into the residual soils. Footings should be inspected by a geotechnical engineer to confirm the ground conditions (see Section 5.6).

If designing footings based on engineering principles, recommended allowable and ultimate end-bearing pressures for various footing systems and likely foundation materials are provided in Table 3 and 4 respectively.

TABLE 3
Recommended Allowable End-Bearing Pressures for Footings

Foundation Material Type	Depth Below Existing Surface Level	Allowable End-Bearing Pressure			Allowable Shaft Adhesion on Bored Piers	
		Strips	Pads	Bored Piers	Downward Loading	Uplift
Existing uncontrolled fill	0.1m/0.2m/ to 1.3m/1.0m/ 2.2m/2.5m	Not applicable				
Newly placed site-won controlled fill	-	100kPa	120kPa	N/A		
Dense/Very Stiff Residual/Alluvial soils	Below 0.1m/1.4m/ 2.5m4.7m	100kPa	120kPa	200kPa	20kPa	10kPa
Extremely weathered material	Below 0.4m/1.5m/ 2.8m/6.0m	300kPa	400kPa	600kPa	60kPa	30kPa

All footings should be inspected and approved by an experienced geotechnical engineer to confirm the foundation material and design values, and to ensure the excavations are clean and stable.

Ground slabs can be constructed on the natural soils, following the removal of any topsoil and uncontrolled fill material. Following excavation to required level, slab areas on soil should be proof-rolled by a pad foot roller to check for any weak, wet or deforming soils that may require replacement. Suitable replacement fill should be compacted in not thicker than 150mm layers to not less than 95%ModMDD.

5.3 Excavation Conditions & Use of Excavated Material

Proposed excavation depths have not been advised. The soils within the upper 1.5m are readily diggable by backhoe and medium sized excavator. However, hard digging conditions due to rock fragments within the soil units ("floaters") could be encountered.

The low/medium plasticity residual/alluvial soils can be used in controlled fill construction of building platforms, although rock particles should be broken down to <75mm size. The existing topsoil should not be used in controlled fill construction.

If imported fill is required, a suitable select fill material would include a low or medium plasticity soil such as clayey sand or gravelly clayey sand, containing between 25% and 50% fines less than 0.075mm size (silt and clay), and no particles greater than 75mm size.

5.4 Stable Excavation Batters

Temporary site excavations to 1.5m depth can be formed near vertical, although any loose fill should be cut back at 1(H):1(V). If required and space allows, deeper temporary cuts can be formed at 1(H):1(V) or benched at 1.5m intervals in soils. A geotechnical engineer should inspect all cut batters during construction to confirm stability. Exposed temporary batters should be protected from the weather by black plastic pinned to the face with link-wire mesh, or similar.

Permanent cut & fill batter slopes should be formed at no steeper than 2(H):1(V) in soil and be protected against erosion by shotcreting, stone pitching or other suitable methods. Alternatively permanent excavations can be supported by structural retaining walls.

5.5 Low Retaining Walls

Retaining walls constructed in an open excavation, with the gap between the excavation face and the wall backfilled later, can be designed for an earth pressure distribution given by:

$$\sigma_h = (K\gamma' h) + Kq$$

where,

σ_h is the horizontal earth pressure acting on the back of the wall, in kPa

K is the dimensionless coefficient of earth pressure; this can be assumed to be 0.4 when the top of the wall is unrestrained horizontally, and 0.6 when the top of the wall is restrained (i.e. by building slabs etc.)

γ' is the effective unit weight of the backfill, and can be assumed to be 20kN/m^3 for a lightly compacted soil backfill

h is the height of the backfill, in metres

q is any uniform distributed vertical surcharge acting on the top of the backfill, in kPa

Apart from structural restraints such as floor slabs, resistance to overturning and sliding of retaining walls is provided by frictional and adhesive resistance on the base, and by passive resistance at the toe of the wall. For a natural soil or controlled fill foundation, an ultimate base friction factor (tanδ) of 0.4, base adhesion (c) of 50kPa, and allowable passive earth pressure coefficient Kp=2.5 can be used for calculation of sliding resistance.

Free-draining granular backfill or synthetic fabric drains should be installed behind all walls. These should connect to weep holes and/or a collector drain, and ultimately to the stormwater system. Granular backfill should be wrapped in a suitable filter fabric to minimise infiltration of silt/clay fines.

5.6 Controlled Fill Construction

For construction of any new fill foundation platforms and road subgrades, it is recommended that:

- Areas be fully stripped of all topsoil and existing uncontrolled fill. Fill could be up to 2.5m deep at the northern end of the site.. Stripped foundations should be proof-rolled by a vibratory pad-foot roller of not less than 9 tonne static mass to check for any weak or wet areas that would require replacement. No fill should be placed until a geotechnical engineer has confirmed the suitability of the foundation.

- Controlled fill comprising suitable site excavated or imported materials of not greater than 75mm maximum particle size, be compacted in not greater than 150mm layers to not less than 95%ModMDD at about OMC.

- Fill placement and control testing be overviewed and certified by a geotechnical engineer at Level 1 or 2 involvement of AS3798 – 2007 "Guidelines on Earthworks for Commercial & Residential Developments" (Reference 3).

5.7 Design CBR Values

On-grade carpark, and access ramp subgrades should be stripped of all topsoil and uncontrolled fill, and soil subgrades then proof-rolled by a pad-foot roller to check for any wet or otherwise weak spots which may require additional removal. Suitable replacement fill can be compacted in not thicker than 150mm layers, to not less than 95%ModMDD.

A design CBR of 3% is recommended for the site. A geotechnical engineer should inspect prepared subgrades to confirm design values, and preferably view a proof-roll to identify any soft spots or other weaknesses.

5.8 Earthquake Site Factor

Table 2.3 of AS1170.4 "Minimum Design Loads on Structures - Part 4: Earthquake Loads" (Reference 4) lists the earthquake acceleration coefficients for major centres to be considered in structural design. The Canberra area has an acceleration coefficient of 0.08.

Section 4.2 of AS1170.4 "Minimum Design Loads on Structures – Part 4: Earthquake Loads" lists the site sub-soil classes to be considered in structural design. The site is classified as a "Class C_e – Shallow Soil Site".

5.9 Site Drainage

Standing water was only encountered in one borehole during the investigation. The permanent groundwater table is expected to be well below expected excavations, although temporary perched seepages will be present following rain, but should be readily controllable through the use of pumps during construction.

Suitable surface drainage should be provided to ensure rainfall run-off or other surface water cannot pond against buildings or pavements. Drainage should be provided behind all retaining walls, and subsoil drains should be installed along the upslope sides of access roads and carparks.

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REFERENCES

1 Abell, R.S., 1992, Canberra (1:100 000 scale geology map), Bureau of Mineral Resources, Commonwealth of Australia.

2 Standards Australia, "AS2870 – Residential Slabs & Footings", 2011.

3 AS3798, "Guidelines on earthworks for commercial and residential developments".

4 Standards Australia, "AS1170.4 – 2007 – Minimum Design Loads on Structures – Part 4 Earthquake Loads".

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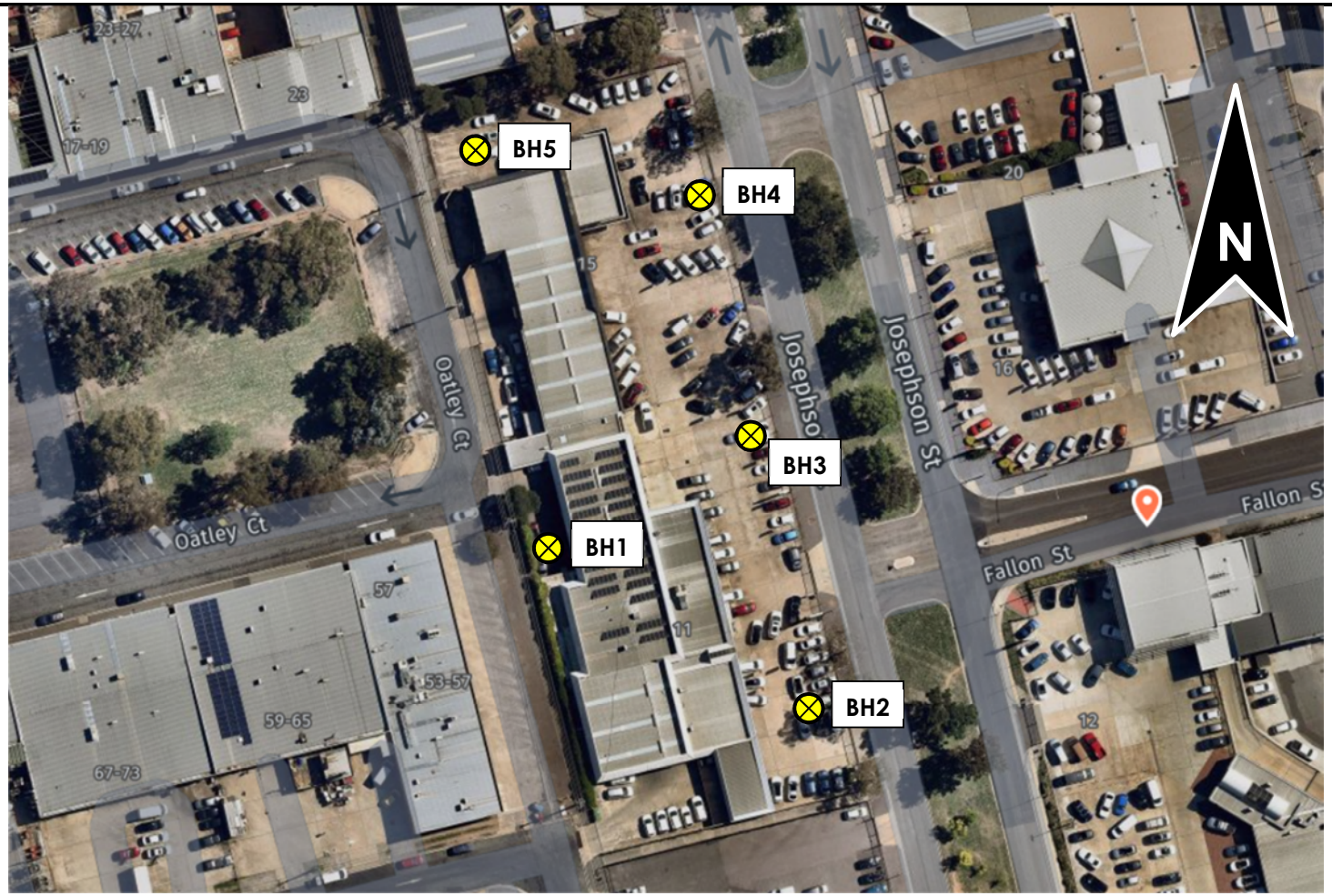
BLOCKS 11 &12, SECTION 10 – BELCONNEN, ACT
SITE LOCALITY

ACT Geotechnical Engineers Pty Ltd	C11805	FIGURE 1



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BLOCKS 11 &12, SECTION 10 – BELCONNEN, ACT
SITE PLAN & BOREHOLE LOCATIONS

ACT Geotechnical Engineers Pty Ltd	C11805	FIGURE 2

APPENDIX A
Borehole Logs BH1 to BH5

Borehole Log

Borehole No.	**BH1**
Sheet	1 of 1
Job No.	C11805

CLIENT: Morris Property Group

PROJECT: Geotechnical Investigation
Blocks 11 & 12 Section 10 Belconnen

Location : Refer to Site Plan

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : EZ36
Hole Diameter : 120mm

Samples	Water	Casing	Depth (Metres)	Graphic Log	U.S.C.S.	Material Description, Structure Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure	Consistency or Relative Density	Field Test Results	Geological Profile
			0.24			CONCRETE			CONCRETE
			0.4		SP	FILL: Gravelly SAND: fine to coarse, grey brown, moist, fine gravel [ROADBASE]	MD		PAVEMENT
			0.75		CH	FILL: Sandy CLAY: medium to high plasticity, light brown, fine to coarse sand, m<pl	St		FILL
			1.0		CLS	FILL: Sandy Silty CLAY; light brown, low to medium plasticity, fine to medium sand, dry	St		
			1.1		SM	FILL: Sandy SILT: low plasticity, dark brown, fine to medium sand, moist	L		
			1.3		CL	FILL: Sandy CLAY: low to medium plasticity, brown, fine to coarse sand, trace fine gravel, m<pl	St		
	Not Encountered		2.0		CL	Sandy SIlty CLAY; low to medium plasticity, grey, fine to medium sand, m<pl, slight hydrocarbon odour	St		ALLUVIUM
			2.5		CH	Sandy CLAY: medium to high plasticity, brown, fine to coarse sand, trace fine gravel, m<pl	VSt		RESIDUAL SOIL
			2.8			DACITE: highly weathered, light brown			WEATHERED ROCK
			3.0			BOREHOLE TERMINATED AT 3m Refusal			
			4.0						

Logged By : MT Date : 27/5/21 | Checked By : JM Date : 28/5/21

BOREHOLE/EXCAVATION LOG C11805 NATIONAL CAPITAL MOTORS.GPJ ACT GEO.GDT 3/6/21

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Borehole Log

Borehole No.	**BH2**
Sheet	1 of 1
Job No.	C11805

CLIENT: Morris Property Group

PROJECT: Geotechnical Investigation
Blocks 11 & 12 Section 10 Belconnen

Location : Refer to Site Plan

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : EZ36
Hole Diameter : 120mm

Samples	Water	Casing	Depth (Metres)	Graphic Log	U.S.C.S.	Material Description, Structure Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure	Consistency or Relative Density	Field Test Results	Geological Profile
	Not Encountered		0.1			CONCRETE			PAVEMENT
					SC	Clayey SAND: fine to coarse, dark brown, dry	MD		RESIDUAL SOIL
			0.4		SC	Clayey SAND; fine to coarse, light brown, dry, friable [EXTREMELY WEATHERED MATERIAL]	VD		EXTREMELY WEATHERED MATERIAL
			0.7			DACITE: highly weathered, light brown			WEATHERED ROCK
			0.8			BOREHOLE TERMINATED AT 0.8m Refusal			
			1.0						
			2.0						
			3.0						
			4.0						

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Borehole Log

Borehole No.	**BH3**
Sheet	1 of 1
Job No.	C11805

CLIENT: Morris Property Group

PROJECT: Geotechnical Investigation
Blocks 11 & 12 Section 10 Belconnen

Location : Refer to Site Plan

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : EZ36
Hole Diameter : 120mm

Samples	Water	Casing	Depth (Metres)	Graphic Log	U.S.C.S.	Material Description, Structure Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure	Consistency or Relative Density	Field Test Results	Geological Profile
	Not Encountered		0.19			CONCRETE			PAVEMENT
					SC	FILL: Clayey SAND: fine to coarse, dark brown, moist	D		FILL
			0.5		CH	FILL: Sandy CLAY: medium to high plasticity, dark brown and grey brown, fine to coarse sand, m<pl	St		
			1.0		CH	Sandy CLAY: medium to high plasticity, light grey brown mottled light red brown, fine to coarse sand, m<pl	St-VSt		RESIDUAL SOIL
			1.4		CH	Sandy CLAY: medium to high plasticity, light grey brown mottled light red brown, fine to coarse sand, dry, friable	VSt-H		
			1.5			DACITE: highly weathered, light brown			WEATHERED ROCK
			1.6			BOREHOLE TERMINATED AT 1.6m Refusal			
			2.0						
			3.0						
			4.0						

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Borehole Log

Borehole No.	**BH4**
Sheet	1 of 2
Job No.	C11805

CLIENT: Morris Property Group

PROJECT: Geotechnical Investigation
Blocks 11 & 12 Section 10 Belconnen

Location : Refer to Site Plan

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : EZ36
Hole Diameter : 120mm

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure	Consistency or Relative Density	Field Test Results	Geological Profile
			0.1			CONCRETE			PAVEMENT
					SW	FILL: SAND: fine to coarse, light brown, with clay, dry	MD		FILL
			0.6		CH	FILL: Sandy CLAY: medium to high plasticity, fine to coarse sand, m<pl	St		
			1.0			becomes light brown mottled grey			
			2.0						
			2.2		CLS	Sandy CLAY: low to medium plasticity, grey and grey brown, fine to medium sand, m=pl	F-St		ALLUVIUM
			3.0						
			4.0						

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Borehole Log

Borehole No.	**BH4**
Sheet	2 of 2
Job No.	C11805

CLIENT: Morris Property Group

PROJECT: Geotechnical Investigation
Blocks 11 & 12 Section 10 Belconnen

Location : Refer to Site Plan

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : EZ36
Hole Diameter : 120mm

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure	Consistency or Relative Density	Field Test Results	Geological Profile
	▽				CLS	Sandy CLAY: low to medium plasticity, grey and grey brown, fine to medium sand, m=pl becomes wet	F-St		ALLUVIUM
			4.7		CH	Sandy CLAY; medium to high plasticity, light brown with light grey horizons, fine to coarse sand	VSt		RESIDUAL SOIL
			5.0						
			6						
			6.0			DACITE: highly weathered, light brown			WEATHERED ROCK
			6.5			BOREHOLE TERMINATED AT 6.5m Refusal			
			7.0						
			8.0						

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Borehole Log

Borehole No.	**BH5**
Sheet	1 of 2
Job No.	C11805

CLIENT: Morris Property Group

PROJECT: Geotechnical Investigation
Blocks 11 & 12 Section 10 Belconnen

Location : Refer to Site Plan

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : EZ36
Hole Diameter : 120mm

Samples	Water	Casing	Depth (Metres)	Graphic Log	U.S.C.S.	Material Description, Structure Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure	Consistency or Relative Density	Field Test Results	Geological Profile
	Not Encountered		0.1			CONCRETE			PAVEMENT
					CLS	FILL: Sandy CLAY: low to medium plasticity, dark brown mottled light brown and grey, fine to coarse sand, trace fine gravel, m<pl	St-VSt		FILL
			1.0			with fine to coarse gravel			
			1.5		CH	Sandy CLAY: medium to high plasticity, brown, fine to coarse sand, trace fine gravel, m<pl. Possible FILL	VSt		Possible FILL
			2.0		CH	Sandy CLAY: medium to high plasticity, brown, fine to coarse sand, trace fine gravel, m=pl. Possible FILL	F-St		
			2.5		CH	Sandy Silty CLAY: high plasticity, grey brown, fine to medium sand, m<pl	F-St		ALLUVIUM
			3.0						
			3.5		CH	Sandy Silty CLAY: high plasticity, grey brown, fine to coarse sand, m<pl	F-St		
			4.0						

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Borehole Log

Borehole No.	**BH5**
Sheet	2 of 2
Job No.	C11805

CLIENT: Morris Property Group

PROJECT: Geotechnical Investigation
Blocks 11 & 12 Section 10 Belconnen

Location : Refer to Site Plan

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : EZ36
Hole Diameter : 120mm

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure	Consistency or Relative Density	Field Test Results	Geological Profile
	Not Encountered				CH	Sandy Silty CLAY: high plasticity, grey brown, fine to coarse sand, m<pl	F-St		
			4.5		CLS	Sandy CLAY: low to medium plasticity, grey and grey brown, fine to medium sand, m=pl	F-St		
			5.0						
			6.0						
			6.5		CH	Sandy CLAY; medium to high plasticity, light brown with light grey horizons, fine to coarse sand	VSt		RESIDUAL SOIL
			7.0						
			7.3		SC	Clayey SAND: fine to coarse, light brown, dry	VD		
			7.5			BOREHOLE TERMINATED AT 7.5m			
			8.0						

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APPENDIX B
Definitions of Geotechnical Engineering Terms

DESCRIPTION AND CLASSIFICATION OF SOILS

The methods of description and classification of soils used in this report are based on the Australian Standard 1726 – 1993, Geotechnical site investigations. In general, descriptions cover the following properties – soil type, colour, secondary grain size, structure, inclusions, strength or density and geological description.

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

Classification	**Particle Size**
Clay	Less than 0.002mm
Silt	0.002mm to 0.06mm
Sand	0.06mm to 2.00mm
Gravel	2.00mm to 60.00mm
Cobbles	60mm (63mm) to 200mm
Boulders	>200mm

Soils are also classified according to the Unified Soil Classifications System which is included in this Appendix. Rock types are classified by their geological names.

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

Consistency	**Shear Strength su(kPa) (Representative Undrained Shear)**	
Very soft	< 12	<2 (~SPT "N")
Soft	12 - 25	2-4
Firm	25 - 50	4-8
Stiff	50 – 100	8-15
Very Stiff	100 – 200	15-30
Hard	> 200	>30

Non-cohesive soils are classified on the basis of relative density, generally from the results of in-situ standard penetration tests as below:

Term	**Relative Density (%)**	**SPT Blows/300mm 'N'**
Very loose	< 15	<4
Loose	15-35	4-10
Medium dense	35-65	10-30
Dense	65-85	30-50
Very Dense	>85	>50

SAMPLING

Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of 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 generally taken by one of two methods:

1. Driving or pushing a thin walled sample tube into the soil and withdrawing with a sample of soil in a relatively undisturbed state.

2. Core drilling using a retractable inner tube (R.I.T.) core barrel.

Such samples yield information on structure and strength in additions to that obtained from disturbed samples 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.

PENETRATION TESTING

The relative density of non-cohesive soils is generally assessed by in-situ penetration tests, the most common of which is the standard penetration test. The test procedure is described in Australian Standard 1289 “Testing Soils for Engineering Purposes” Testing Soils for Engineering Purposes” – Test No. F3.1.

The standard penetration test is carried out by driving a 50mm diameter split tube penetrometer of standard dimensions under the impact of a 63 kg hammer having a free fall of 750mm.

The “N” value is determined as the number of blows to achieve 300mm of penetration (generally after disregarding the first 150mm penetration through possibly disturbed material). The results of these tests can be related empirically to the engineering properties of the soil.

The test is also used to provide useful information in cohesive soils under certain conditions, a good quality disturbed sample being recovered with each test. Other forms of in situ testing are used under certain conditions and where this occurs, details are given in the report.

DEFINITIONS OF ROCK, SOIL, AND DEGREES OF CHEMICAL WEATHERING

GENERAL DEFINITIONS – ROCK AND SOIL

ROCK In engineering usage, rock is a natural aggregate of minerals connected by strong and permanent cohesive forces.

Note: Since "strong" and "permanent" are subject to different interpretations, the boundary between rock and soil is necessarily an arbitrary one.

SOIL In engineering usage, soil is a natural aggregate of mineral grains which can be separated by such gentle mechanical means as agitation in water, can be remoulded and can be classified according to the Unified Soil Classification System. Three principal classes of soil recognized are:

Residual soils: soils which have been formed in-situ by the chemical weathering of parent rock. Residual soil may retain evidence of the original rock texture or fabric or, when mature, the original rock texture may be destroyed.

Transported soils: soils which have been moved from their places of origin and deposited elsewhere. The principal agents of erosion, transport and deposition are water, wind and gravity. Two important types of transported soil in engineering geology and materials investigations are:

Colluvium – a soil, often including angular rock fragments and boulders, which has been transported downslope predominantly under the action of gravity assisted by water. The principle forming process is that of soil creep in which the soil moves after it has been weakened by saturation. It may be water borne for short distances.

Alluvium – a soil which has been transported and deposited by running water. The larger particles (sand and gravel size) are water worn.

Lateritic soils: soils which have formed in situ under the effects of tropical weathering include all reddish residual and non residual soils which genetically form a chain of material ranging from decomposed rock through clay to sesqui-oxide rich crusts. The term does not necessarily imply any compositional, textural or morphological definition; all distinctions useful for engineering purposes are based on the differences in geotechnical characteristics.

ROCK WEATHERING DEFINITIONS

Extremely Weathered (EW)	Rock substance affected by weathering to the extent that the rock exhibits soil properties, i.e. it can be remoulded and can be classified according to the Unified Classification System, but the texture of the original rock is still evident.
Highly Weathered (HW)	Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance and other signs of the chemical or physical decomposition are evident. Porosity and strength may be increased or decreased compared to the fresh rock usually as a result of iron leaching or deposition. The colour and strength of the original fresh rock substance is no longer recognisable.
Moderately Weathered (MW)	Rock substance affected by weathering to the extent that staining extends throughout the whole of the rock substance and the original colour of the fresh rock is no longer recognisable.
Slightly Weathered (SW)	Rock substance affected by weathering to the extent that partial staining or discolouration of the rock substance, usually by limonite, has taken place. The colour and texture of the fresh rock is recognisable.
Fresh (Fr)	Rock substance unaffected by weathering.

The degrees of rock weathering may be gradational. Intermediate stages are described by dual symbols with the prominent degree of weathering first (e.g. EW-HW).

The various degrees of weathering do not necessarily define strength parameters as some rocks are weak, even when fresh, to the extent that they can be broken by hand across the fabric, and some rocks may increase in strength during the weathering process.

Fresh drill cores of some rock types, such as basalt and shale may disintegrate after exposure to the atmosphere due to slaking, desiccation, expansion or contraction, stress relief or a combination of any of these factors.

AN ENGINEERING CLASSIFICATION OF SEDIMENTARY ROCKS

This classification system provides a standardised terminology for the engineering description of the sandstone and shales in the Sydney area, but the terms and definitions may be used elsewhere when applicable. Where other rock types are encountered, such as in dykes, standard geological descriptions are used for rock types and the same descriptions as below are used for strength, fracturing and weathering.

Under this system rocks are classified by Rock Type, Strength, Stratification Spacing, Degree of Fracturing and Degree of Weathering. These terms do not cover the full range of engineering properties. Descriptions of rock may also need to refer to other properties (e.g. durability, abrasiveness, etc) where these are relevant.

ROCK TYPE DEFINITIONS

ROCK TYPE	DEFINITION
Conglomerate:	More than 50% of the rock consists of gravel sized (greater than 2mm) fragments.
Sandstone:	More than 50% of the rock consists of sand sized (0.06 to 2mm) grains.
Siltstone:	More than 50% of the rock consists of silt-sized (less than 0.06mm) granular particles and the rock is not laminated.
Claystone:	More than 50% of the rock consists of silt or clay sized particles and the rock is not laminated.
Shale:	More than 50% of the rock consists of silt or clay sized particles and the rock is laminated.

Rocks possessing characteristics of two groups are described by their predominant particle size with reference also to the minor constituents, e.g. clayey sandstone, sandy shale.

STRATIFICATION SPACING

Term	Separation of Stratification Planes
Thinly Laminated	< 6mm
Laminated	6mm to 20mm
Very thinly bedded	20mm to 60mm
Thinly bedded	60mm to 0.2m
Medium bedded	0.2m to 0.6m
Thickly bedded	0.6m to 2m
Very thickly bedded	> 2m

DEGREE OF FRACTURING

This classification applies to diamond drill cores and refers to the spacing of all types of natural fractures along which the core is discontinuous. These include bedding plane partings, joints and other rock defects, but exclude known artificial fractures such as drilling breaks.

Term	Description
Fragmented:	The core is comprised primarily of fragments of length less than 20mm, and mostly of width less than the core diameter
Highly Fractured:	Core lengths are generally less than 20mm – 40mm with occasional fragments.
Fractured:	Core lengths are mainly 30mm – 100mm with occasional shorter and longer section.
Slightly Fractured:	Core lengths are generally 300mm – 1000mm with occasional longer sections and occasional sections of 100mm – 300mm.
Unbroken:	The core does not contain any fracture.

ROCK STRENGTH

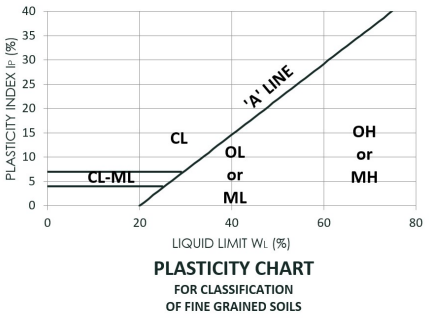
Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance in the direction normal to the bedding. The test procedure is described by the International Society of Rock Mechanics.

Term	Point Load Index Is(50) MPa	Field Guide	Approx qu MPa*
Extremely Weak:	0.03	Easily remoulded by hand to a material with soil properties.	0.7
Very Weak:	0.1	May be crumbled in the hand. Sandstone is “sugary” and friable.	2.4
Weak:	0.3	A piece of core 150mm long x 50mm dia. May be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.	7
Medium Strong:	1	A piece of core 150mm long x 50mm dia. can be broken by hand with considerable difficulty. Readily scored with knife.	24
Strong: (SW)	3	A piece of core 150mm long x 50mm dia. core cannot be broken by unaided hands, can be slightly scratched or scored with knife.	70
Very Strong (SW)	10	A piece of core 150mm long x 50mm dia. may be broken readily with hand held hammer. Cannot be scratched with pen knife.	240
Extremely Strong (Fr)	>10	A piece of core 150mm long x 50mm dia. is difficult to break with hand held hammer. Rings when struck with a hammer.	>240

The approximate unconfined compressive strength (qu) shown in the table is based on an assumed ration to the point load index of 24:1. This ratio may vary widely.

Unified Soil Classification System (Metricated)
Data for Description Indentification and Classification of Soils

MAJOR DIVISIONS				DESCRIPTION				FIELD IDENTIFICATION					LABORATORY CLASSIFICATION				
				Group Symbol	Graphic Symbol	TYPICAL NAME	DESCRIPTIVE DATA						% [2] < 0.06mm	PLASTICITY OF FINE FRACTION			NOTES
COARSE GRAINED SOILS	More than 50% by dry mass, less than 60mm is greater than 0.06mm.	GRAVELS	More than 50% of coarse grains are greater than 2.0mm	GW		Well graded gravels and gravel-sand mixtures, little or no fines	Give typical name, indicate approximate percentages of sand and gravel, maximum size, angularity, surface condition and hardness of the coarse grains, local or geological name and other pertinent descriptive information, symbols in parenthesis. For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics. EXAMPLE: Silty Sand, gravelly, about 20% hard, angular gravel particles, 10mm maximum size, rounded and sub angular sand grains coarse to fine, about 15% non-plastic fines with low dry strength, well compacted and moist in place, light brown alluvial sand, (SM)	Determine approximate percentages of material over 60mm size, maximum size, shape, surface texture, hardness of material, geological description. Identify on estimated percentage mass of the various fractions.	COARSE GRAINED SOILS	More than half of the material less than 60mm is larger than 0.06mm	0.06mm is about the smallest particle visible to the naked eye	GRAVELS AND SANDS	GRADATIONS	NATURE OF FINES	DRY STRENGTH	Group Symbol	Use the gradation curve of material passing 60mm for classification of fractions according to criteria given under 'Major Division'.	0-5	-	>4	Between 1 and 3	1. Identify Fines by the method given for fine grained soils. 2. Borderline classifications occur when the percentage of fines (fraction smaller than 0.06mm size) is greater than 5% and less than 12%. Borderline classifications require the use of dual symbols eg SP-SM GW-GC
				GP		Poorly graded gravels and gravel-sand mixtures, little or no fines						GOOD	Wide range in grain size	"Clean" materials (not enough fines to band coarse grains)	None	GW		0-5	-	Fails to comply with above		
		GRAVELLY SOILS		GM		Silty gravels, gravel-sand-silt mixtures						POOR	Predominantly one size or range of sizes			GP		12-50	Below 'A' line and Ip >7	-	-	
				GC		Clayey gravels gravel-sand-clay mixtures						GOOD TO FAIR	"Dirty" materials (Excess of fines)	Fines are non-plastic (1)	None to medium	GM		12-50	Above 'A' line and Ip > 7	-	-	
		SANDS	More than 50% of coarse grains are greater than 2.0mm	SW		Well graded sands and gravelly sands, little or no fines								Fines are plastic (1)		GC		0-5	-	>6	between 1 and 3	
				SP		Poorly graded sands and gravelly sands, little or no fines						GOOD	Wide range in grain size	"Clean" materials (not enough fines to band coarse grains)	None	SW		0-5	-	Fails to comply with above		
		SANDY SOILS		SM		Silty sand, sand-silt mixtures						POOR	Predominantly one size or range of sizes			SP		12-50	Below 'A' line or Ip < 4	-	-	
				SC		Clayey sands, sand-clay mixtures						GOOD TO FAIR	"Dirty" materials (Excess of fines)	Fines are non-plastic (1)	None to medium	SM		12-50	Above 'A' line and Ip > 7	-	-	
														Fines are plastic (1)		SC						
FINE GRAINED SOILS	More than 50% by dry mass, less than 60mm is less than 0.06mm	Liquid Limit less than 50%		ML		Inorganic silts, very fine sands, rock flour, silty or clayey fine sands.	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, colour in wet condition, odour if any, local or geological name and r pertinent descriptive information, symbols in parenthesis. For undisturbed soil add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions. EXAMPLE Clayey Silt, brown, low plasticity, small percentage of fine sand, numerous vertical root-holes, firm and dry in place, fill, (ML).		FINE GRAINED SOILS	More than half of the material less than 50mm is less than 0.06mm		SILT AND CLAY FRACTION									
				CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.						Fraction smaller than 0 20mm AS sieve size										
				OL		Organic silts and organic silty clays of low plasticity						DRY STRENGTH	DILATANCY	TOUGHNESS								
		Liquid Limit more than 50%		MH		Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts.						None to low	Quick to slow	None		ML		Below 'A' line				
				CH		Inorganic clays of high plasticity, fat clays.						Medium to high	None to very slow	Medium		CL		Above 'A' line				
				OH		Organic clays of medium to high plasticity.						Low to medium	Slow	Low		OL		Below 'A' line				
												Low to medium	Slow to none	Low to medium		MH		Below 'A' line				
												High to very high	None	High		CH		Above 'A' line				
												Medium to high	None to very slow	Low to medium		OH		Below 'A' line				
				Pt		Peat muck and other highly organic soils.		Readily identified by colour, odour, spongy feel and generally by fibrous texture								Pt*	*Effervescence with H2O2					



PLASTICITY CHART
FOR CLASSIFICATION OF FINE GRAINED SOILS

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Limitations in the Use and Interpretation of this Geotechnical Report

Our Professional services were performed, our findings obtained, and our recommendations prepared in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

The geotechnical report was prepared for the use of the Owner in the design of the subject development and should be made available to potential contractors and/or the Contractor for information on factual data only. This report should not be used for contractual purposes as a warranty of interpreted subsurface conditions such as those indicated by the interpretive borehole and test pit logs, cross- sections, or discussion of subsurface conditions contained herein.

The analyses, conclusions and recommendations contained in the report are based on site conditions as they presently exist and assume that the exploratory bore holes, test pits, and/or probes are representative of the subsurface conditions of the site. If, during construction, subsurface conditions are found which are significantly different from those observed in the exploratory bore holes and test pits, or assumed to exist in the excavations, we should be advised at once so that we can review these conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time between conducting this investigation and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, this report should be reviewed to determine the applicability of the conclusions and the recommendations considering the changed conditions and time lapse.

The summary bore hole and test pit logs are our opinion of the subsurface conditions revealed by periodic sampling of the ground as the test holes progressed. The soil descriptions and interfaces between strata are interpretive and actual changes may be gradual.

The bore hole and test pit logs and related information depict subsurface conditions only at the specific locations and at the particular time designated on the logs. Soil conditions at the other locations may differ from conditions occurring at these bore hole and test pit locations. Also, the passage of time may result in a change in the soil conditions at these test locations.

Groundwater levels often vary seasonally. Groundwater levels reported on the boring logs or in the body of the report are factual data only for the dates shown.

Unanticipated soil conditions are commonly encountered on construction sites and cannot be fully anticipated by merely taking soil samples, bore holes or test pits. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. It is recommended that the Owner consider providing a contingency fund to accommodate such potential extra costs.

This firm cannot be responsible for any deviation from the intent of this report including, but not restricted to, any changes to the scheduled time of construction, the nature of the project or the specific construction methods or means indicated in this report: nor can our company be responsible for any construction activity on sites other than the specific site referred to in this report.