

**Transport** Roads & Maritime Services

# Additional crossing of the Clarence River at Grafton

Route Options Development Report Technical Paper – Geotechnical Assessment for Route Options

**SEPTEMBER 2012** 

Roads and Maritime Services

Main Road 83 Summerland Way -Additional Crossing of the Clarence River at Grafton

Geotechnical Assessment for Route Options

August 2012

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 220422/00

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# **Executive Summary**

Roads and Maritime Services (RMS) are currently undertaking investigations to identify an additional crossing of the Clarence River at Grafton to address short-term and long-term transport needs. The objective of this report is to provide a geotechnical assessment of the foundation conditions associated with the six short-listed route options so they can be reasonable compared.

A review of the existing geotechnical information within the vicinity of the preferred route options is presented in this technical paper, and incorporates the results of a geotechnical investigation conducted by Arup in 2012. Geotechnical issues that should be considered for the constructability of the bridge foundations and approaches at each of the route options are:

- The existence of gravel and cobbles immediately above the rock.
- The existence of any loose sand below embankments.
- The existence of any soft clay and organic soils below embankments.
- The depth and quality of rock below the bridge and viaducts.
- Potential ground improvement requirements below proposed approach embankments due to the presence of any soft clay deposits;
- Presence of acid sulphate soils.
- Salinity of channel water and groundwater for durability design.
- The extent of river scour that could be associated around potential piers within the river channel.

It is anticipated that piled foundations will be required for the river crossing piers and approach viaducts associated with each of the route options.

The approximate reduced level (m AHD) for the pile toe for each option, for the approach viaducts and river crossing is shown below.

Route Option	Southern approach viaduct	River crossing piers	Northern approach viaduct
Е	-18	-18 to -33	-33
А	About +5 to -18	-18 to -26	-26
С	-18	-18 to -26	-26
11	-15 to -21	-21 to -23	N/A
14,15	-15 to -23	-23	-23

Ground settlement associated with embankments may be an issue at Options 11, 14 and 15, where some ground improvement may be required. However, these issues are considered manageable.

# 1 Introduction

Roads and Maritime Services (RMS) are currently undertaking investigations to identify an additional crossing of the Clarence River at Grafton to address short-term and long-term transport needs. The objective of this report is to provide a geotechnical assessment of the foundation conditions associated with the six short-listed route options so they can be compared.

This technical paper is an attachment to the Route Options Development Report and will be used to define the preliminary geotechnical conditions for these six short-listed route options. The findings of these investigations will be used as part of the selection of a recommended preferred option.

A desk study review of the existing geotechnical information within the vicinity of the preferred route options is presented in this technical paper, which also incorporates the results of a geotechnical investigation conducted by Arup in 2012.

# **1.1 Project appreciation**

### 1.1.1 Project background

Since the early 1970s there have been various discussions and studies into an additional crossing of the Clarence River near Grafton. A number of these studies have been carried out during the past ten years and provide the background to the current investigation.

In December 2010, RMS commenced a revised process to work more closely with the community to determine the preferred location for an additional crossing. As part of this revised process, a series of public surveys, community forums and meetings with residents and community groups have been held and various studies and project documents released for public viewing and comment.

In June 2011, RMS released the Feasibility Assessment Report, which describes the assessment undertaken by RMS on the 41 route suggestions identified by the community following the announcement of the revised process in December 2010. The report identifies 25 preliminary options within five strategic corridors to go forward for further engineering and environmental investigation.

Between June 2011 and January 2012, RMS carried out investigations in the Grafton area and surrounds to identify constraints relevant to an additional crossing of the Clarence River. The outcomes of these investigations, community comment and a community and stakeholder evaluation workshop provided the inputs to the selection of the short-list of options.

In January 2012, six route options to be investigated further as part of the process to identify a location for the crossing were announced (as shown in Figure 1). The short-listed options were identified in the *Preliminary Route Options Report* – Final (RMS, January 2012) which also provided details of the technical investigations undertaken on the 25 preliminary options and the process to select the short-listed options.

#### Figure 1 Route Options Location Plan



### **1.1.2 Route options**

The proposed form of the approaches and bridge for each option (as presented on Figure 1) has been described below.

For the purposes of this investigation, the results are discussed relevant to three areas:

- Northern Bank (Grafton side of the Clarence River);
- River Channel;
- Southern Bank (South Grafton side of the Clarence River).

Route	Proposed features					
Option	Southern bank approach	River channel crossing	Northern bank approach			
Е	High approach embankment over paddocks from Cowan Street, South Grafton.	The proposed bridge would be 618 metres long and 15.9 metres wide and would be on a constant large radius horizontal curve (1400 metres radius) over the Clarence River for the majority of its length; with a horizontal curve on the last two spans on the Grafton side. The current preliminary concept design for the bridge would provide a 39.5 metre span on the South Grafton side, followed by 11 spans of 49 metres across the river, and another 39.5 metre span on the Grafton side. There would also be a 68 metre long approach viaduct (with two 34 metre long spans) on the Grafton side.	Small viaduct structure (on piers) that grades into minor embankment onto Villiers Street, Grafton.			
Α	Generally at grade with some minor earthworks associated with the abutment on BentThe proposed approximately and 17.7 metre would be a str the Clarence F The current pr design for the provide five 7- spans across th the existing br 61 metre long spa side. There wo metre long spa side. There wo metre long approximately on the Grafton		Viaduct (on piers) grading into a minor embankment into Fitzroy Street, Grafton.			

#### Table 1 Route option features

Route	Proposed features				
Option	Southern bank approach	River channel crossing	Northern bank approach		
С	Approach embankment located within paddocks. A high embankment is also associated with the connection to the Pacific Highway to the south.	The proposed bridge would be approximately 458 metres long and 15.9 metres wide and would be on a constant very large radius horizontal curve (4500 metres radius) over the Clarence River. The current preliminary concept design for the bridge would provide a 44 metre span on the South Grafton side, followed by five 74 metre long spans across the river to match the existing bridge, and a 44 metre long span on the Grafton side. There would also be approach viaducts on either side of the bridge; 64 metres long (with two 32 metre	Viaduct (on piers) grading into a minor embankment between the river bank and Pound Street, Grafton.		
		long spans) on the South Grafton side, and 58 metres long (with two 29 metre long spans) on the Grafton side.			
	High approach embankment associated with the connection to the Pacific Highway, extending half way across the flood plain. The remaining half of the flood plain approaching the river is a large viaduct structure on piers.	The proposed bridge would be approximately 387 metres long and 15.9 metres wide, and would be a straight crossing of the Clarence River. The current preliminary concept design for the bridge would provide eight spans of 48.4 metres across the river. There would also be a 340 metre long approach viaduct on the South Grafton side across the floodplain (with ten 34 metre long spans). In addition to these structures,	High embankment grading to existing road level on Fry Street, Grafton.		
		an additional shorter 110 metre long viaduct would be required to cross a small creek on the South Grafton side, near the Pacific Highway.			

### Table 1 Route option features

Route	Proposed features					
Option	Southern bank approach	River channel crossing	Northern bank approach			
14	High approach embankment associated with the connection to the Pacific Highway. Over the flood plain, a high viaduct structure on piers extends to the river crossing bridge.	The proposed bridge would be 617 metres long and 16.3 metres wide and would be a straight crossing of the Clarence River. The current preliminary concept design for the bridge would provide eleven spans of 53 metres across the river, followed by a 34 metre long span on the Grafton side. There would also be a 782 metre long approach viaduct (with 23 spans of 34 metres) on the South Grafton side across the floodplain. On the Grafton side, there would be a 136 metre long approach viaduct (with four spans of 34 metres). In addition to these structures, there would also be three other shorter bridges for creek crossings.	Small viaduct structure (on piers) that grades into a low embankment onto Kirchner Street, Grafton. Further low embankments are associated with the proposed road and two short creek crossings along North Street, Grafton.			
15		The proposed river bridge would be the same as in Option 14 (617 metres long and 16.3 metres wide and would be a straight crossing of the Clarence River). The current preliminary concept design for the bridge would also be the same as Option 14; with eleven spans of 53 metres across the river, followed by a 34 metre long span on the Grafton side. The approach viaducts would also be the same as Option 14; with a 782 metre long approach viaduct (with 23 spans of 34 metres) on the South Grafton side across the floodplain, and a 136 metre long approach viaduct (with four spans of 34 metres) on the Grafton side. In addition to these structures, there would also be four other shorter bridges for creek crossings.	Small viaduct structure (on piers) that grades into a low embankment onto Kirchner Street, Grafton. Further low embankments beyond the bridge approach associated with a new road linking to the Summerland Way north of Grafton. One area has higher embankments associated with an un- named creek crossing.			

Table 1 Route option features

# **1.2** Scope of report

This report supports the Route Options Development Report and will be used to define the geotechnical foundation conditions for the six short-listed route options and used as part of the selection of a preferred option.

A number of geotechnical investigations have been carried out across the area covered by the route options since 1975. An additional geotechnical investigation was carried out by Arup in March 2012 to supplement the existing geotechnical information, particularly where gaps in data existed. A summary is provided of all geotechnical information relevant to the project in Section 3 of this report.

This report presents a geotechnical assessment of the foundation conditions for each of the route options. The assessment is a high level review to provide founding levels and to identify high risk areas to input into the costing of each of the route options.

No geotechnical parameters for design are presented as part of this report. Once the preferred route option is identified, a detailed geotechnical investigation will be carried out and design parameters will be developed.

### 1.3 Limitations

This report contains an interpretation of existing available geotechnical information of the site. The ground is a product of continuing natural and manmade processes and therefore exhibits a variety of characteristics and properties which vary from place to place and can change with time. No warrantee can be given for the information used and no responsibility is undertaken.

The geotechnical assessment was based on the current preliminary concept design for the bridge and may be refined with further development of the option during the detailed design of the preferred route. The work undertaken, combined with information available from other sources and previous field investigations, is considered suitable for a comparative assessment of the six route options.

# 2 Desk study review

# 2.1 Topography

The route options are located within the flood plain of the Clarence River. The Clarence River forms a meander between Grafton and South Grafton where the river runs through the Clarence Valley. The Clarence River and Grafton are at reduced levels of below 10m AHD and are flanked to the east, south and west by hillsides that gently rise to an approximate elevation of 70m AHD.

A number of natural water courses and artificial drainage channels are present within the area.

Historical air photos from 1964 and 1979 have been reviewed as part of the desk study. No significant development has occurred within the area between 1964 up to the present day. In terms of the floodplain morphology, the southern bank area has remained as open paddocks.

A review of historical bank erosion as part of the South Grafton Levee scheme (Cameron McNamara Consultants, 1987) has indicated that no significant widening of the Clarence River has occurred from 1870 to 1979. Between the current rail bridge and the Alipou Creek confluence, approximately 5m of bank erosion has occurred in this time period.

### 2.2 Geology

### 2.2.1 Regional geology

The route options are located within the Clarence-Moreton Basin that has been described by McEvilly *et al* (2004) as a broad, gently dipping basin with localised areas of fold and fault zones. The basin axis trends north-south and runs in close proximity to Grafton. Geological units in the basin comprise terrestrial sandstone and shale with minor conglomerate and coal (McEvilly *et al* (2004)).

### 2.2.2 Local geology

The Grafton 1:250 000 scale geological Sheet 56-6 (Brunker and Chesnut, 1976), indicates that the bedrock underlying the route options is the Jurassic to Cretaceous period, Grafton Formation, comprising sandstone, siltstone, claystone and minor coal.

The geological map indicates that Quaternary Alluvium overlies the Grafton Formation at the route options. The Alluvium is described as stream alluvial deposits that are sandy to silty with minor gravels. In addition, Packham (1969), states that boulder beds are present in the Clarence River near Grafton.

The anticipated geology underlying the route options is presented as Figure 2.

The Grafton Area 1:25,000 Coastal Quaternary Geology Map (2008) indicates the route options are underlain by alluvial deposits that have been sub-classified depending on their position relative to the Clarence River. The surface alluvial deposits are Holocene in age and occur within the active depositional system associated with the Clarence River flood plain.

#### Figure 2 Anticipated Site Geology



Figure 3 Schematic Cross Section of Meandering River System Morphology and Ground Conditions



Figure 3 presents a conceptual schematic cross section detailing the anticipated ground conditions associated with meandering river systems.

It is anticipated that towards the north of the river, Holocene channel levee deposits (fluvial sand, silt and clay) overlie Holocene in channel bar deposits (fluvial sand, silts, gravels and clay). The river channel is anticipated to comprise fluvial sand, gravel, silt and clay. To the south of the river, Holocene levee deposits are anticipated to overlie Holocene in channel bar deposits beyond which Holocene flood plain deposits (fluvial sand, silt and clay) overlie Pleistocene deposits (clay, silt, fluvial sand and marine sand).

An extract of the Grafton Quaternary geology map is presented as Figure 4.

It is anticipated that the geotechnical characteristics between the Holocene and Pliestocene deposits would differ. A generalised distinction between the Holocene and Pleistocene deposits is summarised as follows (Troesdson and Hashimoto (2008)):

Holocene alluvial deposits have minimal weathering, are generally loose to firm in consistency, friable when moist, and brown to brown grey in colour.

Pleistocene alluvial deposits exhibit substantial dissection and weathering, are generally stiff to very stiff in consistency with well defined soil structure, plastic when moist and orange to red orange brown in colour and intensely mottled.

### 2.3 Acid sulfate soil

Typically acid sulphate soils are found in the following environments/conditions:

- Holocene (most recent part of Quarternary) sediments.
- Soil horizons less than 5mAHD.
- Marine or estuarine sediments and tidal lakes.
- Coastal wetlands or back-swamp area, coastal sand dunes.
- Mangrove or other swamp-tolerant or marine vegetation is dominant.
- Deep older (Holocene or Pleistocene) estuarine sediments >10m below ground surface.
- Sediments/rock with sulphide bearing minerals, coal deposits or former marine shales/sediments.

The 1:25,000 scale Grafton Acid Sulfate Risk Soil Map (1997) indicates that the route options are in areas of high and low probability of acid sulphate soil risk (Figure 5).

#### Figure 4 Anticipated Quaternary Geology



#### Figure 5 Acid Sulfate Soil Risk



A high probability of acid sulphate soil is associated with the river channel sediments and the alluvial plain deposits beyond the southern bank adjacent to the Pacific Highway. A low probability of acid sulphate soil is associated with the alluvial levee and alluvial plain deposits on the northern bank, through Grafton, and the alluvial levee and alluvial plain deposits along the southern bank adjacent to the river.

Limited existing acid sulphate soil screening has indicated a low potential for acid sulphate soil and pH testing generally indicates that the alluvial deposits are acidic. Groundwater testing recorded pH over 6.

### 2.4 Salinity

The Australian Dryland Salinity Risk for 2000, 2020 and 2050 (NLWRA, 2000) does not indicate a high hazard or risk of dryland salinity within the area of the route options.

Based on the Clarence River Fact Sheet (produced by oceanwatch.org), the tidal limit reaches over 100km inland up to Copmanhurst and it is therefore anticipated that the channel water and groundwater at Grafton may be saline.

### 2.5 River scour

A scour investigation carried out by the Bridge Maintenance Engineer in 2003 recorded up to 7m and 5m of scour on the downstream and upstream sides (respectively) of Piers 2, 3 and 4. A gap was reported under part of an unspecified pier.

Based on the assumed as built drawing, one pier location was constructed within the river channel deposits (towards the north of the bridge). Based on the anticipated river erosion (towards the southern bank) it is considered that the formation of a gap below this pier would be unlikely as further sediment deposition is likely to occur towards the northern river bank.

# **3** Geotechnical investigations

### **3.1 Existing geotechnical information**

As part of the 2003 Route Selection Study a desk study and geotechnical investigation was carried out by the then Roads and Traffic Authority (RTA) for seven crossing locations between Susan Island and Elizabeth Island. The following information from the RTA 2003 Geotechnical Investigation Route Selection Report (refer to Appendix F of the Environmental Overview Report, RTA, January 2004) has been reviewed:

- Seven boreholes from a geotechnical investigation carried out in 1975. Five of which are located within the river channel to the east (downstream) of route options A and C;
- A geological cross-section marked on an assumed as-built drawing for the original bridge based on 17 boreholes (attached to RTA report G3510, Geotechnical Investigation at Concept Stage dated 26 October 2003, of which the cross section is produced in Appendix A of this report);
- Four boreholes and seven test pits carried out by the RTA as part of the route selection investigation, 2003;
- Limited geotechnical laboratory testing carried out on test pit samples from the 2003 investigation;
- Bridge pier scour depth investigation.

The existing borehole and test pit locations from both the 1975 and 2003 investigations are presented on Figure 6 and copies of the borehole logs, test pits, as-built cross-section and scour report are reproduced in Attachment A.

In addition to the 2003 route selection geotechnical investigation the following historical geotechnical investigations have been reviewed:

Coffey and Partners Pty Ltd (1981), Clarence River Flood Mitigation Assessment of Bank Stability (part of which is attached to RTA Report G3510 in Attachment A). The investigation comprised 12 boreholes, with associated laboratory testing, along the alignment of the proposed levees in close proximity to the current route options. Acid sulphate soil screening was carried out that generally indicated a low potential for acid sulphate soil. However, two samples showed reaction and were scheduled for laboratory testing. Only the sample from GB7 showed actual acid sulphate soil. Thirteen soil samples were tested for pH with results ranging between 3.5 to 5 and two samples from the boreholes that recorded pH over 5. The results generally indicate that the alluvial deposits are acidic. Groundwater testing recorded pH over 6;

Peter J.Burgess & Associates Pty Ltd (1987), South Grafton Levee Geotechnical Investigation Report (part of which is attached to RTA Report G3510 in Attachment A). The investigation comprised 7 boreholes along the proposed levee upgrade alignments, of which BHSG1 to BHSG5 (with associated laboratory testing) are located near current route options E, A and C.

### **3.2** Supplementary geotechnical investigation

A supplementary geotechnical investigation was carried out by Arup in March 2012. The investigation was carried out to supplement the existing data, particularly where gaps in knowledge from previous investigations exist.

The March 2012 geotechnical investigation locations are presented on Figure 6.

The supplementary geotechnical investigation was to provide a comparable level of geotechnical information for each route option so a comparative assessment can be made.

Prior to this route options investigation, there was sufficient existing geotechnical information as follows:

- In the vicinity of the existing Grafton Bridge;
- For the flood plain area on the south side of the river, downstream of the existing Grafton Bridge and this can be extrapolated, to an extent, to interpret ground conditions along the three route options that cross the flood plain (Options 11 and 14/15).

There was no existing geotechnical borehole data for the Grafton side of the river and the area north to Great Marlow.

Therefore, to supplement the existing information, the supplementary investigation concentrated on the northern bank with five boreholes located at route options E, 11, 14 and 15. One borehole was located on the floodplain on the southern river bank in close proximity to route Options 14/15 to provide information on the anticipated rock level in this area.

A land based gravity survey was carried out on the south side of the Clarence River for route options 11 and 14/15. The aim of the gravity survey was to profile the top of the bedrock to the south east of the river up to the Pacific Highway and correlate the findings to the nearest boreholes. This will enable a more accurate estimation of the depth of piles along the floodplain covered by these options.

The factual geotechnical information associated with the current investigation is presented in Arup's Ground Investigation Data Report. The information regarding the type of investigation, methodology, in situ testing, borehole logs and laboratory test results will not be repeated herein and the reader is referred to the factual report presented in Attachment B for these details.



### Figure 6 Existing and Current Geotechnical Investigation Location Plan

### **3.3** Geotechnical laboratory testing

Geotechnical laboratory testing was carried out as part of the existing and current investigations on the alluvial deposits. Testing included Atterberg Limits, particle size distributions, oedometer testing, triaxial testing (both quick undrained and consolidated undrained with pore water measurements) and California Bearing Ratios (CBRs). The laboratory testing conducted as part of the March 2012 investigation is presented in Arup's Ground Investigation Data Report in Attachment B.

No interpretation of the laboratory testing has been carried out in this report.

# 4 **Ground conditions**

### 4.1 General

The sub-surface ground conditions have been split into three geomorphological areas of the Clarence River flood plain, namely;

- Northern Bank (Grafton side of the Clarence River);
- River Channel;
- Southern Bank (South Grafton side of the Clarence River).

Information related to the river channel is limited to near route options A and C. The ground conditions for the river channel are presented as a separate section below (Section 4.2) and will be assumed to apply to all route options at this stage.

The anticipated ground conditions for the northern and southern river banks will be presented for each of the route options (Section 4.3) using the existing and current geotechnical investigation data.

### 4.2 **River channel deposits**

BH1 to BH5 from the 1975 geotechnical investigation were located within the river channel. The alignment of these boreholes is directly downstream of the current route options A and C. The ground conditions encountered within these boreholes is summarised below.

Unit	Description	Reduced level at top of surface (m AHD)	Thickness (m)
Alluvium	Sand with some gravels and trace soft clay.	-3.3 to -12.2	4.5 to 9
	Gravel and sand and gravel with cobbled sized material Not encountered in BH3 and BH5	-6.9 to -9.8	8.5 to 10.2
Bedrock	Sandstone with siltstone layers		
	Assumed extremely weathered (soil strength). Not encountered in BH5.	-19.1 to -21.6	1.3 to 6
	Assumed highly weathered, very low strength, cracked with clay seams	-20.4 to -26.8	-

Table 2 River channel sub-surface conditions

The material descriptions were based on drillers logs. No in-situ testing was recorded on the logs.

In general, a thicker sequence of gravel / sand and gravel with cobble sized material was recorded towards the northern bank. A similar geological sequence is marked on the assumed as-built drawing in Appendix A. The section indicates a thicker sequence of gravel and boulder deposits to the north of the river channel as recorded in the 1975 boreholes summarised above.

The top of rock levels have been presented in the RTA 2003 Geotechnical Investigation Route Selection Report and vary between -14.8m to -22.8m AHD. In general, based on the as-built cross-section of the existing bridge in Appendix A, the rock level shallows towards the south side of the river channel.

### **4.3** Ground conditions at the route options

A preliminary assessment of the anticipated sub-surface conditions at the six route options, utilising the existing and current borehole information is presented in Table 3.

The anticipated ground conditions have been presented as the southern and northern banks. As mentioned in Section 4.1 above, the ground conditions for the river channel will be assumed to apply to all options at this stage.

Route	Southern Bank		Northern Bank		
option	Geotechnical information in close proximity	Anticipated ground conditions	Geotechnical information in close proximity	Anticipated ground conditions	
E	BHSG3(1987), BHSG4(1987), BHSG5(1987) & BH4(2003) considered, offset up to 500m upstream	<ul> <li>Approximately 5.5m of firm to very stiff silty clay, overlying;</li> <li>Very loose becoming medium dense clayey sand to sand from RL 1m AHD.</li> <li>No bedrock encountered (borehole depth RL -6m AHD).</li> <li>Groundwater level at RL 0.5m AHD.</li> <li>Boreholes offset from the option recorded:</li> <li>Up to 7m of loose to medium dense clayey silty sand to silty sand, overlying;</li> <li>Up to 6.5m of loose to medium dense sand with silty clay interbeds from RL 0m AHD</li> <li>Stiff silty clay with organic layers from RL 1.5m AHD was noted in BHSG5 with a thickness of 7m. The clay was encountered as very soft in BH4(2003).</li> <li>Very dense sandy gravel was noted at RL -12m AHD in BH4 (2003).</li> <li>No bedrock encountered (borehole depths ranged between RL -7m AHD to -13m).</li> <li>Groundwater at approximately RL 0mAHD.</li> </ul>	BH101 (2012)	<ul> <li>Approximately 17m of loose becoming medium dense silty sand overlying;</li> <li>Approximately 14m of medium dense to very dense gravel, gravelly sand and clayey gravel encountered at approximately RL -15.5m AHD, overlying;</li> <li>Claystone recovered as stiff to very stiff high plasticity clay at approximately RL -29.5m AHD.</li> <li>Groundwater level encountered at RL 1m AHD.</li> </ul>	

Table 3 Anticipated ground conditions of routes E, A, C, 11, 14 and 15

Route	Southern Bank		Northern Bank		
option	Geotechnical information in close proximity	Anticipated ground conditions	Geotechnical information in close proximity	Anticipated ground conditions	
A, C	BH7(1981), BH10(1981), BHSG1(1987), BHSG2 (1987) Existing as- built bridge cross-section.	<ul> <li>Based on as-built cross-section: material overlying bedrock comprises interbedded clays and sand (possible levee deposits). Based on the boreholes the material overlying the bedrock is interbedded silty clay and clay, firm to very stiff in consistency with an approximate thickness 14m. Clayey gravel / gravelly clay between -8m to -10m AHD was noted above the bedrock in the boreholes further south.</li> <li>Maximum depth of rock up to -15m AHD.</li> <li>Groundwater level varies between RL 1.1m AHD to -0.2m AHD.</li> </ul>	BH1(1975), BH3(1975), BH2(1975), Existing as- built bridge cross-section.	Sand 4.6m to 5.6m thickness, overlying; Gravel with cobble sized material, maximum thickness of approximately 10m, overlying; Interbedded sandstone bedrock at a maximum reduced level of approximately -23m AHD. No groundwater information.	

	Route	Southern Bank		Northern Bank		
option	Geotechnical information in close proximity	Anticipated ground conditions	Geotechnical information in close proximity	Anticipated ground conditions		
	11	Gravity survey (2012) (lines 3 and 4) No borehole information on the alignment. The following exploratory holes are within 500m: BH8(1981), BH9(1981), BH11(1981), GB7 (2003),	<ul> <li>Up to 5m of loose to medium dense silty sand to clayey sand, overlying;</li> <li>Firm to very stiff sandy clay to silty clay and clay, from RL 3.1m to 0.5m AHD. Localised very soft band from RL -0.5 to -2m AHD, overlying;</li> <li>Medium dense becoming very dense silty sand becoming sandy gravel to gravel from RL -10m AHD. Gravel not encountered in BH8(1981).</li> <li>Interbedded siltstone and sandstone from RL -17.7m AHD. Medium strength, fresh rock. Only encountered in BH2(2003).</li> <li>Gravity survey indicates rock level to vary between RL 0m AHD (at the Pacific Highway) to RL -12.8m AHD near the river bank.</li> <li>Groundwater from RL-0.6m to 1.2m AHD.</li> </ul>	BH102(2012)	<ul> <li>Very soft sandy clay, 1.2m in thickness overlying;</li> <li>Very loose to loose sand and silty sand from RL 2.2m AHD, with a thickness of approximately 6m, overlying;</li> <li>Medium dense silty sand from RL -2.1m AHD, overlying Medium dense to very dense clayey gravel from RL -13m AHD, overlying;</li> <li>Interbedded claystone/sandstone from RL -20m AHD. Encountered as distinctly weathered to slightly weathered, high strength.</li> <li>No groundwater noted.</li> </ul>	

Ro	Route Southern Bank		Northern Bank		
opt	ion	Geotechnical information in close proximity	Anticipated ground conditions	Geotechnical information in close proximity	Anticipated ground conditions
14,	15	BH106 (2012); Gravity survey (2012) (lines 1 and 2); BH1(2003) closest to southern bank; GB1(2003), GB2(2003), GB3(2003), GB4(2003) considered but offset up to 400m downstream.	<ul> <li>BH106 encountered:</li> <li>Soft to firm silty clay approximately 10m in thickness, overlying;</li> <li>Very loose becoming medium dense silty sand from RL -5.7m AHD, overlying;</li> <li>Dense to very dense sandy gravel and gravel from RL -15m AHD, overlying;</li> <li>Interbedded siltstone/sandstone from RL -20.7m AHD. The rock was encountered as fresh, medium to high strength.</li> <li>The existing information suggests:</li> <li>Up to 20m of firm to hard silty clay. Locally clay very soft to soft at or below the groundwater level within the test pits. Peat layer from RL -2.2 to - 3.9m AHD recorded in BH1(2003).</li> <li>Very dense sandy gravel from RL -14.2m AHD, overlying;</li> <li>Possible siltstone bedrock from RL -21.4m AHD.</li> <li>Groundwater from RL -0.5m AHD.</li> <li>Gravity survey indicates rock level to vary between RL 7m AHD (at the Pacific Highway) to RL -19m AHD near the river bank.</li> </ul>	BH103 (2012), BH104 (2012), BH105 (2012) ( for Option 15 only)	Soft to firm silty clay, ranging in thickness of 2m to 5m (in BH104 clay is firm to stiff), overlying; Very loose to loose silty sand encountered from RL -0.2 to -3m AHD, overlying; Medium dense silty sand encountered from RL -4.7m to - 10.7m AHD, overlying; Dense to very dense sandy gravel encountered from RL - 13m to -14.4m AHD. Interbedded claystone/sandstone was encountered in BH103 at RL -20m AHD. The rock was encountered as extremely weathered becoming slightly weathered, very low to low strength. Groundwater encountered at RL-2.3m AHD in BH104.

# 5 Geotechnical assessment for route options

### 5.1 General geotechnical considerations

The information in Table 3 is approximate only and is based on limited geotechnical information. The following issues should be considered for the constructability of the bridge foundations and approaches at each of the route options:

- Thickness of gravels and possible boulders within the river channel and the extent of these deposits beyond the northern and southern banks. This could result in problems with soil backfill into pile excavations in uncased holes and also issues with the driving or boring of deep foundations.
- Thickness and density of alluvial sand deposits within the river channel and beyond the river banks.
- Thickness of cohesive alluvial deposits beyond the river channel towards the north and south and extent of peat layers/pockets which will decay over time and will result in associated settlement. They also provide negligible shaft resistance for deep foundations.
- Thickness of weathered bedrock (if present) and uniformity of bedrock including strength of bedrock. Pile construction may be more difficult if rock is encountered at a shallower depth or if the rock is more competent than has been interpreted from the investigation. In this case a larger piling rig and drilling components may be required.
- Potential ground improvement requirements below proposed approach embankments due to the presence of any soft alluvial clay deposits;
- Presence of acid sulphate soils.
- Salinity of channel water and groundwater for durability design.
- The extent of river scour that could be associated around potential piers within the river channel.

### 5.2 Bridge structures

It is considered that the proposed river crossing structure will require geotechnical solutions for the following structures:

- Deep foundations for the proposed piers and abutments of the river crossing bridge and approach viaducts;
- Approach embankment design incorporating slope stability and settlement.

The following geotechnical constraints could be associated with the above structures based on the review of the geotechnical data.

### **5.2.1 Pier foundations**

Pier installation costs within the river channel are anticipated to be high in addition to difficult ground conditions to the north of the river channel in the form of boulder obstructions within thicker granular alluvium deposits.

Pier spacing should give consideration to the potential difficulty of constructing foundation piles through thicker gravel deposits in the northern part of the river channel.

Generic foundation options for the pier and viaduct localities are discussed below.

#### Shallow Foundations

Shallow foundations have been considered not to be viable because of the following:

- Soft and loose alluvial soils on both the northern and southern river banks;
- Scour associated with the river channel.

Piled foundations socketing into the bedrock are considered the most suitable option for piers located within the river channel and the viaduct structures.

#### Deep Foundations

It is anticipated that deep piled foundations would be founded in the bedrock. Optimisation of the pile design by use of the alluvial sand and gravel in shaft friction may be feasible for the viaduct structures. For the river channel this would depend on the change in thickness of the deposits across the river channel and degree of scour anticipated. This may reduce the number of piles required.

The following geotechnical issues are associated with the following piling methodologies.

#### Driven Piles

Driven piles (precast concrete piles, H section or tubular steel piles) would be suitable to achieve the required capacity. These could be used for the viaduct structures on the southern river bank. However, the presence of boulders within the alluvial gravel in the river channel may inhibit the required penetration depth. The verification of the required penetration in relation to the scour depth would be difficult and post construction scour may reduce the capacity of the piles in the river channel.

H section piles are used in marine environments and the toe can be strengthened to allow the pile to punch through thin layers of boulders. However, the H section piles can deflect along the weak axis and if penetrated into rock, the pile driving can shatter the rock and degrade the bearing capacity (Tomlinson, 1996).

Hollow tubular steel piles may be driven in conjunction with drilling out the basal section of the pile prior to successive drives. Construction delay may be associated with this methodology.

#### Continuous Flight Auger (CFA) Piles

CFA piles may be a suitable option in the granular alluvium as to avoid the installation of permanent casing, for example on the southern and northern river

banks. The boulders that were recorded within the alluvial gravel deposits in the river channel may prevent the piles being installed to the desired depth for the river crossing piers. If piles refuse at shallow depths, the required bearing capacities may not be achieved and scour may reduce the capacity of the piles.

#### **Bored** Piles

Large diameter bored piles could be a viable option but the presence of granular alluvium deposits would necessitate lining of bored piles to avoid shaft collapse. Lining of the piles by use of permanent casing would be required to allow formation of the pile within the granular deposits on the southern and northern river bank areas and partly within the water column in the river channel.

### 5.2.2 Durability

No information regarding the salinity of the river channel and groundwater was determined as part of the ground investigations. It is considered that the river channel may be saline due to the extent of the tidal range and may cause corrosion and durability issues.

Further information regarding durability will be required to aid foundation design once a preferred location for an additional crossing is identified.

### 5.3 Approach embankments

The existing geotechnical information suggests that compressible alluvium is isolated to lenses of peat and localised very soft to soft areas. It is not anticipated that settlements will be a significant issue and slope stability will be a function of the embankment fill material, slope angles and slope heights adopted.

Construction related settlements may also be associated with the loose granular alluvial deposits identified over the southern river bank flood plain and predominantly within the northern river bank area.

Future geotechnical investigation for the preferred option will need to address these issues and determine the need for ground treatment to avoid the need for lengthy construction staging and avoid potential instability and excessive settlement.

Construction details of the existing flood levees towards the northern and southern banks are unknown. Details regarding the construction of the levees would be valuable if the proposed approach embankments are to incorporate the existing levees. If the levees were not engineered, issues regarding slope stability and settlement may occur. This is applicable to all route options. Further investigation for the preferred option would be required.

### **5.4 Option specific considerations**

A high level geotechnical assessment for each of the route options is summarised below based on the assumed geology presented in Section 4.2.

### 5.4.1 Option E

#### Southern Bridge Approach

On the southern approach to the bridge, a short low approach embankment is proposed. This will be underlain by a crust of stiff clay and very loose to medium dense sand deposits.

Minor ground settlement issues will need to be considered in detailed design, but are not likely to be significant. Short term settlement is likely to occur due to the very loose sand but this is likely to be driven out during construction. Longer term settlement may be associated with near surface organic layers and potentially soft clay lenses/bands.

#### Bridge

The abutments and piers for the bridge will probably be founded in rock, which is likely to vary in depth from about RL -15m AHD on the southern bank to about RL -29.5m AHD on the north bank. No information is present within the river channel, however a rock level of about RL -23m AHD is anticipated based on information for Options A and C.

A risk in the form of the thickness and extent of the gravel/cobble deposits and the rock level will need to be investigated further if Option E is identified as the preferred option.

#### Northern Bridge Approach

A short viaduct and minor earthworks are proposed on the north side of the river. The ground conditions in this area comprise the thickest layer of sand/gravel and deepest bedrock of any route option.

The short section of viaduct may require piled foundations due to the presence of loose granular deposits. The piers for this viaduct could be founded within the gravels or, depending on loading, could be founded in the rock.

### 5.4.2 Option A

#### Southern Bridge Approach

The southern bridge approach will likely be at grade and underlain by residual soil and rock. The bridge abutment could be founded on shallow footings or short piles.

#### Bridge

The piers for the bridge will require piled foundations. Gravel with cobbled sized material increases in thickness across the river from south to north and in addition, the rock level drops. Cased bored piles (potentially large diameter) would be a suitable option due to the gravel/cobble deposits. The maximum rock level is anticipated to be RL -23m AHD.

### Northern Bridge Approach

On the northern bank it is assumed that the gravel/cobble layer is continuous. In addition it is assumed that predominantly granular (sand) deposits could be encountered.

A small viaduct is proposed for the approach and the piers would be founded within gravel or, depending on loading, could be founded in the rock.

### 5.4.3 Option C

### Southern Bridge Approach

The bridge approach and connection to the Pacific Highway is proposed to be formed on embankment and viaduct, which will be underlain by about 14m of stiff clay above the bedrock. Consolidation settlement of the stiff clay is likely to be minor and manageable.

For the short viaduct, piers may be constructed on piles founded in rock at approximately RL -15m AHD. Shorter piles may be suitable depending on the design loadings of the viaduct.

### Bridge

The piers and abutments for the bridge will require piled foundations probably founded in rock. The rock is anticipated to be at about RL-23m AHD and may increase with depth to the north. Gravel with cobbles increases in thickness toward the north. Cased bored piles (potentially large diameter) would be a suitable option due to the gravel/cobble deposits.

#### Northern Bridge Approach

It is anticipated that the gravel and cobble layer continues under the northern approach and that granular (sand) deposits are dominant.

A small viaduct is proposed for the approach and the piers could be founded within the gravels or, depending on loading, could be founded in the rock.

### 5.4.4 **Option 11**

#### Southern Bridge Approach

This bridge approach will comprise a high embankment over half of the length and the remaining half, towards the river, will be supported on viaduct.

The rock level drops from near surface at the Pacific Highway, to between RL - 13m and -18m AHD near the river bank. The alluvial deposits over the southern approach are anticipated to comprise an upper layer of stiff clay with localised soft bands that overlie medium dense sands and gravels with depth.

Ground settlement beneath the embankment may be an issue and will need to be considered in the detailed investigation and design. However, any issues are likely to be manageable. It is likely that the viaduct structure will require piles founded in the rock at approximately RL -12m to -18m AHD. Shorter piles founding within gravels may be suitable depending on the design loading of the viaduct.

There is a higher risk of acid sulphate soils on the southern bank as compared to other route options.

#### Bridge

There is no information on the ground conditions within the river, but it is anticipated that conditions will be similar to those at Option C. The bridge will need to be supported on piles probably founded in rock. It is anticipated that the rock level across the river channel varies between about RL -18m to -20m AHD. A risk in the form of the thickness and extent of the gravel/cobble deposits and the rock level will need to be investigated further if Option 11 is identified as the preferred option.

#### Northern Bridge Approach

A short high embankment is proposed for the northern approach. A 1m to 1.5m thick layer of soft clay may be present at the ground surface that overlies very loose to medium dense sand with depth. Dense gravels are anticipated to overlie the bedrock at RL -20m AHD.

The soft clay may need to be removed to avoid excessive settlement. Construction related settlements associated with the loose granular material may occur during construction.

### 5.4.5 Option 14 and Option 15

#### Southern Bridge Approach

A high embankment and viaduct structure is proposed over the southern approach for both options.

The rock level varies from ground level at the Pacific Highway dropping to RL - 19m AHD near the river bank. The alluvial deposits comprise up to 10m of soft to firm clays, overlying dense gravels that overlie the bedrock.

Ground settlement beneath the embankment associated with the soft clay is likely to be an issue and will need to be considered in the detailed investigation and design. Some ground improvement may be required. However, any issues are likely to be manageable.

The viaduct over the floodplain will require piles probably founded in the rock. The rock level varies under the viaduct from about RL -12m to -20m AHD. The piles could be founded in the gravel layers depending on the viaduct loading.

#### Bridge

There is no information on the ground conditions within the river, but it anticipated that conditions will be similar to those at Option C. The bridge will need to be supported on piles probably founded in rock. It is anticipated that the rock level across the river channel varies between about RL -18m to -20m AHD. A risk in the form of the thickness and extent of the gravel/cobble deposits and the

rock level will need to be investigated further if Option 14 or Option 15 is identified as the preferred option.

#### Northern Bridge Approach

For both options, the northern approach is in the form of a small viaduct grading into minor earthworks. For each option further embankments are proposed that are associated with new roads and creek crossing upgrades.

Soft to firm clay is present at the ground surface overlying very loose granular material, which become dense with depth. Gravels were found to overlie the bedrock.

It is anticipated that the viaduct structure will require piled foundations bearing onto the bedrock at RL -20m AHD or within the gravel.

Embankment settlements associated with the soft clay will need to be considered at detailed investigation and design. This soft material may need to be improved if either of these options are identified as the preferred option. Construction related settlements may also be associated with the loose granular materials underlying the clay.

# 6 Conclusions

### 6.1 **Preliminary piled foundation lengths**

It is anticipated that piled foundations will be required for the river crossing piers and the approach viaducts associated with each of the route options.

To provide a costing comparison between the route options, bored piled foundations should be assumed for the river crossing and approach viaducts at this stage. There may be scope on the southern river bank to utilise alternative piling methods for the viaducts such as driven piles. This would need verification once a preferred option is chosen.

The approximate reduced level (m AHD) for the pile toe for each option, for the approach viaducts and river crossing is shown in Table 4.

Route Option Southern approach viaduct		River crossing piers	Northern approach viaduct
Е	-18	-18 to -33	-33
А	+5 to -18	-18 to -26	-26
С	-18	-18 to -26	-26
11	-15 to -21	-21 to -23	N/A
14,15	-15 to -23	-23	-23

Table 4 Approximate pile toe reduced level (m AHD) for the route options

Note: An increase in bedrock depth occurs progressively from south to north across each route option

It should be noted that the pile toe levels presented in Table 4 incorporate the following assumptions:

- The pile toe level incorporates an assumed 3m rock socket, i.e. the pile will be embedded 3m into the bedrock.
- The pile size and length will be reviewed once bridge loading and design refinements are undertaken for the preferred option.
- The pile toe levels are indicative and are subject to further geotechnical investigation to confirm the ground conditions assumed once a preferred location is identified.
## 6.2 Approach embankment considerations

Table 5 summarises the geotechnical considerations associated with the approach embankments for each of the options.

Route Option	Geotechnical considerations
Е	No significant issues
А	No significant issues
С	<u>Southern Bridge Approach</u> Minor long term settlement associated with localised soft/organic bands/lenses, which can be managed.
	<u>Northern Bridge Approach</u> No significant issues
11	<u>Southern Bridge Approach</u> May have long term settlement issues associated with localised soft bands/lenses, which will need to be managed. <u>Northern Bridge Approach</u>
14/15	Minor settlement associated with soft soils, which can be managed.      Southern Bridge Approach      Long term settlement associated with soft to firm clay is likely to be an issue and will need to be addressed during detailed investigation and design. Ground improvement may be required.      Northern Bridge Approach      Long term settlement associated with soft clay is likely to be an issue and will need to be addressed during detailed investigation and design. Ground improvement may be required.      Southern Bridge Approach      Long term settlement associated with soft clay is likely to be an issue and will need to be addressed during detailed investigation and design. Ground improvement may be required.

Table 5 Approach embankment considerations

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## Attachment A

Existing Geotechnical Investigation Data

MR 83 City of Grafton Grafton Bridge and Approaches Geotechnical Investigation for Route Selection

## **APPENDIX B**

Borehole Logs and Photographs-Geotechnical Report No: G3510



NEW BRIDGE OVER CLARENCE RIVER AT GRAFTON.

GEOTECHNICAL INVESTIGATION AT CONCEPT STAGE.

## Report No: G3510

26 October 2003



## INTRODUCTION

This report presents the results of an initial geotechnical investigation, at concept stage, for the route selection of a proposed new bridge over the Clarence River at Grafton. The locations for the investigation were chosen to give a wide perspective on the possible foundation conditions that can be expected when the actual bridge location is chosen. The work was requested by Mr Peter Black, Project Manager, Operations.

### GEOLOGY

Reference to the 1:250 000 Metallogenic Series Sheet for Grafton – Maclean shows the area of interest to be underlain by undifferentiated Quaternary alluvial sediments overlying rocks of the Grafton Formation of late Jurassic age. These are described as; interbedded sandstone, clayey siltstone, claystone and minor coal. The presence of brick pits in these rocks close to Grafton is noted.

### FIELDWORK

One borehole was drilled at each of four locations on the banks of the Clarence River. Borehole 1 was drilled on the left bank of the river close to the existing bridge. The other three boreholes were drilled on the right bank. Coordinates and levels of the boreholes are given in Table 1 below. The boreholes were drilled by Craig Pullman Site Investigation Pty Ltd, using a truck mounted Jackro Drilling rig for Borehole 2 and a P160 drilling rig for the other boreholes. The boreholes were started using a continuous flight auger and continued using a rock roller with water and polymer flush. Standard penetration tests were done, generally at intervals of 1.5m unless otherwise indicated. (See the log for Borehole 3.) 50mm diameter tube samples were taken in some of the clays encountered. The rock was cored only in Borehole 2 using NMLC equipment.

BH No	Eastings	Northings	RL
1	496234.2	6717162.8	5.8
2	495613.6	6715388.3	5.9
3	494311.0	6714884.0	1.7
4	493099.9	6714527.5	1.7

Table 1:	Coordinates and Levels of Boreholes
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## RESULTS

Borehole 1 encountered very stiff silty sandy clay with some stiff and firm material with peat over hard silty clay. From a depth of 16m, the material becomes progressively more sandy and has a lower cohesive strength. A very dense sandy silty gravel was encountered below 20m depth. A material thought to be siltstone was encountered below 27.2m.

Borehole 2 encountered a clayey and silty sand close to the surface and then clayey silt and silty clay, some of which was very soft or firm. Loose silty sand was encountered below 12.6m and very dense sandy gravel below 15.8m. Medium strength sandstone was encountered below 23.6m. This was found to be interbedded with siltstones and laminite. The borehole was cored to almost 30m.

Borehole 3 encountered firm silty clay at the surface. There was a gradational change from 1.7m to 2.65m below which was found loose sand with some gravely sand. Medium dense gravely sand was encountered below 9.5m and sandy gravel below 11.9m. Standard penetration testing was discontinued in this borehole to enable completion of the investigation within the allotted time frame. An indication of the density of the gravels may be obtained from the column in the logs, which describes the drilling penetration. Sandstone was encountered below 20.7m

Borehole 4 encountered 0.7m of fill over very soft silty clay to a depth of 5.2m. Loose silty sand was encountered below this. At the base of this layer, the material became medium dense, and a dense to very dense sandy gravel was encountered below 10.6m. This borehole was terminated on instruction at 11.5m in the gravel.

A description of the materials encountered in the boreholes and the results of the standard penetration tests are given on the borehole log sheets. These, together with a photograph of the core from Borehole 2 and an explanatory sheet, are given in Appendix A.

### DISCUSSION

From the results of the investigation it is considered that driven piles would be required at all the sites investigated. The nature of the piles and the depth of embedment will depend on the chosen bridge design. It is probable that the gravels above the rock would be of sufficient density to support the piles. This should be reassessed at the time of the actual design of the bridge at the chosen location. However, if required, bored piles to bedrock may be considered to provide a higher load bearing capacity. The design loading of the bridge will therefore dictate the type of pile that will be used. Whatever type of pile is chosen, the presence of clays that could settle under the weight of the approach embankment (see below) could be a source of negative skin friction and may require that the embankment materials be placed before the construction of the piles. Most of the borcholes encountered very soft to firm clays and silty clays above the gravels. These will be a source of settlement in the approach embankments and should be thoroughly investigated for both settlement characteristics and stahility implications once the alignment of the bridge has been chosen.

p.J.

Manager Geotechnical Investigation 26 October 2003

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Manager Geotechnical Engineering

Reviewed by:

# **APPENDIX A**

## BOREHOLE LOGS AND CORE PHOTOGRAPHS

### EXPLANATORY NOTES - DRILL & EXCAVATION LOGS

### GENERAL

Information obtained from site investigations is recorded on key proces. The "Cased Drill Hole Log" presents data from an operation where a core barrel has been used to recover material - commonly rock. The "Non-Core Drill Hole - Geological Log" presents data from an operation where come has not been used and information is haved on a combination of regular sampling and instituteming. The material penetrated in non-core defiling is commonly soil but may include rock. The "Excavation - Geological Log" presents data and the material penetrated in non-core defiling is commonly soil but may include rock. The "Excavation - Geological Log" presents data and drawings from excavation of pits, unclusi, etc.

The freading of the log sheets containt information on Project Identification. Hole or Pit Identification, Location and Elevation. The main section of the logs contains information on methods and conditions, material publishance description and structure presented as a series of colorens in relation to depth below the ground surface which is plotted on the left side of the log sheet. The common depth scale is Bin per duill log sheet and about 3-Sm for oxeavation logs sheets.

As far as is practicable the data contained on the log sheets is factual. Norminterpretation is inevitable in the identification of material bostoducies in arcast of partial sampling, the location of areas of core loss, description and classification of material, estimation of strength and identifications of drifting induced fractures. Material description and classifications are based on SAA Site Investigation Code AS 1726 - 1993 with poper medifications as defined below.

Three notes contain an explanation of the terms and abbreviations commonly used on the log sheets.

### DRILLING

### Drilling & Casing

	•
AS	Auger Screwing
AD/V	Auger Drilling with V-Bit
ADA	Auger Drilling with TC Bit
Ś <b>YD</b>	Wash bore drilling
RR	Rock Roller
<b>NME</b>	NMLC core barrel
NO	NQ core barrel
TIME	HMLC core barrel
HQ	IIQ core barrel

#### Oriting Floid/Water

The drilling fluid used is identified and loss of return to the surface ortimated as a percentage.

#### Drilling Penetration/Drill Depth

Core lifts are identified by a line and depth with case (on per on at a percentage. Ease of penetration in non-core dolling is abbreviated as follows:

	<u>Very Easy</u>	
	Basy	
E.	Firm	
11	Hard	
<b>VII</b>	Very Hard	

#### Groundwater Levels

Date of measurement is shown.

- Standing water level measured in completed borchole
  I and takes during an immediated
  - Level taken during or immediately after drilling

Sample/Tots  $\mathbf{D}^{*}$ Disturbed notessis Undistantical Core Sample SPORE Standard Penetration Test N COUNT Result of SPT (\*sample taken) VSBAR Vano Shear Test TRAIL SOL Borchole Impression Device Plate Bearing Test ïpx ⊗.⊙ Piezometer Installation tin seedad Hand Pencirometer Test

### EXCAVATION LOGS

Baplanatory notes are provided at the bottom of duilt log shrots, Information about the wight, geology and pedalogy may be entered in the "Structure and other Observations" column. The depth of the bate of excavation (for the logged social) at the appropriate depth in the "Material Description" column. Refugal of excavation plant is noted should it occur. A aktich of the exposure may be added

### MATERIAL DESCRIPTION - SOIL

Classification Symbol - In accordance with the Unified Classification System (AS 1726-1993, Appendix A, Table A1)

Material Description - In moordance with AS 1726-1993, Appendix A2.3

### Moisture Condition

	Dry, looks and feels dry
M	Moist, No free water on remoulding
N. COLOR	Wet, free water on removiding

Consistency - In accordance with AS 1726-1993, Appendix A2.5

vs	Very Soft	$< 25 kl^2 a$
	Soft	25 - 50 <u>kFa</u>
T.	Firm	50 - 100kPa
SC	Suff	100 - 200kPa
	Very Stiff	200 - 400kPa
Here	Hard	≥ 400kPa

Strength Eguras quoted are the approximate sange of Unconfigred Compressive Strength for each class.

Density Index. (%) is estimated or is based on SFT results. Approximate N Value correlation is shown in right column.

<b></b>	Very Loose	< 15%	0.4
a sa	Loose	15 35%	4 - 10
MD	Medium Dense	35 - 65%	10 - 30
and a second	Dense	65 - 85%	30 - <u>50</u>
<b>YD</b>	Very Dense	> 85%	> 50

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	<u>DCA</u> 1 280		l:									SHEET: 1 of 4	
	IG TY	PE	: 1	400		ROUNT	NG :	TRUÖ	CONTRACTOR - PULL		เลยา เพิ	ANGLE FROM HORIZON (	AL : 90*
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		DR	ļιu	NG	_			<b>.</b>	MATÉRIA	L			
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	N (	~	C				νς 20 20		SANGY BE 7 : BROWN LINE GRAINER LOW PLASTICITY, SLIGHTEY MOISE.			ALLUVIUM	
			r		1.00 SPT 7,3,2 N°-5 1.45	· 1.0-		•	CHITY SANOY CLAY DARK BROWN MEDIUM PLACTICITY FINE CIVAINED SAND		vši (HF) ar (3PT)		
RICET	N/4				2 60 5 67 4,4 3 N~9 2,09	20- 3.D			2. <u>00</u>	¥ 0:	भ (भाग) उन हा सम्बद्ध		
596v Jr					4 <u>00</u> SPT 7,3,7 N*45 4,45	4.0	· · · · · · · · · · · · · · · · · · ·		ŠR. TY BANDY CEAY : FALL GREY & DRANGT NROWN MOTTLD, HIGH H ASTROTY, SOME LINE & MIDNIM GRAINED SAND WITH A TRACT OF NDARSE ORAN ALEU	м	VSI 4(P) 9 5 (3P7)		
	NZA			.30in X	6 50 364 7.3.5 N=6 9.99	6.0- 	2 2		AS ABOVE EXCEPT CREY A Onance brown mothers some woot parts preasing	Μ	VSr 91 (HP) 91 93 (SI'T)	— 14° ← 147 - 743 MPµ	.
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See Setal	Explo Explo	nalor Inbre	y No Vinti	Nos for	. )	<u>اللہ میں</u>	.119		ROADS AND TRAFFIC AUTHORITY		 *w		
99	alA nf	desc	djatic	atin.									

NON-CORE DRILL HOLE-GEOLOGICAL LOG PROJECT : GRAFTON BRIDGE SITES LOCATION : SHEFT : 2 of 4												
POSITION :			·	SURFACE ELEVATION :		ANGLE FROM HORIZONTAL : 90"						
RIG TYPE : P	400 M(	DUNTING	TRUCK	CONTRACTOR :	PULLMAN DR	ILLINGORILLER : M. KENNEDY						
DATE STARTED	): 23/8/03	DATE	COMPLETED : 25/9	0/03 DATE LOGGED: 23/0/03	I LOG(	GEO BY : U.T. CHECKED BY : 🖊 🚧						
DRILLIN	IG	(		MAT	TERIAL							
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	5 9,10 341 2,2,3	8.0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	 	SILTY CLAY (PEAY ) DARK GRÊY & LOUK LIKOWN MÔTHLLD, HIGH PLASTICITY, UNGANIC MATTER PRESENT UMITHING A VERY OTRONG ODOUR,		ALLUMUM (1-5) (19)						
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	3941 8941 894,6 77-12 11.95	11.0-1 		SILTY CLAY : PALS GREEN & GREY MOT ILED, HIGH PLASTICITY.	8 9 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	F-54 SPT) 						
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	F	10.00 807 6.7,0 N <sup>4</sup> 2 10, <u>45</u>			SH GF Hit ML	I TY SANDY CLAY REY & URANGE BROWN MOTT OH PLASTICITY, SOME FING & LOUM GRANED SAND		м	31 (МР) 55 УА (59 Т)	- HET +348 KP4	<b>_</b>
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	CATI	ON :										SHEET: 2 of 4
RIC	STAL TYP	2N ; 2E : J	IACRO	M	DUNTI	NG :	TRUC	CONTRACTO	N: )R: PULLMA	N DF	ULLING	ANGLE FROM HORIZONTAL : 90*
DA	TE S	TARTE	D: 1	6/9/03	DA	IE C	OMPL	LETED: 10/0/03 DATE LOGGED: 18	-16/9/03	LOG	GED	Y: I.W. CHECKED BY / AL-
	,	RILLI	NG					M	MATERIAL			· · · · · ·
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<b>^</b>		r		6 %) SPT 6.4.14 N°-422 5.95	9.0		•	SKITY (3 AY ) Vielow Brown & Brown High Mlasticity,		м	v51	
		<b>v</b> i:		10.00 SPT 2,3,4 №=7 10.45	10.0-			9,70 DLAYTY DIL F BROWN WITH FIVE SAND, MICACL'OUS, LOW TO MEDRM PI ASTIGITY,		-	r	µ4} = 60 - 60 Mra
HILDER CONTENT	160-06 SOLAT			33.00 5121 7.1.1 N°=2 11.03	11.0						5	
			1	13 00 SITI 2.2,6 N=7 13.46	19.0			12.00 SILLY BAND : GRANGE DIRGWM, FINE, MEDIUM & COARSE GRAINED SAND, MICAGEOUS, NON-PLASTIC,			l.	
		F			بر. ۱۹,0-۱ ۱۹,0-۱۹			14.30				- SMALL GRAVEL LAVERA -
		e		34 60 9PT 4.4.6 N*49 14.65	15.0	11111		SILTY SAND : ORANGE BROWN, FINE TO MEDIUM Orange Brown, micacégéus, Orassional Clayry Sand Layres, plasticity varying trom Non-plastic to norderline.				
	Espia In ote		lotos far		10.0	5.0		16,00 SANDY GRAVITE YOULOW BROWN DARK CHEY, GILL RED AROWN (1841, MEDIUM & COARSE OF/WEL WITH C ROADS AND TRAFFIC AU1			vo	
& 1 m	0 5 01	descript	lóna.									

ль ст	CR	AFTO	N BROD		-CORE	DRILL	HOLE-GEOLOG	ICAL	LO	G	FILL / JOB NO : GOSTO
ATIO	N :						SURFACE ELEVATION :				ANGLE FROM HORIZONTAL : 00
TION	<u>41</u> 	ROP	160MO		IG : TRUCK		CONTRACTOR	PULLMAN	( DRI	UNOD	RILLER : \$ SIMON 711 KENNEDY
E STA	ARTED	: 16	/eku3	DAT	E COMPLE	TED : 10/9/03	DATE LOGGED : 16-18	/ə/01) L	000	JED RÅ	T.W. CHECKED BY : A1-
DF	RILLIN	G				J	MA	TERIAL	-		
RUNG RUIC PPE 6 LOSS	Selling Sherrarton	CUND WITHER LEAGE	SAMES. TEILET	DEPTH())	SAPPICIUS USSFCUICA	MA Soli Typa, Çele Sece	TERIAL DESCRIPTION ur, Plasticity of Particle Churaci Indary & Minur Components	orintic.	CADICH CALL	NEWDAR V	STRUKTURE & Other Observations
8	x :	đ	18.98	10.0- 591 - 30 R		\$/	ANDY GRAVEL : AS PREVIOUS.		*	σv	л., <b>(</b> , <b>М</b> і), н.
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1 5501 <b>1</b> 52			<u>17.50</u> SP1 12,7,7 N=14 17.05				RILTY SAND : DEANGEL UIDWN, FINE, MEDILIM R COAUSEL ÚIMNÍED SAND. NORFPLASTRO.				NO SAMPLE REFERENCES
				18.0-		<u>199.26 .</u> .					
	<b>v</b> H		19.00 571 341 19.16	19.0-			RAVEL : MRK GRY & YELLOW URDWN. HERUMA COARSE GRAVUI WITH HERUENT CORRES & BOULDERS.				NO RUMUM NI COVERED
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	4		21.60 SPY # 71.65	я <b>н</b>	2000 000 000 000 000 000 000 000 000 00						HI) LANDL & RECOVERY ()
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\$0 ₹ ₩						2 <u>3.60</u> &An090 (	ONE : LIGHT GRÉY, HNR GRAINED DA OCOASIONAL THN CLAY LAVIERS. NI OR NON CORL DHILLING AT 24.00m				START OF BEORDER
		/ Notice	for	- 24.	0	ser BC	CORED DRILL LOU SHEAT FOR DETAIL		ΓY. (	NSW	

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L.		IQN :	WES.	T \$10 <u>C (</u>	<u>N: NOR</u>	FRN PIER, EXISTING STEEL BRIDGE	SHEET: 1 of 8
B	G TY	PE:	P 400			G TRUCK	ANGLE FROM HORIZONTAL : 90*
D/	TE:	TAR	<b>1</b> 60 ;	26/9/0	N D/	COMPLETED ; 26/2/03 DATE LOGGED : 20/2/03 LOGGED	BORILLER: 11 KONNEDY
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	#/	E				SILTY CLAY : DICOWN. 18GH PLASTICITY, SOME UNC & MEDIUM GRAINED SAND	
- FLORED C. BT		E		1. <u>00</u> 59T 1.1,1 N <sup>4</sup> +2 1.45	- 1.0-	ЦіÓ <u>89</u> SR TY CLAY : ОАЯК ВКОЖИ МГОЦИИ ТО НІСН PLAS ICCT, SOMP, PINE & MLOILM GRAINED SAND, SR TY CLAY : ОАЯК ВКОЖИ ТО НІСН В СТИТОВИТИ ОВ СТИТОВИТИ С СТИТОВИТОВИТИ С СТИТОВИТИ С СТИТОВИТ С СТИТОВИТИ С СТИТОВИТИ С СТИТОВИТИ С СТИТОВИТИ С СТИТОВИТИ С С СТИТОВИТИ С С СТИТОВИТИ С ССТИТОВИТ С СТИТОВИТ С С СТИТОВИТИ С СТИТОВИТ С СТИТОВИТ С СТИТОВИТ С СТИТОВИТ С С СТИТОВИТ С СТИТОВИТ С С СТИТОВИТ С С СТИТОВИТ С СТИТОВИТ С С С С С С СТИТОВИТ С С С СТИТОВИТ С С С С С С С С С С С С С С С С С С С	HP = 03 kP
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	4			2,60 3PT 0.1,1		SIL IY SAND: GREY. FINE & MECKUM GRAUNUD. ▼	
				2.95	3,0- -	SAND YTELGW BROWN / PALE DROWN. PREUDMINANTLY METRIM GRAMLU. SOME FINE & COARSE GRAIN PIKLSENT.	- - 
	S (P2174EN)	E		4.00 SPT 3.5.5 N=10 4.47	4.0- - - - - - - - - - - - - - - - - - -	AS ABOVE EXCEPT FINE TO COALSE W MD GRAINED SAND.	26/9 - 5 50m - 7 60m - 6 150m - 10,60m - 10,60m
22,005	201306-932			<u>6,50</u> 3+1 3,3,4 N=7 6,05	- - - - - - - - - - - - - - - - - - -	AS ABOVE EXCEPT WITH A TRACE OF COARLIG SUPED GRAVEL WY L	- - - - - - - - - - - - - - - - - - -
		F				GRAVELLY SAND; YELLOW IROWN, FINE TO LODARST GRAINED SAND. SOME FINE TO COARST SIZED GRAVEL.	
		E	Z	. <u>00</u> SPT A.0.7 N=13 (45	7.0-	SAND : BROWN, FINL TO COARDE GHAINED MED	
ne Ex Italia Dăsir	column of abi of de	lary Ne Savist Issriptic	ons for ons		8.0-100	ROADS AND TRAFFIC AUTHORITY, NSW	

PROJE LOCAT		; ;	RAFT			I-CO TES	OR		OG	HOLE NO : 3 FILE / JOB NO : 63510 SHEET : 2 of 5
POSIT	ION	:						SURFACE ELEVATION :		ANGLE FROM HORIZONTAL : 90"
RIG TY	PE	; P	400	м	OUNTI	NĠ:	TRUC	CONTRACTOR : PULLMAN D	RILLIN	GDRILLI FR : H. KENNEDY
DATES	STA	RTF	D; 2	28/0/03	DA.	TE CX	OMPL	ETED : 20/0/03 0ATE LOGGED : 20/0/03 LO	GGED	BY: J.T. CHECKED BY: # S++
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1 4	7			1	0.0 -					• <b></b>
		•		1				SAND: YPLLOW DROWN, FINE TO		
				<u>n 60</u>	-			CORRST, GRAINED SAND.		ALLOVIUM
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6	Γ	6			1		- 1			
		<u>à</u>						CRAVELLY SAND :		
				10 10	10,0			SOME SANDY GRAVEL LAYERS (10000)		
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_+					11.0-					NOTE :
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MR 83 City of Grafton Grafton Bridge and Approaches Geotechnical Investigation for Route Selection

## **APPENDIX C**

## **Test Pit Logs and Photographs**

## EXPLANATORY NOTES - DRILL & EXCAVATION LOGS

### GENERAL

Information obtained from site investigations is recorded on log shears. The "Courd Drill Hote Log" presents than from an operation where a core barret has been used to recover material - commonly tock. The "Non-Core Drill Hote - Geological Log" presents data from an operation where coring has not been used and information is based on a combination of regular sampting and insite testing. The material penetrated in non-core drifting is commonly soil hat may include rock. The "Excavation -Geological Log" presents data and drawings from exposures of soil and rock resulting from excavation of pits, neoches, etc.

The heading of the log sheats contains information on Project Bentification, Itole or Pit Identification, Location and Elevation. The main section of the logs contains information on methods and conditions, material substance description and structure presented as a series of columns in relation to depth below the ground surface, which is plotted on the left side of the log sheet. The common depth work is fin per drill log sheet and about 3-5m for excavation logs sheets.

As far as is practicable the data contained on the log shocts is futural. Nome interpretation is inevitable in the identification of uniterial boundaries in areas of partial sampling, the location of areas of core loss, description and classification of inaterial, estimation of strength and identification of drilling induced tractorys. Material description and classifications are based on SAA Site Investigation Code AS 1726 - 1993 with some modifications as defined below.

These notes contain an explanation of the terms and abbreviations commonly used on the log sheets,

### DRILLING

### Prilling & Casing

TIME SINE AND STREET	· · · · · · · · · · · · · · · · · · ·
<b>BAS</b> SHEET	Auger Screwing
<b>K</b> DZV	Auger Drilling with V-Bit
AD/T	Augest Dedling with TC His
1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 -	Wash-bore drilling
2 <b>8.</b> 0	Rock Roller
NNILC	NMLC core barrel
NO V	NQ core barrel
UND C	HMLC core burrel
Moses [	HQ core barrel

### Delling FichtWater

The drilling fluid used is intentified and laws of return to the surface estimated as a percentage.

### Dellling Penetration/DelD Liepth

Core lifts are identified by a line and depth with core loss per run as a percentage. Passe of penetration in non-core drilling is abbreviated as follows:

The second second second second second	
	Very Easy
	Easy
	l'irm
	Haid
<u>Y10</u> 882	Very Hard

### Groundwater Levels

Date of measurement is shown.

Standing water level measured in completed horebote

Level taken during to monocliptely after driffing Samples/Cests

	Distorbed
	Undistu bed
C.	Core Sample
	Standard Penetration Test
Na	Result of SPT (*sample taken)
	Vane Shear Test
IMP	Borehole Impression Device
BBT	Plate Bearing Test
1. <b>1.</b> Z	Piezoneter Installation
2018.20 S	Hand Penetrometer Test

### EXCAVATION LOGS

Explanatory notes are provided at the bottom of drill log siteers. Information about the origin, geology and pedology may be entered in the "Structure and other Observations" column. The depth of the base of excavation (for the (ogged section) at the appropriate depth in the "Material Description" column. Refusal of excavation plant is noted should it occur. A sketch of the exposure may be added.

### MATERIAL DESCRIPTION - SOIL

Classification Symbol In accordance with the Unified Classification System (AS 1726 1993, Appendix A, Table A1)

Material Description - to accordance with AS 1726-1993, Appendix A2.3

Moisture Condition

Dry, looks and feels dry	
Moist, No free water on remoulding	
Wet, free water on remoulding	

Consistency - In accordance with AS 1726-1990, Appendix A2.5

WS Level Very Soft	< 25kPa
Sector Soft	25 - 50kPa
Firm	50 - 100kPa
Strange Suit	100 - 200kl*a
Very Stiff	200 - 400kPa
Hard Hard	[ ≥ 400kPa

Strength figures quoted are the approximate stage of Uncontined Compressive Strength for each class.

Density Index. (%) is estimated or is based on SPT results. Approximate N Value correlation is shown in right column.

All and a second second second second second second second second second second second second second second se	· — -	<del>,</del> , <u>.</u>	· · ·
	Very Loose	< 15%	0.4
	Loose	15 - 35%	4 - 10
MD	Medium Drinse	35 - 65%	10 - 30
	Dense	65 - 85%	30 - 50
YD	Very Dense	> 85%	> 50

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### MATERIAL DESCRIPTION -ROCK Material Description

Identification of mok type, composition and texture based on visual features in accordance with AS 1726-1993. Appendix A3 1-A3.3 and Tables A6a, A6b and A7

#### Core Loss

is shown at the borrow of the run intess otherwise indicated

#### Bedding

Description	Spacing (mm)
Thinly Laminated	< 6
Laminated	6 - 20
Very Thinly Bedded	20 - 60
Thmly Bedded	60 - 200
Medium Bedded	200 - 600
Thickly Bedded	600 - 2000
Very Thickly Bedded	> 2000

*Weathering* - No distinction is made between weathering and alteration Weathering classification assists in identification but does not imply engineering properties.

	Rock substance unaffected by weathering
Suration (Second Second S	Rock substance partly stained or discoloured. Colour and texture of fresh rock recognisable.
Modernius Vennered (MW)	Staining or discolouration extends throughout rock substance. Fresh rock colour pot recognisable.
Unenty Weighered: (UW)	Stained or discoloured throughout. Signs of chemical or physical alteration. Rock lexture retained,
Tracenety av radies of	Rock texture evident but material has soil properties and can be remoulded.

Strength - The following forms are used to described rock strength:

Trock, Strength Stiffs A Strength	Tebreration.	Point Load Strength Index 95(50) (MBn)
Extremely flow	<u>FI</u> ,	< 0.03
Very Low	VL	0.03 to 0.1
Low	1	0.1 to 0.3
Medium	М	0.3 to 1
Nigh	II.	1 to 3
Very High	VH	3 to 10
Extremely High	RH	S 10

Strengths are estimated and where possible supported by Point Lond Index Testing of representative samples. The insults are plotted on the graphical estimated strength by using.

#### Axial Iroint Load Test

Where the evaluated strength log covers more than oue range a ludicathe rock strength varies herween the finite shown.

### MATERIALS STRUCTURE/FRACTURES

### ROCK

Natural Fracture Spaning - A plot of average fracture spacing excluding defects known or suspected to be due to thilling, oute boxing or testing,

Visual Log - A diagrammatic plot of defects showing type, spacing and orientation in relation to core axis. Closed defects are shown as dashed lines.

Additional Data - Occuription of individual defects by type, infentation in-filling, shape and roughness in accordance with AS 1726-1993 Appendix A Table A10, notes and Figure A2

	BP	Bedding Parting	—)
1.6.6.6.6.6.	$\mathbf{u}$	Joint	1
A. 4 A. 65 A. 65	SM	Seam	
	FZ	Fracture Zone	
	SZ.	Shear Zone	
九日安徽的职行	NN	Vein	- ( )
	FL	Foliation	
	CL	Cleavage	;

Orientation - augic relative to the plane normal to the core axis.

100000 Sec. 12	CN	Clean	
- 经期间 - 日	x	Carbonaccoas	
1. A A A A A A A A A A A A A A A A A A A	Clay	Clay	
Section and the	кт	Chlorite	
	CA	Calcate	
	Fe	Iron Oxide	
	Qx	Quartz	
	MS	Secondary Mineral	
和認識的影響	мо	Unidentified Mineral	;
2Suppose gui	PR	Planar	,
<b>一种问题</b> 记录》注	CU	Curved	· (
<b>REAL PROPERTY</b>	UN	Undulose	8
	ST	Stepped	3
340333.332	IR	treegular	- 2
0.0 <b>.</b>	1218	Discontinuous	
Roughness	POL	Polished	
	SL	Slickensided	
<b>《公开》</b>	S	Smooth	ť
APPRIL AN	RF	Rough	1
Constant State	VR	Very Rough	

### SOIL

Structures - Dissuring and other deleass are described in 400 AS 1726-1993, Appendix A2.6, using the terminology for b

Origin • Where practicable an assessment is provided fit and given of the soil, og fill, topsoil, attavium, collavium, reflected

[		RT	а тес	HNICAL SERVICES NORTHERN	1	••••		
		EX	ĊAVA	TION - GEOLOGICAL LOG	3			JOB H/40866 No. SHEET 1 OF 2
PROJECT: Ga LOCATION: EQUIPMENT T METHOD: BAC EXCAVATION	afton Brid YPE: Vo KHOE DIMENS	<mark>don Dup</mark> lici enlori 923 S <b>IONS;</b> 0,4	tion Rea 5m wide,	lignment Options	SUA POS DATI	FACE I ITION: E OF E	ELEVA.	( ) ПОМ: NTION: 17/9/03
	SUPPORT GROUND WATER LEVELS	NOTES. SAMPLES. TIGIS, EY¢.	OEFH IVETAESJ	CLASSIFICATION SYMBOLS AND SCOL DESCRIPTION Based on United Charactering System MATERIAL DESCRIPTION SOIL 3YPE, PLASTICITY OR PARTIE: D: CHARACTERIE: IC, COLOUR, SECONDARY AND MINIMAR COMPONENTS		NOTCHON CONCINCIA	CONSISTENCY CONSISTENCY PERATINE DENSITY	STRUCTURE & O (HL/) QUOIDIVATIONS
		0.15		Clayey SILT – light grey-brown, low plasticity		D to M	L	TOPSOIL and GRASS
		ĠВ1А 0.fi	- <b>0.5</b>	Silty CLAY/Clayoy SiLT gray-brown, low plasticity	OL 10 CL	м	н	ALLUVIAL RIVER SILT Trace Charcoal HP: 400+Kpa
	ĪZ		-1.0-					
			-1.6-					1
		2.0 G81B 2.3	-2.0-				VST	HP: 300 to 400Kpa
			-2.5-	- as above except light errorge brown, fow plasticity			VST	HP; 200 to 300KPa
PHOTOGRAPHS		YES	NO	UPPORT 1 - Interang MOLETUIA: AXI: 0/ FACAVATION - EASY 2 - Moderate 3 - Hand 0 - Drv	CÓNSIST VS – Verv	ENCY70	ן 1-באדויע <u>ר</u> 15 – עסמי	рсманту Sylt L = Looso
	GROTH	)			9 - Sok F - Film 87 - Sill CHECK	ייי אַרו <u>יינוא</u>	H - Hold Fü - I Hab VL Vury	MD – Modorately Densu lo D – Dense Loone VD – Very Cense ROTH
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					RT.	A TEC	HNICAL SERVICES NORTHERN	1			PIT GB1
		-			EX	CAVA	TION - GEOLOGICAL LOC	;	L		JOB HV40856 No.
PRO. LOCA EQUI META EXCA	JECT ATIOI PME IOD: IVAT	: Gre N; NT T BAC	TYPE XHC DIM	E: Vo DE DE	lgu Duplica miori 923 SONS: 0,45	tion Haal am w/de, .	Ignment Options	501 PQ: DA1	RFACE SITION: TE OF E	ELEVA XCAVA	SHEET 2 OF 2 TION: NTION: 17/9/03
5 5 5 1	C ENCAVATOR		S.PPCAT	GPOIND WATER LEVELS	NOTES, SAMPLES, TESTA, ETC,	NETHES)	CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION Besid on United Classification System MATE/OAL DESCRIPTION SOIL TYPE, PLASTICITY OR PARTICLE CHARACTI, JUSTIC, COLOUR, SILCONDATY AND MINCRAL COMPONENTS	DutesFechion Streed	HOLLIGH HOLLIGH	ZONSUTENCY PELADNE DENSITY	STRUCTURE & OTHER ODSLITVATIONS
		ч-			3.0 GB1C 3.3		Х.Р.D	OL to CL	<sup></sup> м <sup>-</sup>	VST	
		į	2	7		-3.5-					
					4.0 GB1D	-4.0-	Silty CLAY – grey motifed orange, medium plantelty	сі	- <u></u>	Vŝī	HP: 200 to 300KPa
			·			-4.6-	Tost Pit ends at 4.3m (Limit of Reach)				
						-5.0-					
						-5.5-					
PHOTOC	GRAP	11\$ VID	<u>—</u> Энб	<u> </u> ∎ ਸਜ	/ES 🗌		JPPORT = 1 - Induiding  MOISTURE    SE OF EXCAVATION  D - Dry    ATEH  M. Moist    Water Inflow  Water Childow    ESIGNATION: SCIENTIFIC OFFICEH  1	CONSIS <sup>®</sup> 5 - Soft 1 - Com <u>ST - Sim</u> CHECł	TENCY / HU y Soft VS F (ED: DA	ELATIVE T - Very H - Hard B - Friedd A - Very VID GH	DENSITY SIIH I - Loose MD - Moderately Dense 6 D - Dense Loose V <u>D Very Dense</u> RØTTH

Grafton Bridge Route Selection - Test Pitting

TEST PIT 1



_	_	_	RT	ATEC	CHNICAL SERVICES NORTHER	М	-		PI	GB	
			EX	CAV	ATION - GEOLOGICAL LO	G			JON	B HV408	
ROJECT: OCATION QUIPMEN ETHOD: E XCAVATIO	Graft T TYI BACKI DN DI	PE: V HOE MEN	dge Duplic enior) 923 SIONS: 0.4	ation Re	alignment Options , 3.9m long	SU PC DA	RFACE SITION TE OF I	ELEV	ATION: /ATION: 17/9/0	3	
N EASE OF BICAVATION	SUPPORT	GROUND WATER LEVELS	NOTES, SAMPLES, TESTS, ETC.	DEPTH (METRES)	CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION Based on United Classification System MATERIAL DESCRIPTION SOIL TYPE, PLASTICITY OR PARTICLE CHARACTERISTIC, COLOUR, STCONDARY AND MINERAL COMPONENTS	CLASSIFICATION	MOISTURE	CONSISTENCY PELATIVE DENSITY	ата отнего	ICTURE & BSERVATIONS	
			0.25		Ironstone Gravel and Clayey SILT – orange and grey-brown, low plasticity, trace river gravel cobbles	+	D to M	L	TOPSOIL Gravel Grass root fibres	and Fload s and root	
		-	GB2A 0.5	-0.5-	Clayey SILT/Silty CLAY - dark grey- brown, low plasticity	OL 10 CL	D to M	н	ALLUVIUN Root Fibre Charcoal HP: 500+K	UVIUM It Fibres and trace Irccal 500+KPa	
		-	0.95 GB28 1.3	-1.0-	- as above except brown , low to modium plasticity			н	HP: 500+KJ	Pa	
			GB2C	-2.0- 2.05	Silty CLAY – grey mottled orange, medium to high plasticity, trace fine gravel	G 5 H	м	ST to VST	HP: 180 to 3	00KPa	
		2	.5	-2.5-							
		2.	75 382D 0	2.75	Silty CLAY - light grey mottled red, high plasticity	СН	M to W	ST F	HP: 120 to 20 HP: 50 to 100	ookpa IKPa	
OGRAPH	S B	Y N	res 🗌	NO NO	UPPORT - T = Timbering      MOISTURE        ASE OF EXCAVATION - Easy 2 = Moderate 3 - Hard      D - Dry M + Molet        Vater Inflow      Water Outflow        ESIGNATION:      SCIENTIEC	CONSIS VS - Var S - Soft F - Firm ST - Stiff	TENCY 7 R	ELATIVE T - Very H - Hard B - Friat /L - Very	DENSITY Saff L - Loos MD - Mod Ne D - Der Loose VD - Ver	e erately Dense wo y Dense	

RTA	TECHNICAL SERVICES NORTHERN			PIT GB2
EXC	AVATION - GEOLOGICAL LOG	<b>i</b>		NO. , JOB 1/40856 No. SMEET 2 OF 2
PROJECT: Grafton Bridge Duplication LOCATION: EQUIPMENT TYPE: Venieri 923 METHOD: BACKHOE EXCAVATION DIMENSIONS: 0,45n	n Realignment Options	SURFACE POSITION DATE OF	ELEVA	TION; ATION: 17/9/03
NOTES, SAMPLES, SAMPLES, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, NATE, SAMPLES, SA	CLASSIFICATION SYMBOL & AND SOIL DESCRIPTION Based on United Classification System MATERIAL DESCRIPTION SOIL TYPE, PLASTICITY ON PARTICLE CHARACTELISTIC, COLOUR, SECTINDARY AND MINE THAT COMPONENTS	STASSF CUTCH STABOL NGSTUME CONDING	COMMERTERCY RE-MTARE DEUKSTY	SYNUCTURE & OTHER OBSERVATIONS:
	• A.P.D	ĊĦ W	F	<u>+</u>
3,42 GR2E	-3.5- CLAY – durk groy with yollow and red mottles, high plasificity	CH W	VS to S	HP: 50 to 60KPa Clay oppoars to have EW rock structure, and
				нр; 10 to 50КРа
. <u>4.0</u> G92F	q.ŭ-			НР: 30 to 70КРа
4.35	Test Pit onds at 4.35m (Limit of Reach)			Test Pit in-tillod with water, Standing water level at a depth of 3.4m.
	.0-			
-5	5-			
	CASE OF EXCAVATION 1 - Fagy & - Modorato 3 - Hand WATTR Water Inflow Other Inflow Other Inflow Difference Other Inflow Mater Outflow W- Water Other Inflow Mater Outflow Mater	S = Vary Solt V 3 = Solt = Solt <u>E Solt</u> HECKED: by	ST Very 5 N – Hord FB – Frideli V <u>L – Very (</u>	Senan V MD – Moderately Dense D – Dense D – Dense D – VD – Very Dense

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### Grafton Bridge Route Selection - Test Pitting

TEST PIT 2



### Grafton Bridge Route Selection - Test Pitting

TEST PIT 2










#### TEST PIT 3



			RT	ATE	CHNICAL SERVICES NORTHERN				PIT GB4
			EX	ÇAV	ATION - GEOLOGICAL LOG				JOH H/40856 No. SHEET 1 OF 2
F: Gar N: NT 7 BAC (ION	atto FYE 2KH Dij	n Bric 'E: Vo IOE MENS	ige Ouplica mieri 923 Si <mark>ONS: 0.4</mark>	ition Hi Sm wid	e, 3.6m long	SUR POS DAT	TION: ATION: 17/9/03		
,	SUPPORT	GPOLIC WATER	NÓTIS, SAMPLIS, TESTS, ETC,	JEFTH JEFTH	CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION Based on United Cressification System MATERIAL DESCRIPTION SOIL, TYPE, PLASTICITY ON PARTICLE CHAMACTURISTIC, COLOUR, SECONDARY AND MINERAL, COMPONENTS	CLASS FCATTCS STABOL	NOTION Souther	OCINISTENCY BELATIVE CENSITY	STRUCTURE & OTHER OBSERVATIONS
i					Clayoy SILT - groy, low plosticity	•	£)to M	L	TOPSO/L and Grass
				0.2	Clayuy SILT – groy, low plasticity	•	D to M	MD	Secondary Soll Horizon Root Fibras
	Ŋ		0.50 GB4A	0.4 -0.5	CLAY – durk gray mottfod orange, high plaatieity	СН	м	ST	ALLUVIUM Root (Bres throughout HP: 150 to 200 KPa
				- <b>1.0</b> 1.2					
				-1.5	CLAY - gray motiled orango brown, high plasticity	СН	w	F to ST F	HP: 80 to 150KPa Some pockets of EW rock fragmonta HP: 80KPa
		▶  -	1,7 GB48 ASS 1						
			2.0	-2.0-	CLAY – dark grey motiled crange, high plasticity	сн	w	vs	HP: 10Kpa Pit walls callapsing
			2,5	-2.5-	CLAY light grey mottled red and pronge, (		~	ST	НР: 120 to 180Кра
and the second second second second second second second second second second second second second second second			45\$ 2		high plasticity				Gypsum crystals in clay matrix
XIS.			Y#5 [_]	NO	30(PPOH)     → Timboring       BUBPOH)     → Timboring       EASE OF EXCAVATION     →       1 - Fany 2 - Moderate 3 - Hand     D - Dry       Water     Water Inform       Water Inform     Water Inform	OWSER 5 - Vory 3 - Son		ST - Vory H - Hard	OERSITY Sil/f L - Leans MD - ModerMely Dense - Dense
AL.	G	<del>ί</del> στ Ή	· <u> </u>			<u>1 – 2010</u> HECK		VL··Vory	

	RTA T	ECHNICAL SERVICES NORTHERN	!			Pff GB4
	EXCA	VATION - GEOLOGICAL LOG	5			JOB H/40856 No.
PROJECT. Gration Br LOCATION: EQUIPMENT TYPE: V METHOD: BACKHOE EXCAVATION DIMEN	idgo (Puplication Ioniori 923 ISIONS: 0.46m v	Realignment Options	SUR POS DAT	FACE I ITION: E OF E	ELEVA XCAVA	SHEET 2 ÖF 2 TION: 17/9/03
<ul> <li>LEGED<sup>+</sup></li> <li>ECONATION</li> <li>ECONATION&lt;</li></ul>	NOTES, SAMPLES, TESTS, T ETC.	S CLASSIFICATION SYMBOLS AND SOL DESCRIPTION Based on Unified Causification System MATERIAL DESCRIPTION SOL TYPE, PLASTICITY OR PARTICLE CHARACTERISTIC, COLOUR, SECONDARY AND MINERAL COMPONENTS			CONSETERCY RELATIVE DENSITY	STRUGTURE & ОПИ ПОЖа ПУАТЮНЯ
		A.P.D. .1 Sandy Silty CLAY - light groy motiled crange, fine grained sand	Сі	M to W	vst	HP: 200 to 300KPn
	3.6 -3 ASS 3	5- CLAY light grey mottlod red-prange, with fine grained sand	ĊI	M to W	ST	HP: 165 to 200KPa
	4.7	Sandy Silty CLAY – orange-brown and grey, modium to high plasticity	СІ	~	51	RESIDUAL? HP: 120 to 170KPa
	GB4D ASS 4 4.5	j.				
		Test Pit ends at 4,55m (Limit of Reach)				Test Pit in-filled with water and collapsod walla.
	-5,1					
	-6.0					
		SUPPOSIT     T     T     Toroshog     MOISTURE       FAGE OF EXCAVATION     1     Excave     Dory       1     - Leavy 2     - Modations 3     - Hard       WATCH     Modation     Modation     Work       Water Instance     Water Cutlow     Work	CONDIST VS Vory S Son F Film ST Sold	ENCY7H Son VQ	ELATIVE T - Very H - Hezd D - Friad Vi - Very	SUNCHY SUNCHY MD – Moderately Danse Ko D - Danse Lagazo VD – Very Crase

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#### TEST PIT 4









	-		F	R'TA	TEC	HNICAL SERVICES NORTHERN	ł		-•• · •		PIT No	GB
			E	X	AV	ATION - GEOLOGICAL LOC	3		•••••	••••••	JOB No.	H/408
DECT; (3// ATION; JIPMENT T HOD; HAC AVATION	VP XH	n Brid E: Ve IOE MENS	lgu Dup niori 92	olient 23 0 45	ion Rec	llignment Options	SUF POS OAT	IFACE IMON; E OF E	ELEVA	TION:	17/9/03	ET 1 OF
E ECANATOS	Support	GPOLAN WATCH	NOTE SAMPI TEST ETC	35. F8. 5.		GLASSIFICATION SYMIXOLS AND SOIL DESCHIPTION Garef on Wilfed Classification System MATHUAL DESCRIPTION SOIL TYPE, PLASTICITY OR PARTICLE CHARACTERISTIC, COLOUR, STCONDARY AND	CLUSSINGARION 5Y MBOL	MONTRE CONCITION	OUNSISTENCY ELATIVE DENSITY	67	STRUCT HER OIES	URE &
				-		Clayoy SILT - light grey-brown, low plasticity	-	· 🗗	L	TOP Grau fibro:	SO/L s roots o t	und root
					0.20	Clayey SILT / Sity CLAY - dark brown, low to modium plasticity	сі.	D to M	VST	ALLU HP::	200 to 30	———— Ю КРи
					-0.5-							
	N		0.70 GB64 1.00		0.7 -1.0-	Silly CLAY - dark brown, mod/um plasticity	CI	м	ST	LiP: 1 Chan	00 to 13	iokPa root fibre:
					<b>-1.5</b> -							
			2.0 Q858		•2. <b>0</b> =	plaslicity		М	ST VST	HP: 1 Traco HP: 3	00Kpa root (Ibr 40 to 370	ия ОКра
		2	.3		-2.5-					HP: 30	ЮКра	
										HP: 20	ОКРл	
GRAPHS			( <b>E</b> S [		NO I	SUPPORT - T = Tribering     MOISTURE       AUT: OF EXCAVATION     D - Dry       - Carry 7 - Moderate 3- Hand     D - Dry       NATUR     M - Melet       Wates inflow     Water Outlow	CONSIS! VS - Von 8 - Soli F - Flore ST - Plore	ENCY / IT Soli Vs	ILLATIVS IT - Vory It - Lord F& Lited	DENSIT	L – Coase IC – Moder IC – Dengr	atély Coneo
	GЛ	OTH				DESIGNATION: SCIENTIFIC OFFICER	CHECK	ED: DA		1.00% RC1711		Dauge

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•••		-		RT	Α ΤΕς	HNICAL SERVICES NORTHERN	I				PIT No.	GB5
				EX	CAV	ATION - GEOLOGICAL LOG	3				JOB No. SHEE	H/40656
ROJE OCAM QUIPN IETHO XCAV	GT: ION AEN D: E	Graf T TY IAÇH DN E	ton Bi (PE: \ (ROE) ( <b>ME</b> )	ilago Duplica /oniori 923 ISIONS: 0.4	alion Rea 5m wide	lignment Options	SUF POS DAT	RFACE : STION; E OF E	ELEVA	110N: TION: 1	7/0/03	
R EASECF	3	C 00001	CPCUAD WITER	NOTES, SAMPLES, TESTS, ETC.	(SETTRA) VIETE S	CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION United CIRCUTON MATERIAL DESCRIPTION SOIL TYPE, PLASTICITY OR PARTICLE CHARACTERISTIC, COLOUR, SECONDARY AND MINETAL COMPONENTS	CLASSIFICATION	NDUTURE CONTINE	DARIE TROT	OTH	STRUCTU EN ODSEI	RE &
					·	A.P.D.	CI	м	V5T			
		N		e.s GB5C	3.3 - <b>3.5</b> -	Silty CLAY – gruy motified orange-brown, medium plasticity	сı	м	vst	HP; 2:		
					-4.0-	Silty CLAY - grey motifed orange, modium to high plasticity	Ci to CH	M IO W	şr	HP: 1!	50 to 200	 )КРа
				4,3 QB58 4,6	4.3 -4.5-	CLAY –dark grey and black, high plasticity	сн	M to	F to ST	Charce NP: 10	oKPa	ghout '
					-5.0-	Tast Pit ands at 4.60m (Limit of Reach)						
					-5.5-							
	FAF	hs		YES		KUTPORT - T - Terbogno         MOISTURE           EASE OF EXCAVATION	CONSIS VS - Vo S Su	STENCY7 Ny Sont N	RELATIVI /ST - Van K - Han	COGNSITY Y Silt J N N	L – Loose L – Modar	ataty Duriso
			ĠĦŌ	Гн	- •	DESIGNATION: SCIENTIFIC OFFICER	CHEC	NED: D	VI Ver NVID G		/D – Very I	Denso

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				RT	A TEC	HNICAL SERVICES NORTHERN	N			PIT GB6
				EX	CAV	TION - GEOLOGICAL LO	G			JOB 4/40856 No.
ROJEC' OCATIC QUIPME IETHOD XCAVA <sup>-</sup>	T; (3) 2N; ENT ENT ; UA TION	alic TYF CKH	n Brit PE: Ve HOE MEN <u>S</u>	Jge Duplien mieri 923 SIONS; 0,44	tilon Rea 5m wido,	lignment Options	SUI PO: DA1	RFACE SITION: FE OF 6	ELEVA EXCAVA	TION: 17/9/03
<ul> <li>EASE OF</li> /ul>	3	SUFFORT	GEOCHO WATER	NOTES. MMPLES. TLNIN, ETC.	DEPTH DEFTH DEFTHES	CLASSIFICATION SYMBOLS AND SOL DESCRIPTION Marged on Unfiled Cladefication System MATERIAL DESCRIPTION SOL TYPE, IN ASTICITY OR PARTICLL CHARACTERISTIC, COLIDIA, SECONDARY AND MINERAL COMPONENTS	CLASSFICTICN S-MBOL	NOSTLAS SOUTION	CONSISTENCY RELATIVE CONSILY	STRUCTURE & OTHER OBSERVATIONS
					0.20	Silty CLAY / Clayey SILT – fight groy- brown, low to medium plasticity, with cobbins (ox road?)	- 	D to M		TOPSOIL and Grass
						Sendy Silty CLAY - unange-brown, low to modium plasticity, find to coarse sand, with find gravel and trace cobbles and small boulders	CL	м	н	FILL
	ļ	<u>Ki</u>			-0.5-					
				<u>0.70</u> GB6A	0.7	Silty CLAY groy motiled erange-brown, medium to bigh plasticity, with fine grained sand	сı	м	vsr	АLLIVIUM НР: 220КРд
			+	-3_10	-1.0• 1,1		 			• ••••••••••••••••••••••••••••••••••••
						Sandy CLAY - light grey motified erange, high plasticity, fine grained sand, trace hard forruginous nodules	CH to SC	M to W	Ş	НР; 20КРл
					-1.5-			-		
			 -	1.8						
				086B	-2.0-	Clayoy SAND – light grey motilod omngo. tine to medium grainod sand	SC	w	VL	
		-	•		2,4	SAND Hope gove first an address and a				
		-		GB6C . <u>8</u>	-2.5-	ouvo - ngat grey, nao o modiom grained	SC to SM			Saturated sand was
						Test Pit discontinued at 2.6m (test pit walls collapsing and pit filling with water)				
		G		·εε [] 		UTFOIT - T = TIMPOND ASC OF EXCAVATION	CONSISS VS - Ver S - Set F - Firm SY - Star GHECH	IENCY/H / Sok V: / KED: DA	ELATIVE ST - Very I H - Herd I S - Frails <u>VL - Very</u> AVID GS	DENSITY Sam I – Lonan MD – Mudonitely Donne in D – Donse Lucase VD – Very Donge NOTH

TEST PIT 6



TEST PIT 6



			RTA	<b>TECI</b>	HNICAL SERVICES NORTHERN				No. GB7
			EXC	AVA	TION - GEOLOGICAL LOG	÷			JOB H/40856 No. SHEET 1 OF 2
IOJECT: G CATION: UIPMENT THOD: BA	raité TYF GKI V Dil	n Brid YE: Vo IQE MENS	ige Duplicat mieri 923 iIONS: 0.49	tion Real im wide,	lynment Option:	SUF 209 0A7	FACE ITION: E OF E	ELEVAT	TION: 17/9/03
N ELSECT	SUPPORT	GOUND WATER LEVELS	NOTES. SAMPLES, MISTS, FIG.	(NSTRES)	CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION Rased on United Casalifaction System MATERIAL DESCRIPTION SOIL TYPE, PLASTICITY OR PARTICLE CHARACTERISTIC, COLOUR, SECONDARY AND MINERAL COMPONENTS	CLASSFICATOS SYNBOL	NOTITIE LUCATION	COMSKIEVOT RELATING ODUSTY	STRUCTURE & OTHER OBSERVATIONS
]					Silly CLAY - /lght groy-brown, low plasticity	•	D	MÐ 10 L	TOPSOL Grass roots and root fibres
	7			0.25 -0,5-	Sility CLAY – brown, medium plasticity	CI	M	н   н	АШ⊍У≀UМ НР: 400+ КРц
			1.00 GB7A	0. <b>6</b> 5 -1 <b>.0</b> -	Silty CLAY – dark groy mattled arango- brown, módlum plástialty	СІ	м	VST	HP: 300 to 400KPa
		, ,	1.40	-1.6-					
				-2.0-	- dark groy, high plantiçity			ST	HP: 250KPa HP: 120 to 140Kpa
		s.	2.6 G87H 2.9	-2.5- 2.6	CLAY – gray motiled orange, high plasticity	CH	M to W	ŞT	НР: 160 to 200КРа
1 <u>1</u>			YE\$	] ON [	SUPPORT T - Tributing MORSYURE EASE OF EXCAVATION 1 - Easy 2 - Moderato 3 Hand D - Dry WAYER Water Inflow - Water Outling W - Wei	CON9* V3 - V 9 - 34	STENCY / sy Son m	(PELATIV) VST – Vec H – Hpn I H – 1 ns	E DEALUTY y Silf L = Looso d MD = Mederately Depan bla <u>D</u> = Dente
. No	(10 ( 1		H		DESIGNATION: SCIENTIFIC OFFICER	CHEC	NKED; C		<u>у сооз≜_ур – ∨алу ∯елзо</u> 3RQTH

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		RT	A TEC	HNICAL SERVICES NORTHERN				
		EX	CAVA	TION - GEOLOGICAL LOG	;	,		NO. JOB H/40856 No. SHCET 2 OF 2
DJECT: Gra ATION: MPMENT T HOD: BAC AVATION I	llon Bi YPE: \ KHOE DIMEN	idge Dupilea /enlori 923 ISIONS; 0,4	ulon Aesi <u>5m</u> wide,	ignment Options 3.8m long	SUH POS DAT	FACE I TON: E OF E	ELEVA	110N: 110N: 17/9/03
	SUPORT CRUISDWATER	NOTES, SAMPLES, TESTS, TESTS,	NETHES	CLASSIFICATION SYMBOLS AND SOXL DECORPTION Bravel on Unified (Jassification System KATERIAL DESCRIPTION SOIR TYPE, PLASTICITY OR PARTICLE CHADAGTLARDTIC, CON OUR, SECONDARY AND MINITRAL COMPONENTS	D.CSFCM04 Energy	VID STURE COMPILIAS	CONSISTENCY FOLKITVE DENSITY	
				A.P.D.	¢н	W	\$T	Hesting Water table depth (contined by clay)
		3.7 G87C	-9,5- 3.7	CLAY – dark grey molted omnyo, high plosticity	сн	M to W	SI	HP: 120 to 170KPa
		40	-4.0-	CLAY dark grey and bleck, high plosticity, with fine (carbonaceous) concretions	СН	w	S⊡ ⊬	HP: 30 to 80KPa Strong sulfuric odour
	-	4.3 G970 4.6	4.3 -4.\$-					Strong roaction to hydrogen peroxide
				Test Pit ends at 4.60m (Limit of Roach)				
			-3.0-					
			- <b>5</b> .6-					
Yous	<u> </u>	YE\$	NO [	SUPPORT - T - Trademong MORSTURE ASH. CH L XCAVATION I - Lany 2 - Moderate 3 - Hard D Dry MATER M - Molet Water Curraw W - Wet	CONSIS VS - Ver S - Sol C - Dm	reniciv71 rytan v r	КСЦАТАVС КСЦАТАVС И — Very Н — Микс 58 — РАФ	CDENSIYY CSIII I − Loouw I MD - Maderatety Dwnaw De D + Denso
	GRO	<u></u>		► Winder faillow = ♥ - Wester Connexe   W - West DESTGNATION: SCIEN DERD OFFTCFFR	ST - Bri ST - Bti CHEO	, KED: D.	58 - 560 <u>VI - Ven</u> AVID G	olo Din Ceniso (Laazo VII – Very Daniso ROTH

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TEST PIT 7



MR 83 City of Grafton Grafton Bridge and Approaches Geotechnical Investigation for Route Selection

# **APPENDIX E**

## Original Bridge Section (Work as Executed Plan?)



MR 83 City of Grafton Grafton Bridge and Approaches Geotechnical Investigation for Route Selection

# **APPENDIX G**

# Borehole Logs and Site Plan - 1975 Investigation



## <u>HOLE</u> IA

(On & of purple line by Vicinity of Northern Knik RL 9668 Bearing 267 531 ; Chringe guissicities)

<u>Sand Bed</u> - brown, grey with various siger provals scattered throughout. Evidence of odd this lenses of soft muds occurring at various debths.

<u>Gravel Eed</u> - sand bound and donse with their personations of cabble sized material throughout (up to locuse in size recovered interf).

### <u>Gnitty Clays</u> - soft, sticky, graenish groy.

Sandstone - fairly hard, gray madium grained with add minor weak seams occurring. Bedding tagetar and tanding to horizontal.

 Lithic Sonditions - very highly whatliess I layers of soft and Madium hand, array brown. This whole zone is "Bolow very Weak"

HOLE 2

( on to of Green Line in vicinity of Wardworn Book) (Bearing 30" of chainings 63.36 - X-



Sound Bug - medium grained, mud bound in initial stage

Sand Bad - medium grained with regetation fragmants timi black caft sandy mud stringers and small gravels throughout Dansaness of gravels increases with derti.

Groval Bod - sound bound.

Sandy Clay + Soft granish . sticky ...

<u>Lithic Sandetone</u> - fairly hard, greenish green, wenthermal, heavily cracked mediums and fine grained (probably matter bads. Noterial appares to get hardor (cont below

Lithic Sondstone - hand gray, fine grained, cracked. Cracks rouging from horizontal to vertical. A weak some of encloaritanous material comprising allow the multiple water this lignite and conditions because forigentally Luminated which tard to part the accurs at interval 18.90 to 19.15. Badding generally regular and horizontal.

 with dabth and contains traces of mina and add this sold stimly clay chance. Creaks was rear herizontal to vartical with badding tanding by herizontal.

# <u>HOLE 3</u>

(on to of Grean Line in visinity of Southern Bank) (Rearing 156° 11' - Chainage, 15870-RL 5(196)



Snad Bad - gray, brown, maximm to course grained. Slightly mud bound in initial stages and with odd small gravals scattered throughout

<u>Lithic - Sandstone</u> - very highly weathered insitin. Now recembling layers of decomposed soft to firm cohecille black and grey day. The motorial with their layers of have sandstone & sillstone ecottered throughout. Exist variant <u>Sandstone</u> - hard, gray, fine grained. Showing miner cracking and bedding tending to horizontal. Last 2m of core recovered & sighted but not boxed.

<u>HOLE</u>4

( In Vicinity of Rad Line in Vicinity of Northern Bonk) (Bearing \$7° 54. Chainage 21183 PJ. DE 22)

<u>- kivar muds and sands</u> - soft and black.

<u>Soud and Croval Bad</u> - grovals woll rounded and up to summ in cize recovered but suspect that, collides also present. A thin soft black singly along thringer of is call m.

Lithic Sandstone - Gray soft running quickly in Medium Hord weathered. At best very weat

Sudiments (comprising Lithic conditions and cloyay sillstones - probably Gration Formation) Generally very bard, grey cracked, fine product. Will bedding harizontally inclined and parallol. Material contains a partially decomposed seam at 1955 to 2010 which shows minor seams of soft clay-like material and lignite also minor lignite vers southered throughout except for zone 1955 - 2010. Rock appears to improve in hardness with debth. N8. Strinkage cracks appeared upon drying out in initial rock.



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# <u> HIOLE 5</u>

( In visibility of Red Line is visibility of Southers Konth). ( Bearing 1129444; Charage 329.50, RL 89.20).



Sond Bad - gray, brown, mud bound, median grained

Sand Bed - gray brown medium grained , with small grovels scattered throughout (up to som in diameter recovered

<u>Lithic Sandstana</u> - Alternate layers of fairly hard, gray, fine i madium grained sondstanes and druk. gray mudstanes of varying hardnesses (from mature hard through to bard whole gone a lithic Sandstane (probably Graftori Rads) containing nimor weak saams, but with a major soft decomposed fairly cohesive slay-like seam at 13.12m-12.20 m. Material generally cracked with bedding dending to horizontal with traces of lignites pyrites contered throughout.

C

<u>110LE 6</u>

(On 4 of Red Line in vicinity of Southern Bank) (Bearing 136°00'; Chainage WWW60; Ry 10676).

00 . sinnerso, promot, eilty, normy - Topsoil. 1.30 <u>Silty Sandy</u> Clays - stiff , brown, fine grained . C:50 <u>Clays and Pants</u> - niteractive layers of firm to stiff due grey-blackish groasy cloys and multiplad finally Invarian day bound prats. 561 <u> Clays</u> - altarnata layers of stiff bluey-gray greasy clays and brown -gray fine grained elightly condy clays tanding to become silly clays with debth. Lost water at 10.85 m. 17 60 s<u>ility clays - cost</u> to firm dark gray. 10.00 Sand Bad - modium grained with small publies scattered 22/00 throughout C, Lithic Sandstong. (maitu) highly weathered . Now recent ling layers of grey and greenists gray heavily cracked fine grained conditione of varying horanessas (fairly that 24 ዓል and fairly hard to hard) with weak partially (court & Lithic Soudstons - grey , fairly hard to hard, cracted (generally horizontal), fine grained with beddiving inclined to horizorital and containing minute traces of pyritas and lignite 1900 b decomposed some of varying thicknesses contrary throughout. Badding transling to himizontal and motories

## <u>HOLE 7</u>

( l'ast of Rod Line on Southern Bornk) ( Leoning 153"46"; Chainage E63-83; RI 104-12)

> Logmy Topsoil - firm, brown, fine gromed, organic Lonmy Sandy Clays - firm to stiff, light running to dark, fine grained.

Clays - firm to stiff, light gray to alive modified, fairly sticky greasary.

Sandy Glays - firm to stiff brown, fine granied.

Clays - alternative multiple layers of light and dorig brown clay bound gravels and stiff, finn grained sandy loamy clays.

Sadiment (insitu) - very highly weathered. (low reversion loyers of varying thicknesses of brown medium hand to fairly hard generally fine grained "sondstone." (Section from horizontal to 100) with seams of partially decomposed and decomposed sondstone throughout A very hard layer of fine grained consistone of (cont-<u>Sediment</u>. (insitu) wery highly weathered, now recercibling byors of varying thicknesses of medium bards, tring has gray fine to medium grained conditions with control partially decomposed sondstone with control clay-like medium grained conductions with control highly decomposed sondstone and decomposed condy clay-like medium grained to hards, gray the bodium grained, cracked with horizontally inclined bodium grained, cracked with horizontally inclined bodium and containing a decomposed corum at 22.25 to 22.70. Comprising multiple, minor corry clay-like medium scams alternatively with fairly hard condetom

Interval 15 go to 16:20 Initially rock of best very weak? but tanding to deteriorate with defilly were withold your 14:50 to 19:85 appears to be "believe very weak"



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APPENDIX B

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BOREHOLD LOGS - BHSG1 TO BHSG7

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Bor	ወሖ	الم	ا ما	00				Bore	hole No.	BHSG 1
00				.09				Shee	** 1 **	1
CLI	ËN	т;	Ċ	AMERON	≬ M <sup>e</sup> n	ΑΜΑRΑ ΡΤΥ, LTD,		Job	No. 2417	
۴R	ÓJE	EC	Ti: S	оитн (	RALL	ON LEVEL - GEOTECHNICAL INVESTIGATION		Loca	tion : 1 712 294	405.331N 249.576F . 3.17m
Equ Hole	ipm ; Ui	en t om	Type stor	:	TRUC 100m	K MOUNTED EDSON 3000 m		Angl Bear	c From Vertli ing :	cal : 0°
Samples	Water	Casing	_i Bi c Metre	e uepti Grophic Log	U.S.C.S.	Material Description, Structure Soli Type : Plasticity or Particle Characteristics, Colour, Secondary and Minor Components. Molstore, Structure.	Consistency	Relative Density	Field Tost Results	Geologicul Profile
111			1.0		OH/ OL	SILIY CLAY, modium plasticity, dark brown, organic, with fibrous roots. Moist.	FI	₹M		
05 L001	×		2.0			CLAY, medium to high plasticity, brown and prange brown, becoming grey brown with depth. Moist.	ST		TV:65 JIP:160	-
03 3072			3.0	-	СН	NOTE: Groundwater Intersected at 4.10 metres.			SPT, N = 8	_
04			4.0		<u>ъц</u> –	CLAY, as above, becoming green brown.	УЫ 511		<u>"TVT70 AP7270</u>	I AYERED — ALLUVIAL DEPOSITS
1003 105			5.0 6.D		СН	CLAY, as above, brown and orange grey. Moist.		- X 11F	VIP: 360	
004 D6			2.0		CH/ CL	CLAY and SILTY CLAY, high plasticity, grey and brown, with some thin dark brown organic bands, Also some fine Gravel to Jmm. Wet.			1V:>100 \HP:300	_
Q.7 05			8.0			SILTY CLAY, incdiumi plasticity, grey and brown, with some fine Sand and Gravel.		। स्र	17::100	-
<sub>Da</sub>			<b>ή</b> ,Ο			SILTY CLAY, medium to high plasticity, brown, with some fine grained Sand, Moist to wet.	ST: 	(FF	<u>/m::aqu</u> /	-
<u>. vőő –</u>			10.0		CL Z CN	(Singhtiy 7255 Stiff From 10 to 11 metres),			<u>177:50 117:220</u>	-
<u>SP13</u>			12.0-			SILTY CLAY, as above, becoming prange brown,			SIDT M - AG	-
			13.0		:	grey brown, with some time sand and a trace of fine rounded Gravel. Moist.	י אני   גנו	8Y 1171-	9 <u>2.12 10 111</u>	
09 U <u>DV</u>			14.0-		CL/ CL	GRAVELLY SILLY CLAY, median to regn plasticity, brown and grey, with rounded Gravel increasing in size and density with depth, to Gravelly Clay and Clayey Gravel, Maist.	нля	D	<u>(V:&gt;100</u> " NP:≻500	-
						V-01Y REFUSAL AT 14,64 MPIRES IN CLAYEY GRAVEL OVERLYING HIGHLY WEATHERED ROCK. END OF HOLE AT 14,64 METRUS,				-
			-							
• ;			-	$\left  \right $						~
										L
Log	ged	بر وع	y :	с.р.к.		Date : 9.12.86 Checked By : 6	r-K		Date : (6-)	2-86
PB						Patar I Rura		D. 1		

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Borel		le I	امد	r				Bore	hole No.	BHSG 2
				<b>,</b>				Shee	t 1 of	1
CLIE	۲.1	C	ameri	un m <sup>o</sup>	NAMARA PTY. LTD.			Job	No. 2417	
PRO	ЕC	:T: 5	OUTH	GRAF	TON LEVER - GEOTECHNICAL	. INVESTIGATION		Loca	tion : 1 712 294	G34.893 N 524.615 E
Equipr Hole (	non Viarr	t Typ- teter	с; ;	TRL 100	CK MOHNTED EOSON 3000			Angle Bear	e From Verti ing :	3.26m 301:04
Samples Water	Casing	Metre	Grophic	Log	Material Descriptio Soil Type : Planticity of Puri Colour, Secondary and Minor Moistore, Structure.	n, Structure Note Characteristics, Components.	Considency or	Relative Density	Field Test Results	Geologicol Protile
		1.0			SILTY CLAY, medium plast organic, with fibrous ro SILTY CLAY, as above, be less Silty with depth.	icity, dork brown. ots. Noist. coming grey brown	SOF TO FIR	т мм 	SPT, N = 7	
-001 03 SPT 2	-	2.0 3.0			CLAY, high plasticity, g brown. Moist. Becombar I Stity bands from 2.8 met NOTE: Groundwater Inters	rey brown and light ight grey with some res. coled at 3.65 metres.	STI	FF	<u>IV:65_UP:130</u> "SPT, N - 8	-
<u>04</u> = . <u></u>		4,0 5.0			CLAY, as above, with Sil plasticity, green-grey-b brown organic bands and	ty Clay bands, high rown, with some dark inclusions.	VER Sti	IY FF	TV:59,372280	-
00 07 004		6.0 7,0			SILTY GRAVELLY GLAY, med brown, with some fine rou CLAY and SILTY GLAY, hig brown, with some fine rou Smm. Wet,	ium plasticity, green unded Bravel to 5mm, Wet, n plasticity, groen-grey- unded Gravel Fragments to	T.SOF VER \$11 TO HAR	ד <u></u> אי ואי ואי	HP: 400 TV:>100 HP: 400	ALFOVIAL DEPOSITS -
D 8 UD 5		8.0 9.0			GRAVELLY SILIY CLAY, med- brown, with rounded Gravn Net. CLAY and SILIY CLAY, high	ium plosticity, green- el Fragments to Iumm, i plostocity, urange-	VER ST 1	Υ ΓΓ	<u>iv;80;40;350</u>	
09 111)63		10.0 11.0			CLAY and SLLTY CLAY, as I CLAY and SLLTY CLAY, high brown. Maist to wet.	Trom 7.7 to 8.9 motres.			<u> </u>	
D 10 SP1 3		17.0 13.0		<u>1.1 mile</u>	GRAVELLY SLITY CLAY, high with rounded Gravel (ragn Becoming more Gravelly fr	n plasticity, brown Ments to lūma. Moist. Fom 12.9 matres.	VER.		SPT, NET14	
011 107		14.0					STI TO UAR HAR	FF D	TV:80,HP:400	
			•		V-BIT REFUSAL AT 14.6 MET END OF HOLE AT 14.6 METRE	RES IN GRAVELLY CLAY. S.				-
										-
Logge	d B	y :	G.P.)	<	Dote : 10.12.86	Checked By : C.P.	Ķ.		Dote : (6-)	2,`86
PB						Peter I Rura		R 1	Accordance	Pty Jtd

Bor	օհ	പ	ا ما	•				Bore	hole No.	BHSG 3
				-9				Shee	at j of	1
CLI	ΕN	T:	CA	ME RON	I M <sup>o</sup> n/	AMARA PTY, LTD,		գեր	No. 2417	·
PR	o Jt	C	T: SQ	υτη Θ	RAFT	DN LEVEE - GEOTECHNICAL D	INVESTIGATION	L.oco	ition ; 1 713 0 293 8 ar Level : R.L.	28.182 N 21.842 E 5.47m
Fqui Hole	ipm i Di	ent om	type eter :	;	ͳ <b>ϰ</b> ϢϹ 100m	Angl Bear	e From Verth ing :	ca); ( <sup>0</sup>		
Samplea	Water	Cosing	Metrea	Graphic Log	U.S.C.S.	Moterial Description, NoII Type : Clasticity or Costicle Colour, Secondary and Muor Co Moleture, Steaglare,	Structure - Characteristics. 2019/00/012	Considency or Relative Density	Field Test Results	Geological Profile
					SW	BITUMEN ROAD PAVENENT,				- ΓΙ.ι
SPT. 1			1.0- 2.0- 3.0-		4 9 9 СЛ/ СL	ARAVULLY SAND, find to medil brown, with find Gravel. Dry rounded Gravel (to 4Dmm), fi (Hry, SILTY CLAY, medium to high green-brown, with some Grave decreasing with depth, Mois	um grained sand, red- y. Grading into rom 0.6 to 0.9 metres. plasticity, dark brown, plasticity, grey and el fragments to Bmm t.	THED. OFN. FIRM TO STIFF VERY STIFF	SPT, N - 7 IV:80,8P:220	Al,1,1VI UM
<u>m</u> s			4.0-		NA	<u>SANUSIONE, fine grained, or</u>	n depth. ange and yellow. Ory.	HIGHLY WEATHERED	TV:>100 HP:>500	SANDSTONE FLOATER
00 3 0 2 5PTZ 0 3 5PT 3 0 4 5PT4 3PT5 5PT <u>6</u> 5PT <u>6</u>			5.D* 6.0* 7.0- 9.D. 10.0_ 11.0_ 12.0_ - -		SP	V-Bitrefusal, I.C. Bit requi SILTY CLAY/CLAYEY SILT, low brown, with some fine Sand Y CLAYEY SAND, fine to very f dark brown-grey, with low p some Silt, Urganic, Met, Becoming less Clayey with de Sand size (nereasing with de SILTY SAND, fine to medium of arey. low to non-plastic fir SAND, medium grained, dark g graded, END OF HOLE AT 12.45 METRES.	plasticity, dark from 5.0 metres. Moist. inc grained Sand, lasticity Clay, and spth. prained Sand, dark ins. Wat. prey. Wet. Poorly	VERY LOOSE LOOSE MEDIUM DENSE.	TV:25.HP:100 SPT, N = 3 SPT, N = 7 SPT, N = 15 SPT, N = 17 SPT, N = 14 SPT, N = 18	
Log	ged	B	/: (	р.к.		Dote : 10.12.85	Checked By : GP	.K.	Date ; (6-)	7. <sup>°</sup> 86,
РB							Peter J. Burge		Associates	J

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Bor	eh	o	le L	oσ			Bor	shole No.	BRSG4
		_		- 3			She	at of	1.
СЦ	ËN	τ:	CA	MERUN	l M <sup>C</sup> N	AMARA PYY, LTD.	dol	N¢. 2417	
PR Equ	O J E	EC	T: SO туре	UTIK C	TRUCK	DN LEVEE - GEOTECHNICAL INVESTIGATION	Loca Coll	ation : 1 713 1 293 0 ar Level : <sub>R.L</sub> 16 From Verti	89,873 N 67,883 E 7.63 m col : 0°
Hold	: 01	anı	eter ;		100mm		Bed	ring :	- 
Samples	Niater	Casing	⊥ کے لیے Metrcs	Grachic Leg	U.S.C.S.	Material Description, Structure Soil type : Mosticity on Particle Characterialica, Colour, Socondary and Minor Components, Moletore, Structure	Consistency or Relative Density	Field Test Results	Geologica) Profile
ני SPT :			1.0,		ML/ OL	CLAYLY SANDY SILT/CLAYEY SILTY SAND, fine grained Sand, low plasticity Clay, dark brown, Moist, Organic, with some fibrous roots. Becoming Sandior with dopth.	MEDI UM DENSE	SPT. N - LG	LEVEE BANK -
<u>p2</u> <u>U0-1</u>			2.0_		ML/	SILTY SAND, Fine grained Sand, dark brown, with low to non-plastic fines. Partially dry,		TV:>100	
र्षेषिष्			3.0.			SILTY SAND/SANDY SILT, as above, with progres- sively less Sand.		SPL, N = 10	_ , , <b>_</b>
0 0 5PT4			5.0-		ML/ SM	CLAYEY SANOY SHLT/CLAYEY SHLTY SAND, fine grained Sand, low plasticity Clay, dark brown. Moist. Organic. Some this bands of bioton Clay content from 6.6 in	LOOSE	<u>SPT. N = 10</u>	
D 5			6.0-			5.4 metres. Becoming Sandier from 7.0 metres. NOTF: Groundwater Intersected at 7.10 metres.		<u>arr. R - 10.</u>	_
<u>D 6</u> SPT6	Į		7.0-	0.73	_SM _	SILTY SAND, fine to medium Sand, Jow plasticity Fines, Net.		SPT, N = 7	ALLUVIUM _
0 <u>7</u> _ <u>SP17</u>			8.D- 9.0·			SAND, fine to medium grained, brown-grey and grey. Wet.		5PT, N - 15	
<u>spta</u>			10.0-			SAND, grry, as above.	MEDIDM	<u>- SP</u> Y, N <u>- IZ</u>	
SPřg			11.D~		SP		DENSE	_SPT. <u>N - 17</u>	-
SPT 1(	,		12.0-			SAND, grny, as above.		SPT. N - 13	-
			13.0- 14.0-					-	-
. SP111		_				END OF HOLE AT 14.45 METRES.		<u>SPT, N 7 17</u>	
		ļ							-
									-
Log	ged	6)	/; ( 	:.Р.К.		Date: 11.12.86 Checked By: Cf.	μ <u>.</u>	Date : (6-1	ъ. <sup>1</sup> ВС
I E E						Patar I Ruras	<b>2</b> .		

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Bor	eh	0	le L	oa				Bore	hole No.	BRSG 5
		_		- 5				Shac	t of	1
CL	EN	T:	. CA	MERON	M¢N∕	AMARA PTY. LTD.		Јар	No. 2417	
PR	ΟJ	EC	T: so	UTH G	RAFTI	ON LEVEE - GEOTECHNICAL INVESTIGATION		Loco	tion : 1 7)3 292	049.596 N 937.773 F ., 7.520
Equ Hole	lp≀n ≊DI	en i on:	Type eter:	; (	RUCK IODimit	MOUNTED FOSON 3000		Angl Bear	e From Verti Ing :	col 1 <sup>00</sup>
Samples	Wicter	Ccsing	Metres	Graphic Log	U.S.C.S.	Material Description, Structure Soil type : Plasticity of Particle Chuructwindics, Colour, Secondary and Minor Components, Molatoro, Structure	Consistency	Relative D <b>en</b> sity	Fleid Test Rosults	Geologicol Profile
01 SPT 1 D 2			1.0	<u>10.00000000000000000000000000000000000</u>		CLAYEY SANDY SILT/CLAYEY SULTY SAND, fine grained Sand, low plusticity Clay, Dark brown. Moist, Deganic, with some fibrous routs.			SPT, N - 21	- LEVEC BANK _
00 1 0 3 5P7 3 0 4 00 2			3.0	actoria Sectoria Sectoria	ML/ OL	CLAYEY SANDY SILL/CLAYEY SILLY SAND, fine grained Sand, low plasticity Clay. Dark brown. Organic. Moist.	DEN	ISF SF	TV:>100 (IP:>600 SP1. N - 24	,
<u>- 5171 3</u>			5.0. 6.0-	<u>E un tin S</u> E un tin S E un tin S		As above, grading progressively to Clayey Silt, with some thin Sandy Silt Layers,			UP:-500	
05 UD3	N N		7,0. 8,0-			SILTY CLAY, medium plasticity, grey prown-black, Moist, Organic,			<u>TV:40, HP:1,80</u>	? ? " 
<u>06</u> <u>004</u> <u>117</u>			9.0- 10.0-		OL / DH }	SHLTY CLAY, as above, becoming high plasticity from around 9.0 metres.	STI	rr	1V:45 HP:110	LAYERED - ALLUVIAL DEPOSITS -
- <u>D 8</u> . UD 6			11.0. 12.0_			Wet. Organic. Some thin grey Sandy Layers,			TV: 25 <u>RP: 120</u>	
_D 4)			13.0- 14.0-			Sandy Clay and grey medium grained Sand.				-
<u>Ş</u> P1 4			15.0-			Thin (upto 100mm) interbeds of SILTY CLAY, as above, and gray medium grained SAND, Wet.	L00	SE	<u>врт, н ч 2</u>	
D 10 SPt 5			16.0 17.0.		( DH )	SILTY CLAY becoming less prodominant with depth.			SPT. N - 8	-
<u>SP(</u> 6			18,0 19.0			Interbeds (upto 300mm) of SILTY CLAY, as above, in grey, medium grained SAND. Wet.		}	SPT. N - 6	-
SPT 7			.20.0	. <u></u>		END OF HOLE AT 20.45 METRES.			SPL, N - B	
Lay	ged	B	y:	G.P.K.		Date : 11.12.66 Checked By : 6.6	κ.		Date : 16.0	s~`86
BB						Poton I Buro	~~~	ر م		

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Borehole Loa									hole No.	DHSG 6			
				- 9				Shee	et of 1	1			
CLI	EN	Τ:	CA	MERON		Job No. 241/							
PROJECT: SOUTH GRAFION LEVEE - GEOTECHNICAL INVESTIGATION									Location : 1 714 341.012 N 291 065.654 F Collar Level :R.L.6.58m				
Equ Hole	ipm : 01	çrit QM	Type ater :	: 1) 1(	KUCK ) Dünim.	100N /FO FUSON 3000		Angl Bear	c From Vertic ing :	eal: n <sup>o</sup>			
Scmples	Water	Casing	یں ہے۔ اور کے Metrea	Graphic Leg	U.S.C.S.	Moterial Description, Structure Soil Type - Planticity or Particle Characteristics, Colour, Secondary and Minar Components, Moletore, Structure.	Consistency or	Relative Censity	Floid Test Results	Geological Profile			
			1,0-		SM/	SANDY SILT, fine grained Sand, non-plastic fines, brown, Dry.							
01						Becoming Sandier with depth.	j						
SPT 1			2.D-			SILTY SAND, fine grained Sund, non-plastic times. brown, Dry,			SPT, N = 13	-			
			4.0-		см.	SILTY SANO, as above.	1 DE:	NSE		-			
<u>SPT 2</u>			5.0.		-9114 -	SILTY SAND, medium grained Sand, low to non- plastic fings. Brown and orange brown, Dry. Becoming moist from 5.4 metres.			<u>SPT. N - 12</u>				
SP1 3	Ŧ		6.0_ 7.0_		SP (SM)	SAND, medium grained, brown and grey, with some layers of non-plastic Silty Sand, Wel.			SPT, N - 16	65565175 - -			
SP1 4			8.0		DE .	SILIY CLAY, high plasticity, dark grey. Moist.	<u> </u>	<u></u>	SP1,N <sup>°</sup> ≟ 8				
			9.0.		_92 _	SANU, as from 6.0 to 8.2 metros.	<u>, ro</u>	25E /		-			
52 UD 1			10 <b>.0</b> _		ĊН	SILTY CLAY, high plasticity, dark grey. Moist.	VE/ ST1	8 <b>4</b>   Г <b>Г</b>	TV:BLI)(87.430ET				
- <u>D' 3</u>			11.02			CLAYEY SILT, medium plasticity with some fine		5C					
1) 4			-0-8t		_\$P_	SILIY CLAY, as from K.7 to 11.0 metres.	2 - 18 -	<u>&gt;</u>		-			
SPT 5			13.0- 14.0-		SW (CH)	Interbeds (upto 200mm) of SAND, fine to medium grained, grey and brown, wet, and SILTY CLAY, high plasticity, grey and brown, molst. (Sand is wet and loose, Silty Clay is moist and	LOC	ж.с	SPT, N 7 9				
SPT 6			15.0			SANU, fine to medium grained, grey and brown, Wet. With some thin interbeds of Ulayey Sand,			51PT, N - 6	-			
			16.Q		SN (50)	fime to medium grained Sand, low plasticity Clay, Wat.				_			
SPT 7				00 09 19 09	CN .	SANDY GRAVEL, rounded to 30mm, grey and brown, with time to medium grained Sand, Wet.	DEN	SE 	<u>- 397, N = 42</u>				
						V-BIT REFUSAL AT 17.9 METRUS IN SANDY GRAVEL. END OF HOLE AT 17.9 METRUS.				-			
Log	ged	By	i	G.P.N		Date : 12.12.86 Checked By : (P.K	,	i	 Dates : 16-13				
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Borehole Loa								Borehole No. BliSG 7				
	~11			-9			Shee	nt of	]			
CLI	ΕN	T:	CAI	MERON	Јов No. 2417							
PROJECT: SOUTH GRAFTON LEVEE - GEOTECHNICAL INVESTIGATION								Lacation : 1 715 847.939 N 289 801.094 E Collar Level : R.L. 7.76m				
Equi Holo	ipm Di	en l am	: Type eter :	; l 1	Angl Bear	cal; n <sup>a</sup>						
Scmples	Water	Cashig	Metre:	Graphic Log	U.S.C.S.	Moterial Description, Structure Soli type : Flavlicity or Particle Characteristics. Colour, Secondary and Manar Componyots. Maistore, Structure.	Conselency or Relative Density	Fleid Teat Results	Geological Profile			
-01			1.0		ML/ SM	SANDY SILT, fine grained Sand and non-plastic fines, brown, Dry, Some rounded Gravel to Smm.		· · · · · · · · · · · · · · · · · · ·				
<u>D2</u>			z.o.			CLAYEY SANDY SILT, fine grained Sand, low plasticity Clay. Brown and dark brown. Moist.	MEDIUM		LEVER BANK -			
.SPT1			3.0		ML	CLAYEY SILT, medium plasticity Clay, dark grey brown, with some fine grained Sand. Moist.	DEMSE.	SPT, N - 18	-			
D3			4.0					SPT. N # 13	_			
3117			5.0		SW7	SAND, fine to medium grained, grey. Moist. SAND and SILTY SAND, fine grained, with some low to non-plastic fines. Dark grey. Moist.		0/11 (1 - 11	ن ج ج			
<u> Şрта</u>	.3		5.0- 7.0				1.00SE	SPT, N ~ 5	LAYERED			
			8.D-			SILTY CLAY, medium plasticity, grey and grey brown. Molst.	VERY Stiff		UEPOSITS			
<u>00 1</u>	1		9,0-		Сц · — —	Becoming slightly Sandy.		TV: \$100 HP: 330				
<u>(10 2</u>			10.0-		CL (SC)	CLAY and CLAYEY SAND, fine to medium grained Sand, medium to high plasticity Clay, Grey and dark grey. Wet. (Sand 15 Joose/Clay is firm).	FIRM	*)¥;15-10*;90	-			
			12.0-			SAND, fine to medium grained, grey. Wrt. With interbrds of CLAYEY SAND and SANDY CLAY, fine to medium grained Sand, medium plasticity Clay,	100SE					
<u>сет4</u>	4		13,0	 	SW (SC)	SANU, time to medium grained, grey. Wet. With some thin Claycy Sand interbeds from 12.5 to 13.0	MEDIAM DENSE	SPT, N - 10	-			
			14.0-	0.0 0.0	SW/ CM	GRAVELLY SAND and SANDY GRAVEL, fine to medium grained Sand, rounded Gravel to 40mm, Grey and			_			
SPT5		_	15.0-897 brown. Wet.			SPT, N - 29						
			-									
			_						-			
			-						-			
Log	ged	8)	¥ : (	С.Р.К.		Date : 12,12,86 Checked By : 6.f.	<u> </u>	Date : (6-)	r -'86			
<u>en</u>												

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APPENDIX C

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TEST PIT LOGS - RUSHFORIN RUAD TPL TO TP6

Peter J. Burgess & Associates Pty Ltd

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Excavation Log								Excavation No. TP !							
				- 9 -			Shoe	1t 1	of	<u> </u>					
CLIE	NT:	۵,	Job	No. 2417											
PRO	JEC	:T: s	Location : RUSHFORTH ROAD C.R.C.C. LAND.												
Equip Excov	Equipment Type : MASSEY FERGUSON SON DACKHOE Excuvation Dimensions : 0.45 x 3.6m									Surface Level : - BEARING: 32 <sup>0</sup>					
Samples	Water	) f	Graphic Log	U.S.C.S.	Material Description, Structure Solt Type - Floatidity or Marticle Characteristics, Colour, Secondary and Maior Components, Moisture, Structure,	Consistency	er Refotive Density	Field Test Results	1	Geolo Pro	gleal filo				
		0,2	Ш		SILT, low plasticity, brown, dry, numerous roots.	FR	I A81.F			τορεοι	L				
		0.5-		CL	CLAY. Tow plasticity, grey brown, dry to moist. numerous roots.	FR.	IABLE			AI,1.0V1	UM _				
10				си	CLAY, high plasticity, dark grey with some brown motiling, dry to moist, numerous roots and dessignation gracks, FMC < Wp.	HAI 10 FR	RD I ABLE			·					
	,	( 1.0 <del>-</del>		CH	CLAY, as above, but moist, becoming less stiff with depth, FMC > Wp,	VEI S'I I	RY 1FF			·	-				
20	A TERED	1.9 2.0-		сн	CLAY, high plastleity, light grey and brown mottled, moist, FMC > Wp, some discontinuous fissures, truce gravul: calcareous nodules upto l5mm,	STI					- - -				
	AC MATE? ENCR		3,0 <u>-</u> 		3.0										
							TEST PIT TEL TERMINATCO AT 3,4 METRES. LIMIT OF REACH.								
		<b>,</b>									-				
											. <b>1</b> .				
Logge	d 8;	·····································	.A.H.		Date : 25.11.86 Checked By : P.J.E	3.		Date : 0	EC '	86					
PB				"	Peter J. Burges	. 8	. Δς	sociate	5		8				

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Exco	JVC	itio	n L	oa				Exec	vation No.	(P. 2
				- 0				Shee	it 1 - 5	1 1
CLIE	NT:	Ç/	AMERON	N M <sup>C</sup> N	AMARA PTY, LTD.			Job	No. 2417	
PRO	JEC	T: 50	) DUIH (	SRAF I	ON LEVEE			Loca	tion : RUSHEC C.R.C.	RIH ROAD C. LAND
Egulp Exca	men vatio	t Type n Dime	: M Inaion	IASSE¥ ♦ :	FERGUSON 50H BACKHOE 0.49 x 3.1m			Surfa BCARI	nc: 55 <sup>0</sup>	-
Samples	Water	ېنې کې Metrcs	Graphic Log	U.S.C.S.	Moterial Description Son Type - Plasticity or Part Galow, Secondary and Miner Moletary, Structure.	n <b>, Structure</b> Ide Characteristics, Components,	Consistency	Relative Density	Fi <del>c</del> id Tost Results	Geological Profile
				ск	CLAY, high plasticity, gr cracks to 0.4m, dry, some	wy brown, dessication proots.	на	(tD		ALLUVIUM .
ID		0.4 0.5- 1.0_		СН	CLAY, high plasticity, li mottled, moist, FMC > Wp, undulose, striated fissure nodules to 50mm.	ght grey and brown Some roots, some dull. S, some calcareous	F 3) TO S 13	RM 1+⊁		-
  2D	NO WATER ENCOUNTERED	1.5_ - 2.0_			SANDY GLAY, yellow brown medium plasticity, FMC w	and grey mottled, maist. Mp.	FIF	гM		
		 2,7  			ΤΣST PIT TP2 TERMINATED A DEPTH,	T 2.7 MF (RES AT REQUIRED				
					NOTEST PIT TP2 WAS A DANK, THE LOG O THE PIL,	DUG INTO THE SIDE OF S OFTHE NIGH END OF				
Lagge	sd 8;	y :	г. <b>л</b> .н.		Date : 25,11,86	Checked By : P.	J.8.		Dote :	DEC. '86
						Peter J. Burges	- A	Δ.	sociates	Rty Itel

xco	370	itioi	ηL	00		Ē	xcav	ation No.	TP 3
				- 3		5	Sheat	1 °	f ]
CLIE	NT:	· ca	MERON	I M <sup>e</sup> n	AMARA PTY, L.TD.		Job N	o. 2417	
PRC	JEC	⊤: SU	UTH (	BRAF F	0N LEVEL	L	ocati	ion : RUSHF BROTH PROPE	ORTH ROAD
Equip Exca	oment vatior	t Type i Dime	: M naion	ASSEY 8 :	FERGUSON 500 BACKNOE 0.95 x 3.0m	5	5urfac	e Level :	-
Sampies ;	Water	Matres Depth	Graphic Log	U.S.C.S.	Motorial Description, Structure Soll Type : Plasticity of Particle Characteristics, Colour, Secondary and Minor Companyors, Moletore, Structure,	Consistency or or	Density	Field Test Results	Geologica) Profile
			$\square$	сн	CLAY, high plasticity, light brown, dry, numerous dessication cracks to lomm wide.	HARD	)		AULUV JUM
		0,3		¢н	CLAY, high plasticity, grey, dry, numerous dessication cracks to 15mm wide, cracks extending to 1.4m,	HARD	,		
.,. <b>.</b>	EKED	- 1. <b>4</b> 1.5		 си	Depth of dessication enacks (from top of bank) CLAY, high plasticity, light grey with some brown mottling, trace black pisoliths to bom, FMC > Wp.	VERY Şi(f	F		
	C X41E3 ENCONT	2.0-			Slickonsided fissures at 2.1-2.4m. dipping 45-60° shingy.undulose, continuous for 0.5m.	STIF TO FIRM	F		
		2.5-		CL	CLAY, medium plasticity, grey and brown motiled, moist, FMC > Wp, trace Sand.	FIRM			
					TEST PIT TP3 TERMINATED AT 3.0 M&(RE\$. REQUIRED DEPTH.				
					NUTES: TEST PIT TP3 WAS DUG INTO THE SIDE OF A Bank. The log is of the wigh end of pit.				-
Logge	ed By	y: r	.A.H.		Oote : 25.11.86 Checked By : P.	J.B.		Dote :000.	186
र्गन					Peter J Burges	< A.	Δ 4 4	ociates	Prv Ird

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Exco	ava	atio	n L	oa		Ľ	excavation No	TP 4
			_	- 3		5	inect 1	of 1
CLIE	INT:	C/	MERO	n M <sup>o</sup> n	AMARA PTY. LID.	J	lob No. 2417	•
PRO	JEC	CT: SO	UTH	GRAFT	ON LEVEE	L	ocation : RUS BR( PRC	HFORTH ROAD THERSON'S PERTY
Equip Excar	vatio	t Typo n Dime	; nsion	<b>B</b> 1	MASSEY FERGUSON H50 BACKHOF 0.45m x 3.6m	5 ภ	iurface Level FARING: 292 <sup>0</sup>	: _
Samp es	Water	רך Eenth Matres	Grophic Log	U.S.C.S.	Material Description, Structure Soli Tymi: Physicily or Perilate Characteristics, Colour, Secondary and Minor Components, Melsture, Structure.	Consistency or Define	Field Test Results	Geological Profile
	1	0.25		QL.	SILT, with trace Sand, low plasticity, black, numerous roots and root holes, dry to moist.	FRIA8	LE	TOPSOIL
		0.5-		СН	CLAY, high plasticity, groy brown, moist, FMC > Wp.	VERY Stiff		ALLUVIUM
		u.o -		¢н	CLAY, high plasticity, light grey and brown mothled, moist, FMC > Wp	STIFF	····-/	
		1.0-						-
		1.5-						
10		-						
		2.0_2				ļ		
	191	-	7274	CH/ CL	CLAY, modium to high plasticity, grey and brown mobiled, calcareous modules to 15mm dia. at 2.2m, moist, FMC $>$ Wp, calcareous podules to 10mm dia.	F1RM TO STJFF		
2.p	ENDODES	   .						
	HELVK O	3.0_						
		3.4						_
					TEST PIT TP4 TERMINATED AT 0.4 MHTRES. LIMIT OF REACH.			_
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		-						
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Logg	ed B	у: г	.А.Н.	•	Date : 25.11.85 Checked By : P.J	), <b>R</b> ,	Dote :	UEC. '86
[ <b>;,]</b> ];]					Peter I Burgor		Accoriate	e Dess Lad

Exco	ive	itioi	n L	og			Exce	wotion No.	TP 5
	,						Shee	at of	1
CI,IE	NT:	·	ME, RO	N M <sup>C</sup> N	AMARA PTY. LTD,		Job	No. 2417	
PRO	JĘC	Th SC	итн	GRAFI	ON LEVEE		Loco	ition : RUSHFO BROTHE PROFER	RTH ROAD RSON'S TY
Equip Excov	men' ratior	t Type 1 Dime	: nsian	<b>;</b>	MASSEY FERGUSON 5011 BACKHOE 0.45m x 3.5m		Surf BEAR)	ace Level : ING: 295 <sup>0</sup>	-
Samples	Woter	Repth Bepth Bepth	Grephic Log	U.S.C.S.	Moterial Description, Structure Soll Type . Plustletty or Porticle Characteristics, Galaur, Secondary and Minor Components. Malature, Structure.	Consistency	er Relative Density	F)eld Teat Results	Geologicat Profile
		0.2		OL	SILT, with some Sand, low plasticity, dark brown dry, numerous roots. SILT, medium plasticity, black, dry, numerous	• + R1	ABLE		TOPSOIL .
		8:32		ос Сн	<pre>CLAY, with some Sand, high plasticity, grey and brown mottled, moist, FMC &gt; Wp.</pre>	FRI VCR S11 TO S11	АВЛ F 77 FF FF		ALLUVIUM -
10	,	1, 6_ 2. D_							- - - -
2D .	R ENCOUNTERED	2,35 2.5			SANDY SILT, low plasticity, yellow brown with light grey mottling, trace Gravel, moist. FMC > Wp	FIR	м		-
	AL NATE	3.0- 3.1 	5 17 3	CII	Gravelly band at 3.05m, 40mm thick, chert, soltsione, sub-rounded fragments to 10mm dia. CLAY, high plasticity, light grey with brown mottling.	FIR TO STII	<b>.</b> м		-
					TEST PIT TPS TERMINATED AT 3.5 METRES, LIMIT OF GEACH.				- - - - - - - - - - - - - - - - - - -
Logge	:d 8;	y: ''	∧,н,		Dote : <sup>25.11.86</sup> Checked By : P.J	.в.,	1	Date: DEC	. '86
					Peter J. Burges	. e J	2 2 4	sociates	Pty. Ltd

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	Excevation No.
Excavation Log	Sheet of 1
CLIENT: CAMERON MENAMARA PTY, LTD.	Job No. 2417
PROJECT: SOUTH GRAFTON LEVEE	Location : RUSHFORTH ROAD BROTHERSON'S PROPERTY
Equipment Type : MASSEY FERCUS Excovation Dimensions : 0.46m x 3.6m	SON SON BACKHOL SUFFORE Level :
第一日 日本 日本 日本 日本 日本 日本 日本 日本 日本 日本	acription, Structure Ity or Particle Characteristics, 경우 방송 Field Geological and Minor Components, 영양 영양 Test Profile 명 가슴 Rosults
0.1 Crt CLAY, high plasti FMC > Wp, numerow	Sund, dark brown, non-plastic, FRIABLE 10PSÖIL icity, dark grey, dry to moist. FRIABLE ALLOVIUM us roots. HAND
10 O.S. CH CLAY, high plasti	icity grey and brown mottled, Sliff
	F 18M TO ST1FF
1.5- 	es to 15mm d10. at 1.7m.
Calcareous nodule	es to 15mm dia. at 2.15m. • •s to 20mm dia. at 3.4m.
20 HI 2.5	
3.0- 3.75 TEST PIT THE TERM	UNATED AT 3 25 METOES
LIMIT OF REACH.	
	· · · · · · · · · · · · · · · · · · ·
Logged By : I.A.H. Date : 25.11.8	86 Checked By: P.J.S. Date : DEC. '86

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#### APPENDIX D

#### RESULTS OF LABORATORY TESTS ON BOREHOLE SAMPLES

A programme of laboratory testing was carried out on soil samples recovered from the boreholes. Testing comprised:

Test Description	<u>No of</u>	Tests	
<b>-</b>			
rield Moisture Content		(See	lahle 4)
Atterberg Limits	5	(See	lable 4)
Particle Size Distribution	11	(See	Table (4)
Hydrometer Analysis	-		
Confined Compression	3		
Consolidated Undrained Triaxial with			
Poro Prossure Measurement	4		
Direct Shenr	2		
Ocdometer	2		









	BOREHOLE	<u>FEATURE</u>	<u>EFFECTIVE STRESS RANGE</u> <u>N SLOPE AVALVSIS</u>	EQUIVALENT MCHR-COULOMB PARAMETERS
				c' ø' (kPa) (degrees)
	:CN/255 F8	HEBER ST. LEVE	0-60 kPa	5 28*
	7CU/252 H8	ARDENT ST. LEVEE	0-50 kPa	5 29°
		<b>N</b> • •		
	22			
(미국가)				
9 SS38.		BH SG5		
15 81	3	BH 562/JC		
73HS		-		
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#### APPENDIX E

#### RESULTS OF LABORATORY TESTS ON BORROW MATERIAL

A programme of laboratory testing was carried out on disturbed samples recovered from test pits in the proposed Rushforth Road borrow area. Testing comprised:

Test Description	No. of	lests		
Field Molsture Content	. 12	(See	Table	5)
Attenheng Limits	4	(See	Table	5)
Particle Size Distribution	4	,		. ,
Hydrometer Analysis	2			
Confined Compression	1			
Consolidated Undrained Triaxial with				
Pore Pressure Measurement	1			
Emmerson Dispersion	5	(See	Table	5)
Standard Compaction Tests	3			-

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#### Peter J. Burgess & Associates

PARTICLE SIZE DISTRIBUTION CHART





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#### Peter J. Burgess & Associates

#### PARTICLE SIZE DISTRIBUTION CHART



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						Consult Consult Consult
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# engineering log borehole



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Digital and the state of the st	generation graphic crassification symbol	material Soil type: plasticity or particle characteristics Colour, secondary and minur components	moisture condition consistency, density moles (0) "perierd d(0) moles	structure and additional observations
U75 No Rec U75 U75 075	8 - CH - ML 9 - CL- CL- CH 10 - SP 11 - SP 11 - SP 12	CLAY, high plasticity, yellow brown and grey CLAYEY SILT, medium liquid limit, black, with some SAND SILTY CLAY, medium to high plasticity, black with some red-brown mottling. Some decayed vegetation SAND, fine to medium grained, grey, with some SILT. Borehole I terminated at 11.95 metres.	Mr St P1 M S/ F HP F PL VD VD	
Ang Constraine Ang Anger Science Ang Anger Science Ang Anger Science Ang Anger Science Ang Anger Constraine Anger Science Anger Scie	The provide state of the state	Spitple         spitple <t< td=""><td>Status Future States Synthesis and an order of the synthesis construction and the synthesis constructions when the synthesis of the synthesis of the synthesis of the synthesis</td><td>Operation space of adverse 1/2 incidence           1/2         order of the officience           2         order           3         order           4         order           5         order           6         order           7         the order           7         the order           7         the order           7         the order           8         order           9         the order           9         the order           9         the order           9         the order           9         order           9         the order           9         the order           9         order           9         order           9         the order           9         order           9         order           9         the order</td></t<>	Status Future States Synthesis and an order of the synthesis construction and the synthesis constructions when the synthesis of the synthesis of the synthesis of the synthesis	Operation space of adverse 1/2 incidence           1/2         order of the officience           2         order           3         order           4         order           5         order           6         order           7         the order           7         the order           7         the order           7         the order           8         order           9         the order           9         the order           9         the order           9         the order           9         order           9         the order           9         the order           9         order           9         order           9         the order           9         order           9         order           9         the order

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# engineering log borehole



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### engineering log borehole



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Note Note	s Barting Barting In depth a merres	material soil (ype, plasticity or partic colour, secondary and mine	io characteristics or components E	constant construction densey index densey index densey index densey of perento- neser	structure and additional observations
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### engineering log borehole



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		CLAYFY SAND, fine to black, with sand par <u>Grained, black</u> . Borehole 3 terminato 10.0 metres	y, M> PL	St-VSt X	"squeezing"						
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deill m bola d	iame <sup>1</sup>	end ter.	100	Ceme mm	o 2108-	-Trailer	slope: bearing:	- 90	rleg. rleg.	н b	.L. sui stum:	face: No	t measur	ed
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### engineering log borehole



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drih model ar hole diameter	or IO	Geneo Omm	2105	-Trailer	slope bearing	90 deg. - deg.	it di	.L. ior (com:	'ece: No	ot measured
The lack	tiútes sampies, sests, etc.	H Wetter Gebip Control 139	s es lication symbol	soil tero, plastic colour, second	material âty er parti âry and mu	ch characteristics nor components	enoistuve ognárijon	consistiency. density inde	10 × 14 15 2010 Tearstro	structure and additional observations
	6,7,9 N = 16		CH SP	CLAY, high brown. SAND, find brown, son fines. Layercd Si and SILTY	i plašč s graio ne SILT ILTY CL SANDY	icity, ed, yellow and CLAY AYEY SAND CLAY	M¢ PL M	ג ס ס/ עס		Compacted Fill?-
VSA 1.K	2,3,4 N = 7		- мі " сн	CLAYEY SI limit, bla fine SAND SILTY CLA city, dar	LT, med ack, wi - Y, high k grey,	)jum )iquid (th some ) ) plasti- ) brown and	М¢ 1+1_	HD /F St		
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	u50		Сн	CLAY, hig grey and some fine	b plast red.brc graine	ticity, dar own, with ed SAND.		St		Clayey sand in tube, fine grains brown-black.
туліці Алараніі А.3 акциніцьки аралі А.3 акцини аралі А.3 акцини аралі А.3 акцини аралі А.3 акцини арал				n their stress -		Landers and ABIS undistanted service 50 mm diameter missicitian compre y antigry processor content ingute a catom SMT is cample is une servicinged 464			gyang gyantan ngangangan hiyon dyalago hiyon dyalago ding ngan ngan	A Contraction of Contraction of Contractions o

## engineering log borehole



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drill model and mounting. Genue of $210B-T\pi\pi i$ ), or hole diameter: 100mm	uopo: 90 deg. hearing: - deg.	R.L. surface: - N datum:	lot measured
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W50       8       CL       SILTY CL         city, bl.       fine gra         9       SM       SILTY SA         grey, wi       CLAY, bl.         1       SC         2,4,13       SP         Nc=17/26       SP         11       SP         SAND, time         11       SP         4,10,15       SP         Nc=25       12         Borehoic       11.95 me         11.95 me       SP         11.95 me       SP         11.95 me       SP	AY, medium plasti- nek, with some ined SAND ND, fine grained, th layers of SILTY ack. AND, fine to medium grey ac grained, grey, e SILT 5 terminated at tres.		collapsing
Key     Constraining       Margin Germany     Margin Germany       A3     Adjet Germany       A4     Adjet Germany       A4     Adjet Germany       A5     Adjet Germany       A6     Adjet Germany       A6     Adjet Germany       A6     Adjet Germany       A6     Adjet Germany       A6     Adjet Germany       A7     Adjet Germany       A8     Adjet Germany       A8     Adjet Germany       A8     Adjet Germany       A8     Adjet Germany       A9     Adjet Germany       A9     Adjet Germany       A9     Adjet Germany       A9     Adjet Germany       A9     Adjet Germany       A9     Adjet Germany       A9     Adjet Germany       A9     Adjet Germany	Mattan - somfatted und forste L/SE - and the teste sammer (d) and diameter (1) - de bard and annes (d) Anne Re - standard annes (d) Anne (mas Region - senator (d) - SEE - pareger Re - gener generation	engine topic	VX very solution VX very solu

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# engineering log borehole



harehole no: 6 <u>shings 1 of</u> 2

			off	ice and Job no:	Sydney, S6568
project: Norehola location	CLARENCE RI CLARENCE RI GRAFTON	PER COUNTY COUNCIL	ñai hai sup che	e commencod: e completed; ervisad by ecked by.	4 June, 1981 4 June, 1981 CHD PKW
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And Andrew States and Andrew S	B V V V	SILTY SARD, fine STITY SARD, fine STATE	grained,	August konstruktur kann var versender med stadio demokratikasi med stadio demokratikasi anteksta konstruktur seksen en Anteres fun ene Anteres fun ener Anteres fu	A constraint of the second of

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### engineering log borehole



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CI. project: CL borehole location: CR	ARENCE RIVER COUNTY COU ARENCE RIVER FLOOD MITI	NCIL GATION	hole commenced hole completed: Supervited by: Checked by:	4 June, 1981 4 June, 1981 GHD PKW
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# engineering log borehole

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# engineering log borehole



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# engineering log borehole



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	8 CH CLAY, high grey with mottling 9 group CLAY, high with some brown moth 10 clay, high yellow brown 12 clay, high yellow brown 13 clay, high brown and 13 clay, high	n plasticity, dark some red-brown ading to n plasticity, groy, red and yellow- tling h plasticity, red- grey.	M> St/ PL VSt x	
- 450	SC SANDY CLA CH fine to m brown, fin 15 SC CLAYEY SA grained, of high p 16	Y/CLAYEY SAND, edium grained, red nes of medium to ticity. ND, fine to medium red-brown, fines lasticity.	M/ L/ W F W MD	
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# engineering log borehole



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kas register A contraction A cont	Borchole 8 terminated a 19,75 minitres.	111

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# engineering log borehole



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# engineering log borehole



sheet 2 of 3

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CLA project: CLA baretiols location: CRA	RENCE RIVER COUNTY COU RENCE RIVER FLOOD MITI FTON	NCII. GATION	<ul> <li>hole commencate</li> <li>hole completed:</li> <li>supervised by:</li> <li>checked by:</li> </ul>	<sup>62</sup> June, 1981 3 June, 1981 GHD PKW
dell model and mounting hole diameter: 100	r Gemeo 2108-Trailer ) mm	stope: 90 deg. Gearing – deg.	H.L. sorface: No datum:	t measured
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# engineering log borehole



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dr h.c	ill model la diame	and Iar:		9 (Gemeo) ) mm	2108	Trailer	slone: beoring:	90 deg. - deg.	H. da	L. surt tum:	ace: No	t measur(	≥d
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# engineering log borehole



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hale completed.	2 June, 1981	
supervised by	GHÐ	
checked by	PKU	

CLARENCE RIVER COUNTY COUNCIL CLARENCE RIVER FLOOD MITIGATION project: checked by: borehole location: GRAFTON R.L. portano. Not measured 10001 90 dea. drill model and mounting Genco 210B-Trailer datum: bearing: d∎g. 100 00 . . nule diamater: r hand goenetic: refer classification symbol ency. knocture and material cenetration n0191 moisture condition additional observations nethod: soll type: plasticity or particle characteristics consister Geneum s ;eddins samples, dia production è. N. colour, secondary and minor components. tests, etc. 6373 y depth IE metres 2.3 M>Sc-CLAY, high plasticity, CH 11 VSt dark brown, with some PL. 1 medium to course grained 1 SAND. <u>USO</u> CLAY, high plasticity, red and grey mottled. U50 × U50 CLAY, high plasticity, vellow-brown and grey. Layer SANDY SILT SANDY SILTY CLAY, medium plasticity, grey-brown, mottled yellow-brown, SAND CL. ۰. 6 050 fine grained. CLAY, high plasticity, CH grey-brown and yellowbrown u50 to... dark yellow-brown and grey to... CLAY, high plasticity, U50 grey. **U**50 7.8 metres Borchole 10 terminated at з ry series a set a set a tares tares 2000-1000 (1000 - 10000) 2010-1000 (1000-1000) age - set a rear of the - market b The second 4 L and an and a second to the second second second second second second second second second second second second s -211 m2 ga ana na tanàna Tanàna kaominina 2 1 1101212-00 W. 0 distanting of managers vera galar Nard ta. gearager in persons as seen web. Reduced in Alberts ------n 4.5 ĉ m#17 **.**... SH1 - 14 - 101-1 ---by survice and an example of the second I. èυ te. بمصافق بالإستيار وسارد A - 1 - 1 للمادين المعولي

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# engineering log borehole



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drill model end mounti hole diameter 10	NG: Gemeo 210B-Trailer sions: 90 Domo bearing: -	dag, R.L. surface, Not mexicaired dag, dagam:
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# engineering log borehole



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drill model and hole diameter.	100 100	Geneo 2) mm	l OB-TT	ailer	slado: bearing:	90 deg. – deg.	R	(, , <b>, , ,</b> , , , , , , , , , , , , , ,	(ac:0)   N	lot measur	ed
method 20 peatrelion 30 peatrelion 44 pearr	AOINI Tarajalas, Insta, etc.	depth Thetes	classification symbo	sail type, plastic colour, tecono	material ity or particle c ary and minor c	haracturistics componence	mentore cardición	consistency. Censity index	200 aperation 200 aperation 200 ameration	structu additional o	re and beervations
	2,2,5 N = 7 5,6,6 N = 12 5,6,6 N = 12		SH SF	SILTY SAN brown. SAND, fine brown, wit As above. As above. SILTY SAN	SILT Inct	yellow LT. easing	N 157	L MD		Partly ce	mented _
MSN MSN	4,3,5 <u>N − 8</u> U50 			yellow-bro STLTY SANN and brown As above, SJLT part: SILTY CLAY grained, y brown.	with SANI with SANI ings? to (EY SAND, (ellow-bro	brown and finc and finc and and	M	11D			-
	μ50 Ι		Borel	CLAYEY SAL grained, y	ND, fine to yellow bro	o mirciina WTD - WTD - It /.8 mm - materia Web- 	<u>t = c : :</u>	i ganga tan mang tang mang tang mang tang mang tang tan tan tan tan tan			

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### engineering log excavation



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equipment type and max excernition dimensions:	et. Hand Shovel. 2.0 mlang.	0.7 m with:	H.L. surface. No datum:	t mensured
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n Loga A S E Log herr mailinget Al Antorit exclusion f statistics bet parkings backet building to blacket f regime	NASHING I LANDARING THE LANDARING THE LANDARING THE LAND THE LANDARING THE LAND THE LANDARING THE LAND THE LANDARING THE LAND THE LANDARING THE LAND THE LANDARING THE LAND THE LANDARING THE LAND THE LANDARING THE LAND THE LANDARING TH	Postanos Integran	анција у Андууни и Кар анција и Кар анција и Кар анција и Кар анција и Кар анција селатор и Кар анција селатор окрумите окрусто ок	CR

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Melhod N penerusion U 1Jppc:1 Walt	notes samples, texts, etc.	_) deoth gimetres	y april unit classifical on symbol:	soli type i pla colour, secu	m nthénty ndary ér	iaterial o- particle che no minor comj	ractoristics. Soments	moisture cond Lign	солынылсу. Селясу ілдех	00 hard 00 hard 00 herero 00 herero	strue additions	ture ac	ni ations
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Cottey & Paranen Pty, Ltd.

S6568/1-AB 27th August, 1981

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#### RESULTS OF LABORATORY INVESTIGATION

A programme of laboratory testing has been carried out on soil samples recovered from the field. The testing has been aimed at determination of the strength and drainage characteristics of the soils encountered, together with other indicative testing such as the determination of erodibility of the various materials. The testing has included:-

*	Visual Classification	(23)
*	Atterberg Limits	(7)
*	Moisture Content	(35)
*	Confined Compression	(7)
*	Consolidated Undrained Triaxial Testing with	(4)
	pore pressure measurement	
*	Sherard pinhole dispersion test	(4)
*	Permeability tests (Falling head method)	(5)
*	Particle size distribution	(7)
*	% Passing 75um	(19)

Coffey & Partners Sty. Ltd.

# soil classification





office and job no: Sydney, S6568

Clarence River County Council

date: 30th July 1981 tested by: RM, MJL, JB, VT, AC checked by: KB

project? Clarence River Flood Mitigation location: Grafton

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location	depth m from to	sanpie typs	classif.cati 1ymbc1	roll type: planticity or particla characteristi colour, useendary and minor components, Attentory Limits III determined).	Toistur Condition	ccosistea Ceosistea Ceosity in	uktorlier compress strength kfa	day densi teanatim	
BH1	5.0-5.5	U75	SC	SILTY CLAYEY SAND, fine grained, dark brown.		VSt	230	1.25	Sherard pinhole test - class D1/ D2
	7,0-7.5	U75	CL/ CH	CLAY, medium plasticity, brown, some fine soul	30.3	vs	350	1.35	Fissured, Sherard pinhole test - class ND2.
вн2	7.0.7.3	U50	сн	CLAY, high plasticity, grey, trace of fine sand.		VSI	240* 320	1.54	Confined at 120 kPa. Sherard pin- hole test - class D1.
	0.58.8	U50	SC/ SM	CLAYEY SAND/SILTY SAND, fir grained, dark grey, fines o medium plasticity. W <sub>L</sub> =37,Wp 23,Ip=14,L.S.#7.07	e M> f Wp 37.4	ł		1.31	c' • 2 kPa Ø' - 34° Sherard pinholc Lest class ND1.
внЗ	4.0-	<b>U</b> 50	CL	SILTY SANDY CLAY, low to medium plasticity, brown, fine grained sand.		vs:	380	1.62	65% pacsing 750m k <sub>v</sub> = 8x10 <sup>-8</sup> cm/sec
:	5.0-5.3	115C	CL	SILTY SANDY CLAY, low to medium plasticity, brown, find grained sand. $W_L=35,Wp=18,Ip=17,L.5.*9.57$	21.	1		1.49	c' = 2 kPa Ø' = 34 <sup>0</sup> 57% passing 75µm
131.14	1.0-1.4	<b>U7</b> 9	MIT.	SANDY CLAYEY SHUT, low to medium liquid limit, brown fine grained sand.	D-М 14_	o I		1.32	57% passing 75 $\mu$ m ky = 1x10 <sup>-3</sup> cm/sec Note abundant root hole channels.
1	2.0-2.2	075	ł		20.	3			77% passing 75µm
	3.0-3.5	5 073	×		17.	4			99% passing 7500
	<u> </u>		nter-ti-		incy	- der	hory inde	<u> </u> 1	uncontined compressive
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Colley & Partners Pty. Ltd.

project:

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### soil classification

Grafton



ihers 2 of 4

office and job not Sydney, S6568

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Clarence River County Council Clarence River Flood Mitigation date: 30th July 1981 mested by: RM, MJL, JB, VT, AC checked by: KB

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Ipostion	depth m from to	sample Nype	olassification symbol	soil type: plasticity or particle characteristics, colour, secondary and minor components, Asterberg Limits (if determined)	moistare condition at content %	stani yriangl	urcont hed compressive strength kPu	dry densigy tanasim	additional observations
вн4	4.0-4.3				• • •	<del>.</del> .			39% passing 75pm
	6.0- 6.45								10% passing 75µm
внэ	5.5-5.8	<b>U</b> 50	CL/ CH	SANDY SHATY CLAY, medium to high plasticity, dark grey, fine grained sand.	М>   Wp   31.6	St	165* 350	1.39	
	7.0-7.3	u50	sc	CLAYEY SAND, fine grained, brown-black, medium plasti- city. W <sub>L</sub> =46,Wp=23,Ip=23,L.S.=10%.	м» И 27.3	3		1.47	c' = 1 kPa $\phi' = 36^{\circ}$
<b>B</b> I16	4.0-4.5	U75	CL	SANDY SILTY CLAY, low plas- ticity, brown, finc grained sand. W <sub>L</sub> -29,Wp=17,Ip=12,L.\$7.0%.					59% yassing 75µm
BH7	6.0-6.5	075 1075	SM/	CLAYEY SILTY SAND, fine to medium grained, brown, fines of low plasticity. $W_L=29, W_P=16, T_P = 13, S.=5.5\%$ .	M> Wp 29.3	S	49* 20	1.42	Confined at 120 kPa. Some organic content. 45% passing 75pm
	10.0- 10.3	<b>U5</b> (	CH	CLAY, high plasticity, brown, some fine to modium grained sand. W <sub>L</sub> =38,Wp <sup>(1)</sup> 8,Ip=20,L.S.=10%	M> Wp 18.5	н	680* >500	1,75	Confined at 160 kPa.
вн8	2.0-2.5	5 073	5 CL	STLTY CLAY, medium plassi- city, brown.	M≥ ₩p 27.6	St.	130		85% passing 75µm
	4.0 4.4	5   		SILTY CLAY, modium plasti." city, brown.	М> Wp 29.5	st S	160		97% passing 75pm
	flor record	·····	- I	on Shen 11 moisture condition Couling	¢γ	de	soty indu	*	uncontinuel compressive
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soil classification



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office And job not Sydney, \$6568

dete: 30th July, 1981 tested by: NM, MJL, JB, VT, AC theorem by: KB

project: Clarence River Flood Mitigation location: Grafton

Clarence River County Council

10	mple details		5		material			<sup>е</sup> Бүх	. ភ្នំ	<u>ಶ.೪</u> _		structure and additional observations
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BHS :	7.0-7.3	บรถ	Сн	CLAY, Brey.	high plasti trace of fi	city, ne sa	dark nd.	אי> Wp 36.0	St	150* 170	1.34	Confined at 120 $kPa$ . Sherard pin- bole test - class D1/D2.
	8,5	U50						34,2	St	130		
	10.0	050						20.4	н	>500		
	11.5	¥50						23,0	н	430		
	13.0	050						26.9	vs	230		
BH9	1.0-1.5	υ75						18.3		Ì		34% passing 75µm
	2.0-2.3	U50		Į				24.7	ĺ			69% passing 75µm
	3.0-3.5	U75		SANDY SILTY city, brown	CLAYEY SILT CLAY, mediu fine grainu	r/SAND มก pla เปิดสบ	Y Isti⊷ Id,	72.9	VS	260		73% passing 75µm
	5.0-5.3	U50	СН	SANDY brown W <sub>L</sub> ** 50	CLAY, high , fine grain ,Wp-26,Ip=26	plast ned sa 1,L.S.	:icity, Ind. .=13.0%	М> Мр 37.€	2		1.27	Blocky structure. Fissured. c' - O kPa Ø = 31 <sup>0</sup>
BHIO	1.0	U50	ļ					23.5	я	420	1	
	2.0-2.3	U5(	Сн	CLAY, grey,	high plast; trace of f:	jaity, ine sa	, dark and.	М> ₩р 27.0	VSt	230* 550	1.57	Confined at 40 kPa.
	٥.٥	U50	2					30.9	WSL:	240		
	5.0	<b>U</b> 50	q					26.0	н	450		
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# soil classification



sheet 4 of 4

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dofe: 30th July, 1981 tested by: RM, MJL, JB, VT, AC chroked by: KB

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Clarence River County Council

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toention	depth m from to	erple Srpe	classificati sym905	voit type: plasticity or particle choracteristics colour, secondary and minor components. Attorberg Limits (if determined).	Laton Control Control	COLS SIET CARS SIET	entrophis Serenge Strenge	ուները։ անդորց։	
BHLI	4.0-4.3	U50	СН	SILTY CLAY, high planticity, dark grey to black.	M> Wp 28,9	St	125* 140	1.43	Confined ar 80 kPa. Some root fibres.
BH12	5.0-5-3	υ	MI./ SM- SC	CLAYEY SANDY SILT/CLAYEY SILTY SAND, fine grained sand, low liquid limit fines yellow-brown and brown.	21.1				52% passing 750m
TPI	0.6 (HOR)	U	SM	SILTY SAND, fine to medium grained, brown, fines of low to medium liquid limit.	8.1			1.45	31% passing 75µm k <sub>H</sub> = 3x10 <sup>-3</sup> cm/80
	1.0 (HOR)	υ	SP	SAND, fine to medium grained yollow-brown-	5.7	7		1.40	$6\%$ passing $75\mu m$ $k_{\rm H} = 1 \times 10^{-2}$ cm/se
1 <b>P</b> 2	1.0 (HOK)	U	ML.	SANDY CLAYEY SILT, low to medium liquid limit, dark brown, fine grained sand.	22.2	2 VS	00E	1.62	59% passing 75um k <sub>H</sub> = 2x10 <sup>-7</sup> cm/se
TPĴ	0.5-0.8	D			12.0	5			52% passing 75µm
notes Lampia r	(for terms : vpd	мет "Е.	) natoriati classific	an Sheet 1') moisture condition transister 	ney very so sott	de It VI	nsisy inde ver _ loo	y Indta	unconfined completion strength T from test; Otherwise
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matorial	lassification: (CH) SANDY CLAY, hi	h plasticity, brown	, fine gi	ained sand,
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### particle size distribution



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### Attachment B

Ground Investigation Data Report, Arup 2012 Roads and Maritime Services **Main Road 83 Summerland Way - Additional Crossing of the Clarence River at Grafton** 

Ground Investigation Data Report

July 2012

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 220422/00

Arup Arup Pty Ltd ABN 18 000 966 165 **Arup** Level 10 201 Kent Street PO Box 76 Millers Point Sydney 2000 Australia www.arup.com







Page

### Contents

1

Introd	luction	1
1.1	Project background	1
1.2	Scope of ground investigation	1
1.3	Project execution	2
1.4	Boreholes	2
1.5	Laboratory testing	3
1.6	Gravity survey	3

#### Appendices

#### Appendix A

Site Layout

#### Appendix B

Borehole Logs

#### Appendix C

Laboratory Tests

#### Appendix D

Gravity Field Survey

### 1 Introduction

This report contains the factual data from the ground investigations undertaken for the Arup Geotechnical Investigation for the Route Options report.

#### **1.1 Project background**

Roads and Maritime Services (RMS) are currently undertaking a route selection investigation of an additional crossing of the Clarence River at Grafton. Six route options are currently being considered as discussed in Section 1 of Arup's Geotechnical Investigations for Route Options report. The objective of the ground investigation is to provide a geotechnical assessment of the foundation conditions associated with the six route options so they can be reasonably compared.

This report presents the factual results of the ground investigation for the project. Results included in this report comprise all site works completed and all results of laboratory testing

#### **1.2** Scope of ground investigation

Prior to this route options investigation, there was existing geotechnical information as follows:

- In the vicinity of the existing Grafton Bridge;
- For the flood plain area on the south side of the river, downstream of the existing Grafton Bridge and this can be extrapolated, to an extent, to interpret ground conditions along the three route options that cross the flood plain (Options 11 and 14/15).

There was no existing geotechnical borehole data for the Grafton side of the river and the area north to Great Marlow.

Therefore, to supplement the existing information, the supplementary investigation concentrated on the northern bank with five boreholes located at route options E, 11, 14 and 15. One borehole was located on the floodplain on the southern river bank in close proximity to route Options 14/15 to provide information on the anticipated rock level in this area.

A land based gravity survey was carried out on the south side of the Clarence River for route options 11 and 14/15. The aim of the gravity survey was to profile the top of the bedrock to the south east of the river up to the Pacific Highway and correlate the findings to the nearest boreholes. This will enable a more accurate estimation of the depth of piles along the floodplain covered by these options.

The borehole locations and gravity survey undertaken for this investigation is presented in Appendix A. Table 1 provides a list of the investigations undertaken and their relevance to the route options.

Location	Route option	Primary purpose
BH101	Е	Investigation of bridge abutment founding materials and depth
BH102	11	Investigation of bridge abutment founding materials and depth
BH103	14/15	Investigation of bridge abutment founding materials and depth
BH104	14/15	Investigation of embankment founding materials and depth
BH105	15	Investigation of embankment founding materials and depth surrounding Lawrence Road
BH106	14/15	Investigation of founding materials and depth for bridge abutment and floodplain crossing
Gravity Survey along McLaers Lane and adjacent road	11	Correlation of bedrock depth across the floodplain crossing
Gravity Survey along Meona Lane and Eggins Lane	14/15	Correlation of bedrock depth across the floodplain crossing

Table 1 Summar	v of investi	gation	purpose
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#### **1.3 Project execution**

The ground investigation was carried out between the 5<sup>th</sup> and 23<sup>rd</sup> of March 2012. All works were conducted in accordance with the following documents:

- Summerland Way Geotechnical Investigation, Review of Environmental Factors, Revision 2;
- Main Road No. 83 Summerland Way Additional Clarence River Crossing, Geotechnical Investigation Environmental Management Plan, Issue 2;
- Main Road No. 83 Summerland Way Additional Crossing of the Clarence River at Grafton, Geotechnical Investigation Health and Safety Management Plan, Issue 3.

#### **1.4 Boreholes**

All boreholes were carried out by Terratest Pty Ltd, using a Hydropower 5000 truck mounted rig. Site supervision and logging was carried out by an Arup Engineer. Boreholes were advanced using washbore with standard penetration tests at 2m intervals. Undisturbed samples were taken of soft cohesive soils. Where rock was encountered the boreholes were advanced with NMLC core recovery (52mm core).

The boreholes were carried out in the locations presented in Table 2. Borehole locations were surveyed by GPS accurate to  $\pm 3$  m.

Boreholes located at abutment foundations were progressed 3 metres into rock. Due to difficulties in advancing casing through gravels, poor core recovery was obtained from BH101. BH105 was terminated within the gravels on approval from RMS.

Borehole logs and explanatory notes are presented in Appendix B. The core boxes were stored at the RMS Laboratory in Grafton.

Borehole	Easting	Northing	Elevation (mAHD)	Total Depth
BH101	493755	6714983	2.49	35.5
BH102	495161	6715352	3.4	27.24
BH103	495438	6716883	3.77	27
BH104	494995	6717473	1.75	16.7
BH105	494720	6718301	6.7	27.5
BH106	495904	6716405	4.79	28.8

Table 2 Summary of borehole locations

#### **1.5** Laboratory testing

Laboratory testing of soil samples was undertaken by Trilab Pty Ltd, Brisbane, which included six atterberg limit, six particle size distribution, two oedometer, and one undrained triaxial tests. Laboratory testing of rock core samples was undertaken by SGS Australia Pty Ltd, Alexandria, NSW, which included twelve point load tests, six diametral and six axial. All laboratory testing results are presented in Appendix C.

#### **1.6 Gravity survey**

A gravity survey was undertaken for route options 11 and 14/15 to the east of the Clarence River. The survey was conducted along existing tracks between the river and the Pacific Highway. The survey was used to correlate bedrock elevation below the flood plain with borehole BH106 and previous investigation data. The results are presented in Appendix D.

Appendix A

Site Layout



# Appendix B

Borehole Logs
#### DESCRIPTION AND CLASSIFICATION METHODS

Soil and rock descriptions are generally in accordance with the recommendations of Australian Standards AS 1726-1993 and cover the following properties:

SOIL	Classification Group	ROCK	Name
	Soil Name		Grain Size
	Plasticity		Texture and Fabric
	Grain Size		Colour
	Colour		Strength
	Texture and Fabric		Weathering
	Secondary Components		Structure
	Minor Components		Defects
	Moisture		Weathering of Rock Mass
	Consistency		
	Structure		
	Origin		
	Other Relevant Information		

Field tests have been used extensively to assess soil consistency, rock strength and grain size. Unless specifically stated otherwise, these assessments have been transferred directly to the record sheets and not modified to coincide with laboratory test results. Field descriptions may therefore be used as an independent estimate of material properties which can be correlated with other data.

#### SOIL CLASSIFICATION SYMBOLS

The appropriate group symbol is given as shown on Sheet 2. This is based on the Unified Classification procedure - Visual Method for field identification in accordance with ASTM D 2487 - 83 and D 2488 - 84.

#### COMPOSITE SOIL TYPE

As most natural soils are a mixture of basic soil types, the primary soil is described and modified by secondary constituents as follows:

	Coarse Grained Soils	Fine Grained Soils		
% Fines	Terms	% Fines	Terms	
≤5	omit, or use 'trace'	≤15	omit, or use 'trace'	
>5 ≤12	describe as 'with clay/silt' as applicable	>15 ≤30	describe as 'with sand/gravel' as applicable	
>12	'silty/clayey' preceding primary soil	>30	'sandy/gravelly' preceding primary soil	

#### **GRAIN SIZE**

FIELD TEST	i ii iii	Not visible with x10 lens Does not dilate on shaking Adheres to fingers when dry	i ii iii iv	Particles >10µm visible with x10 lens Dilates on shaking Does not adhere to fingers when dry Feels gritty on teeth	i II	<ul> <li>Particles &gt;75µm visible to naked eye</li> <li>Fine sand feels gritty in fingers</li> </ul>		Visible identification					
DESIGNATION		CLAY		SILT			SAND			GRAVEL		COBBLES	BOULDERS
						Fine (f)	Medium (m)	Coarse (c)	Fine (f)	Medium (m)	Coarse (c)		
GRAIN SIZE		2		75	5	200	600	2.36	6	20	63	200	
				microne						millimotros			

			GROUP	GENERAL DESCRIPTION
	GRAVEL	CLEAN GRAVELS	GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
EVE SIZE)	GRAVELLY	(LITTLE OR NO FINES)	GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
NO. 200 SIE	MORE THAN 50%	GRAVELS WITH FINES	GM.	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
AGER THM	FRACTION RETAINED ON NO. 4 SIEVE	(APPRECIABLE AMOUNT OF FINES)	GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
EPIAL IS LA	SAND	CLEAN SANDS	sw	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
O% OF MAT	SANDY	(LITTLE OR NO FINES)	SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
SHE THANS	MORE THAN 50% OF COARSE	SANDS WITH	SM	SILTY SANDS, SAND - SILT MIXTURES
OWC	FRACTION PASSING ON NO. 4 SIEVE	(APPRECIABLE AMOUNT OF FINES)	sc	CLAYEY SANDS, SAND - CLAY MIXTURES

	Terrer Internet		SYMBOL	GENERAL DESCRIPTIONS
			ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50	CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
NILS -			OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
NED SC	*	4	мн	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
E GRAI	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50	СН	INORGANIC CLAYS OF HIGH PLASTICITY
- FINE			он	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
NAHT 3POI	HIGHLY ORGANIC SOILS		РТ	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS
8	FILL		101	ALL

-

#### PERCENTAGE AND SHAPE CLASSIFICATION



Essentially two-dimensional particles with the third dimension small by comparison may be described as 'flaky' or 'platy'.

Essentially one-dimensional particles with the other two dimensions small by comparison may be described as 'elongated'.

#### COLOUR

Individual assessment of colour has been made at field moisture condition, or as received using simple terms like **black**, **white**, **grey**, **red**, **brown**, **orange**, **yellow**, **green** or **blue**. No reference has been made to standard colour charts unless specifically stated. These may be modified where necessary using 'pale', or 'dark' or 'mottled'. Borderline colours shall be described as a combination of colours e.g. **red-brown** etc.

Mottling shall be described as '(Primary colour) mottled (secondary colour)'. Where a soil consists of two colours present in roughly equal proportions the colour description should be 'Mottled (first colour) and (second colour)'

#### SOIL MOISTURE CONDITION

Condition	Cohesive	Granular
DRY (D)	Hard and friable or powdery, well dry of plastic limit	Cohesionless and free-running
MOIST (M)	Cool, darkened in colour, can be moulded	Cool, darkened in colour, tends to cohere
WET (W)	Weakened. Free water forms on hands when handling	Tends to cohere

Moisture content (mc) may be compared to the plastic limit (PL), eg mc>PL means moisture content greater than the plastic limit. The presence of any water seepage may be noted on the borehole records.

#### CONSISTENCY Cohesive Soils

FIELD TEST	Exudes between fingers when squeezed	Moulded by light finger pressure	Moulded by strong finger pressure	Indented by thumb, cannot be moulded by fingers	Indented by thumbnail	Indented with difficulty by thumbnail
DESIGNATION	Very Soft (VS)	Soft (S)	Firm (F)	Stiff (ST)	Very Stiff (VST)	Hard (H)
UNDRAINED SHEAR STRENGTH kPa	12	25	50	100	200	

#### CONSISTENCY Non-Cohesive Soils

FIELD TEST	Easily excavated with a spade	Some resistance to a spade or penetration with a hand bar	Considerable resistance to spade or penetration with a hand bar	No penetration with a hand bar; requires pick for excavation	High resistance to a pick
SPT 'N' VALUE (blows / 300 mm)	4	10	30	50	
DESIGNATION	Very loose (VL)	Loose (L)	Medium Dense (MD)	Dense (D)	Very Dense (VD)
<b>DENSITY INDEX %</b>	15	35	65	85	

#### DILATANCY Cohesive Soils

A positive reaction consists of the appearance of water on the surface of the pat which changes to livery consistency and becomes glossy. When the sample is squeezed the water and gloss disappear from the surface, the pat stiffens and finally cracks or crumbles.

The rapidity of appearance of water during shaking and its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

#### SOIL STRUCTURE

Zoning: May consist of separate zone differing in colour, grain size or other properties. These should be described with the following descriptions:

- a. "Layer" i.e. zone is continuous across exposure or sample
  - b. "Lens" i.e. a discontinuous layer of different material, with lenticular shape
  - c. "Pocket" i.e. an irregular inclusion
  - (the thickness, orientation an distinguishing features of the zones should be described).

Defects: described dimensions, orientation and spacing. Defects may include fissures, cracks, root-holes etc.

Cementing: Coarse grained soils may be cemented together by various agents. If the cementing agent allows the particle aggregations to be easily fractured by hand when the soil is saturated it is described as "weakly" cemented. If the cementing agent prevents fracturing by hand of the particle aggregations when saturated, it is described as "strongly" cemented.

#### ORGANICS

The presence of organic material shall be described using proportion terms such as 'with' or 'trace' using the following terms: **fibrous peat; charcoal; wood fragments; roots** (greater than 2 mm diameter); or **root fibres** (less than 2 mm diameter).

#### TYPICAL REPRESENTATION AND TERMS USED FOR CARBONATE ROCK

Soil Consistency and Rock Strength	In	creasing grain s	size of particulate de	posits	Total Carbonate Content (%)			
	0.002 mm	0.06 mm	2 mm	60 mm				
	CARRONATE	CARBONATE SILT	CARBONATE SAND	CARBONATE GRAVEL	90-100			
Soil Density/Consistency used as per AS1726-	CLAY	Siliceous CARBONATE SILT	Siliceous CARBONATE SAND	Mixed carbonate and non-carbonate	50-90			
1993	Calcareous CLAY	Calcareous SILT	Calcareous silica SAND	GRAVEL	10-50			
	CLAY	SILT	Silica SAND	GRAVEL	0-10			
	CALCILUTITE	CALCISILTITE	CALCARENITE	CALCIRUDITE	90-100			
Extremely Low to Medium Strength	Clayey CALCILUTITE	Siliceous CALCISILTITE	Siliceous CALCARENITE	Conglomeratic CALCIRUDITE	50-90			
l₅50<1MPa UCS<12,5MPa	Calcareous CLAYSTONE	Calcareous SILTSTONE	Calcareous SANDSTONE	Calcareous CONGLOMERATE	10-50			
	CLAYSTONE	SILTSTONE	SANDSTONE	CONGLOMERATE	0-10			
	Fine-grained L	IMESTONE	Detrital LIMESTONE	CONGLOMERATE LIMESTONE	90-100			
High to Very High Strength. I₅50>1MPa	Fine-grained Argillaceous LIMESTONE	Fine-grained Siliceous LIMESTONE	Siliceous detrital LIMESTONE	Conglomeratic LIMESTONE	50-90			
UCS >12.5 MPa	Calcareous CLAYSTONE	Calcareous SILTSTONE	Calcareous SANDSTONE	Calcareous LIMESTONE	10-50			
	CLAYSTONE	SILTSTONE	SANDSTONE	CONGLOMERATE	0-10			

Classification of calcareous materials (modified from Clark and Walker)

1. The strength of rock was determined in the field based on visual identification in accordance with page 3 of the Arup Explanatory Notes and was subsequently confirmed by laboratory testing.

2. Classification based upon rock displaying a crystalline fabric.

The term 'siliceous' replaces the term 'silica' when a secondary descriptor are used to indicate the presence of clay or silt fractions. These terms are as follows: - Calcareous Siliceous Silty Sand

- Calcareous Siliceous Clayey Sand

- Siliceous Silty Sand

- Siliceous Clayey Sand

#### ROCK STRENGTH Based on visual identification

FIELD TEST	Easily remoulded by hand to a material with soil properties	Material crumbles under firm blows with sharp end of pick. Pieces up to 3cm thick can be broken by finger pressure	Easily scored with knife. A piece of core 150mm long and 50mm diameter may be broken by hand.	Readily scored by knife; a piece of core 150mm long by 50mm diameter can be broken by hand with difficulty	A piece of core 150mm long by 50mm diameter cannot be broken by hand but can be broken by a pick with single firm blow	Hand specimen breaks with pick after more than one blow; rock rings under hammer	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer
POINT LOAD STRENGTH INDEX	0.03	0.1	0.3	1	3	10	
ls(50) MPa							
DESIGNATION	Extremely Low	Very Low	Low	Medium	High	Very High	Extremely High
	(EL)	(VL)	(L)	(M)	(H)	(VH)	(EH)
UNCONFINED COMPRESSIVE STRENGTH (q <sub>u</sub> ) MPa	The unconfined compressive strength is typically about 20 x ls(50). The ratio may vary widely for different rock types.						

#### ROCK WEATHERING Based on visual identification

FIELD APPEARANCE	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported	Rock is weathered to an extent that it has 'soil' properties, ie it either disintegrates or can be remoulded, in water	Rock strength usually changed by weathering. The rock may be highly discoloured, usually by iron staining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.	Rock is slightly discoloured but shows little or no change of strength from fresh rock.	Rock shows no sign of decomposition or staining
DESIGNATION	Residual Soil	Extremely weathered rock	Distinctly weathered rock	Slightly weathered rock	Fresh rock
	(RS)	(XW)	(DW)	(SW)	(FR)

#### **BEDDING STRATIFICATION**

Te	rm	Description	Separation of Stratification Planes
Stratification n	ot recognisable	Massive	-
		Very thickly bedded	>2 m
		Thickly bedded	0.6 - 2 m
Stratification more than 20 mm apart	Bedded	Medium bedded	0.2 - 0.6 m
		Thinly bedded	60 mm-0.2 m
		Very thinly bedded	20 – 60 mm
Stratification planes loss than 20 mm apart	Lominated	Thickly laminated	6 – 20 mm
Stratification planes less than 20 mm apart	Laminaleo	Thinly laminated	<6 mm

Table based on Geological Society Engineering Group Working Party report on *The Logging of Rock Cores for Engineering Purposes* - Q JI Eng Geol Vol 3, 1970, pp1-24.

#### **DEVELOPMENT OF STRATIFICATION**

Term	Description
Poorly Developed	Bedding is barely obvious as faint mineralogical layering or grain size banding, but bedding planes are poorly defined
Well Developed	Bedding is apparent as distinct layers or lines marked by mineralogical or grain size layering
Very Well Developed	Bedding is often marked by a discrete colour banding as well as by mineralogical or grain size layering

### ROCK TEXTURE AND FABRIC

Texture of rock refers to individual grains. Terms used frequently are: Crystalline, porphyritic, granular, cryptocrystalline, amorphous, glassy. The arrangement of the grains (fabric) should be described as massive or layered (bedded, foliated, cleaved) Calcareous rocks should be described using the table below.

		Depositional texture not			
	recognizable				
(clay an	Contains mud d fine silt-size car	bonate)	Lacks mud and is grain	togetner	
Mud-s	upported	Grain- supported	supported		
Less than 10% grains	More then 10% grains				
Mudstone	Wackestone	Packstone	Grainstone	Boundstone	Crystalline
P	A CONTRACT				

Carbonate rock fabric descriptive terminology based on Dunham 1962.

G:\A4 GEOTECHNICS\A4-06 TECHNICAL INFORMATION\03 STANDARD SHEETS\SITE INVESTIGATIONS\EXPLANATORY NOTES\GEOTECHNICAL EXPLANATORY NOTES REV 8.DOC

#### ROCK STRUCTURE

Sedimentary rocks – Bedded, laminated (<20 mm) Metamorphic – Foliated, banded or cleaved Igneous – massive, flow banded

#### DEFECT DESCRIPTION

Order of description: type, angle, thickness, planarity, roughness, coating, infill.

#### Defect Type

Symbol	Description
Sh	Sheared Zone - zone of multiple closely spaced fracture planes with roughly parallel planar boundaries, usually forming blocks of lenticular or wedge-shaped intact material. Fractures are typically smooth, polished or slickensided; and curved.
Be	Bedding plane parting - arrangement in layers of mineral grains of similar sizes, near parallel to surface of deposition along which a continuous observable parting occurs. Generally no microfractures.
Fo	Foliation Parting – As for bedding plane parting except discontinuous microfractures may be present near parallel to the layering.
Jo	Joint - a fracture across which rock has little or no tensile strength and is not obviously related to rock fabric.
Cr	Crushed Seam - zone with roughly parallel, planar boundaries (commonly slickensided) containing disoriented usually angular rock fragments of variable size often in a soil matrix.
CI	Dyke – Igneous intrusion - often weathered and altered to a clay-like substance.
We	Weathered/Decomposed Zone - zone of any shape but commonly with parallel planar boundaries containing moderately to gradational boundaries into fresher rock.
SC	Solution cavity

#### Inclination

For specific defects, the orientation of each individual defect is noted in degrees from core normal. If the orientation cannot be measured, a dash (-) is used.

#### SPT SAMPLE DESCRIPTIONS

Where SPT tests are carried out in regions of core loss, a separate description of the SPT sample is provided. A separate description of the SPT sample is not however provided when core loss has not been recovered.

#### SHAPE

Symbol	Description
PL	Planar - forms a continuous plane without variation in orientation
IR	Irregular - has no clear orientation
CU	Curved - has a gradual change in orientation
UN	Undulating - has a wavy surface shape
ST	Stepped - has one or more well-defined steps

#### ROUGHNESS

Symbol	Description
Ro1	Slickensided or polished - very smooth, reflects light
Ro2	Smooth - roughness not detected with finger
Ro3	Defined ridges - Sandpaper feel (fine to medium sandpaper)
Ro4	Small steps - sandpaper feel (medium to coarse sandpaper)
Ro5	Very rough - very well defined ridges and/or steps.

#### **INFILL TYPE**

Symbol	Description
CL	Clean
CA	Calcite
CB	Carbonaceous material
СН	Chlorite
СТ	Carbonate
FE	Iron oxide
LM	Limonite
QZ	Quartz
SU	Sulphides
RF	Rock fragments
g	gravelly
s	sandy
m	silty
С	clayey
G	Gravel
S	Sand
М	Silt
С	Clay

Note: lower case letters are used as prefix

#### **INFILL THICKNESS**

Where infilling is present, the thickness of infill is recorded using the following convention:

- ST Iron oxide staining less than 1mm
- VN Veneer coating less than 1mm

If the infilling is greater than 1mm, the actual thickness of infill is recorded in millimetres. If infill is not present, a dash (-) is recorded.

#### SAMPLE CODES

Symbol	Description
С	Core sample
SB	Small bulk disturbed
AMAL	Amalgamated sample
В	Bulk disturbed
BLK	Block
CBR	CBR mould
CD	Plastic tub for chemical analysis
D	Small disturbed
DEN	Denison Sampler
DENm	Denison Sampler (modified)
Е	Environmental
G	Gas
J	Jar
К	Amber chemical jar
LB	Large bulk disturbed
LDS	Large disturbed
М	Mazier type
Р	Piston
TW	Thin walled push-in
U	Undisturbed – open drive
U100	100mm diameter undisturbed
U63	63mm diameter undisturbed
U76	76mm diameter undisturbed
W	Water

#### STANDARD PENETRATION TEST REPORTING

The results of SPT's are reported on both borehole and cored borehole logs.

Typically the test is reported as the number of blows for the seating drive ; and the number of blows of the two increments of the main drive e.g. N 5;10,15

For a test which is terminated during the main drive, the blows for the seating drive are reported followed by a semi-colon (;) and then the total number of blows and the total distance driven (mm) is reported e.g. N 15;50/250

For a test which is terminated during the seating drive, the total number of blows and the distance driven (mm) is reported and the result is suffixed with an "s" to designate the test was terminated during the seating drive e.g. N 50/75s.

For a test that is terminated within the seating drive the N values is determined by extrapolation of the penetration and number of blows recorded and is denoted with "\*\*".

For a test that is terminated before achieving the full main drive penetration, the N values is determined by extrapolation of the penetration and number of blows recorded and is denoted with "\*".

HB – Hammer double bouncing

#### POINT LOAD TESTING

 $I_{s(50)}$  Diametral test results to be recorded on log as: 2.05 DI  $I_{s(50)}$  Axial test results to be recorded on log as: 2.05 AX  $I_{s(50)}$  Irregular test results to be recorded on log as: 2.05 IR

# ARUP

#### SYMBOLS & ABBREVIATIONS

Drilling			
Method		Support	
AD	Auger drilling (drilled depths shown (m))	VV	Water
	Steel V bit	M	Mud
	Tricope (rock roller) bit	U T	Casing
	Mashboring	1	Linsupported
NMLC, BMLC	Triple tube rotary core drilling (52mm, 35mm diameter)	0	Unsupponed
NH HQ	Wireline core drilling		
D	Diatube coring		
Sample and Fie	eld Testing		
D	Disturbed sample	R	SPT refusal
U(x)	Undisturbed sample x mm diameter	V	In situ vane test (showing peak/residual value (kPa))
U(x)+	U(x) attempted, little or no recovery	W	Water sample
PT	Pressuremeter test	В	Bulk sample
PL	Point load test (AX - axial, DI - diametral test)		
ls(50)	Point load strength index (MPa)	Water – Mois	sture
q <sub>c</sub>	Cone resistance (from CPT)		
q <sub>p</sub> , PP	Unconfined compressive strength estimated from	W	Wet
DOD	pocket penetrometer (kPa)	M	Moist
RQD	Rock quality designation expressed as:	D	Dry Standning installed to death shown
	sum of lengths of sound core pieces > 100mm total	5	Standpipe installed to depth shown
SCR	Solid core recovery	P	
TCR	Total core recovery		Outflow (loss)
	Dip/dip direction of rock discontinuity (degrees)		Level (date)
CPT	Cone penetration test	·	Partial loss
SPT	Standard penetration test	•	
Ν	SPT blow count (blows/300 mm)		
• · · • · ·			
Soil Properties			11
CBR	California Bearing Ratio		Iesi Liguidity index
C.	Effective snear strength	LI	
C <sub>c</sub>	Compressed Index		Liquidity IIIIIt
C <sub>u</sub>	Coefficient of consolidation	PI	Plasticity index
C <sub>v</sub>	Coefficient of secondary compression	PI	Plastic limit
	Dry density	a. UCS	Unconfined compressive strength
D.	Dry density expressed	W	Moisture content (% of dry weight)
E	Elastic modulus	γ <sub>b</sub>	Bulk density
е	Void ratio	γd	Dry density
G	Shear modules	γw	Density of water
Gs	Specific gravity	υ	Poisson's ratio
k	Coefficient of permeability	φu	Apparent angle of friction from quick undrained triaxial
MDD	Maximum dry density obtained in compaction test		
m <sub>v</sub>	Coefficient of volume compressibility	φ <sub>u</sub> φ <sub>u</sub> '	Effective angles of friction in drained and undrained
NDD	Natural dry density		conditions
NMC	Natural moisture content		
OMC	Optimum moisture content obtained in compaction		
Design Parame	ters	2	
Ab	Footing or pile base area	Pp	Passive earth pressure
В	Footing or pile width or diameter	Ps	Pile shaft adhesion
D	Pooting or pile depth	S т	Settlement
u K	Diameter of pile (m)	1 <sub>V</sub>	Time
Ka Ka	Coefficient of active pressure	ι 11	Degree of consolidation
Ko	Coefficient earth pressure at rest	0	Pore water pressure
Kn	Coefficient of passive pressure	a	Shaft adhesion factor
L	Footing length	δ	Angle of friction between soil and structure
No No No	Bearing capacity factors	о Г	Total normal stress
NSF	Negative skin friction	σ'	Effective normal stress
P	Load	τ	Shear stress
Pa	Total active force	Subscript all	Allowable or working
Pb	Pile base load	Subscript h	Horizontal
P	Total passive force	Subscript r	Residual
Ps	Pile shaft load	Subscript ult	Ultimate
Pa	Active earth pressure	Subscript v	Vertical
Pb	Pile base pressure		



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ARL	ЈР в	OREHOLE RECORD	BH101	SHEET 3
CLIENT	RMS		HOLE LOGGED BY RG	OF 5
PROJECT	Summerland Way Additional	Clarence River Crossing	CHECKED BY AB DRILLED DATE 06-Ma	r-12 to 09-Mar-12
CONTRACTOR DRILL MODEL DRILLER	Terratest Pty Ltd Hydropower 5000 Terratest (DC)	ANGLE Vertical BEARING - HOLE DIAMETER 100mm ()	GROUND LEVEL RL 2.4 LOCATION 49375 ELEVATION DATUM Austral COORDINATE SYSTEM AM684	I9m 5 E 6714983 N ian Height Datum I Zone 56
DRILLING	STRATA	MATERIAL DESCRIPTION	CONDITION	OBSERVATION
Sample, test, bit, support, etc.	R.L. DEPTH AND MAND MAND MAND MAND MAND MAND MAND	SOIL TYPE Plasticity / Grain Size, Colour, Minor Components	CONSISTENCY WONSISTENCY COHESIVE COHESIVE COHESIVE COHESIVE COHESIVE COHESIVE COHESIVE COHESIVE COHESIVE	SOIL ORIGIN, STRUCTURE, ETC.
	- GP	GRAVEL, (GP) fine to coarse grained, poorly graded, sub-angular to - sub-rounded, dark grey mottled brown-white. <i>(continued)</i>		Alluvium
- D N=38 19;18,20 -	-21	20.50m becoming Clayey, medium plasticity, brown		
-	-22			
-	23	Borehole continued as a Cored Drillhole		-
-	- 24	- - - -		
- - - -	- 25	- - - -		
- - - -		- - - -		
-		- - - -		
- - - -	- 28			
- - - -				
NOTES Hole Diar 75mm to End of bo	meter 100mm to 2.50m depth. (Au 22.5m depth, washbore, then 52r orehole at 35.50m as agreed with	ger, then 100mm to 20.5m depth, washbore, then Im to 35.5m depth, NMLC) he RMS	јов 2	20422

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0			r	RMS		v Addi	tional Clarance Diver Crossing				LOGO CHEC	SED I	BY ) BY		RG AB	
С	ON	TRA	CTOR	Te	rratest Pt	/ Ltd	ANGLE	V	'ertical		DRILL GRO	.ED [ UND	DATE	E /EL	06-Mai RL 2.4	<sup>-</sup> -12 to 09-Mar-12 9m
0	RILI	L MC	DEL	Hy Te	dropower rratest (D	5000 C)	BEARING HOLE DIAMETEI	- R 1	00mm ()		LOCA ELEVA COORI		N I DAT TE S`	UM YSTEN	49375 Australi A AMG84	5 E 6714983 N an Height Datum Zone 56
	DRI	LLIN	IG		STRATA		MATERIAL DESCRIPTION						[	DISCO	ONTINUI	TIES
	(ac	RN %	S CS, etc)			LOG		SING		ŝ	ENCY	SF	PECI	FIC	GENE	RAL DESCRIPTIO
	SCR / (R	FLUSH RETU (TYPE)	SAMPLES aco <sub>3</sub> , SPT, U	mAHD	m	GRAPHIC	ROCK TYPE Grain Size, Texture/Fabric, Colour, Minor Components	WEATHEF			FREQUE	ТҮРЕ	ANGLE	THICKNES (mm)	Pla	narity, Roughness, Coating, Infill
+			Q				-				₩ ₩ ₩ ₩ ₩ ₩ ₩					
					+		-	-								
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					- 22		-									
					- 22		-									
			55	-20.11	- 22.60		Continued from Borehole	-								
		1	A 30/2	-20.26	22.75 - 22.85	Ņ	GRAVEL, (GP) coarse grained, sub-rounded, very dense, with cobbles.	-								
	- (0)				- 23		Gravelly SAND, (SP) medium to coarse grained,	-								
				-21.01	23.50		gravel is fine to coarse grained, sub-rounded, trace									
I	1	- % 0			-		1 23.15m - 23.40m without gravel, sand becoming / \fine to medium grained	-			· · · · ·					
	- (0)/	- 7			- 24	X	CORE LOSS (probable wash out of fines around gravels).									
				-21.76	- 24.25	$\left  \begin{array}{c} \\ \\ \\ \\ \\ \\ \\ \end{array} \right $	Gravelly SAND. (SP) medium to coarse grained.	-								
	<b>¥</b>		30/60s	-22.01 -22.16	- 24.50 - 24.65	$\sim$	poorly graded, sub-angular, pale brown, very dense, gravel is fine to coarse grained, sub-rounded, trace /	-								
+	ð	X			ł	· · ·	\clay. \CORE LOSS (probably Gravelly SAND).	-								
					- 25 -	· · ·	<ul> <li>Gravely SAND, (SP) medium to coarse grained, poorly graded, sub-angular, pale brown, very dense, gravel is fine to coarse grained, sub-rounded, trace</li> </ul>									
		% 02 (			-	· · ·	clay.	-								
		shbore			+	· · · · · · · · · · · · · · · · · · ·	-									
		- (Was			- 26	· · ·	-	-								
					-	· · ·										
		ł	N 30135s		+	· · · · · · · · · · · · · · · · · · ·	<ul> <li> 26.50m with gravel, fine to medium grained, sub-rounded, mixed lithologies</li> </ul>	-								
				.	- 27	· · · · ·										
					+	· · ·	-	-			· · · · ·					
					_	· · ·	-									
		— %		05.51	ļ	· · · ·	-	-								
		e) 60 (		25.51	<b>28</b> <sup>28.00</sup>		Clayey GRAVEL, (GC) fine to coarse grained,									
		ashbor	SO		+	E 6	grey-brown.	-								
		— (Wê	N 30/10		+	6X6	L 									
					- 29	120	+	_								
					t	9.0%	4 - 8									
					ļ	E E	- -	-								
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2	TES													J	OB	

gINT v8.2.904 Licenced to Ove Arup & Partners Project: 1/22003202422: animeriand vax/07-00 site and construction/07-02\_site investigations/07-00-03\_geotechnics jan 2012/05\_gint/20120427\_summeriand way\_master.gpj Library: st/uif\_120 infrastructureletengintiaus. Library.pg/b Log: 1.2.1 AuSTRALIA ROTARY: CORE.LOG (rev 16Jan08 checked AB/ACP Feb 2006)

										HOLE	-				0F 5
CLIE	ENT	Г	RMS Summe	erland Wa	ay Addi	tional Clarence River Crossing					SED I KED FD I	3Y BY )ATF		RG AB 06-Mar	-12 to 09-Mar-12
CON DRII DRII	NTRA _L MC _LER	CTOR DDEL	Ter Hyc Ter	ratest Pt Iropower ratest (D	y Ltd 5000 C)	ANGLE BEARING HOLE DIAMETER	V - 1	ertical 00mm ()		GRO LOCA ELEVA COOR		LEV N DATI	EL JM 'STEN	RL 2.49 493755 Australia 1 AMG84	)m 5 E 6714983 N an Height Datum Zone 56
DF	RILLIN	IG	5	STRATA		MATERIAL DESCRIPTION						D	ISCO		TIES
6	% 7	, etc)			gg		ŋ		_	ζ	SF	PECIF	IC	GENE	RAL DESCRIPTION
SCR / (RQI	FLUSH RETURI (TYPE)	SAMPLES (CaCO <sub>3</sub> , SPT, UCS	R.L. mAHD	DEPTH m	GRAPHIC LO	ROCK TYPE Grain Size, Texture/Fabric, Colour, Minor Components	WEATHERI	ESTIMATED ROCK STRENGTH 피국그로포포프	Is 50 (MPa	<sup>30</sup> FREQUEN <sup>3</sup> (per m)	ТҮРЕ	ANGLE	THICKNESS (mm)	Plar	arity, Roughness, Coating, Infill
	A 70 % → A 70 % → A 60 % → 60 % (Washbore) 60 %	A 201105 N	-29.51 _ -30.01 - -30.01 - -30.11 - -30.34 - -30.36 _ - - - - - - - - - - - - - - - - - - -	- 31 - 32 <sup>32.00</sup> - 32 <sup>32.00</sup> - 32.53 - 32.60 - 32.60 - 32.60 - 32.60 - 32.60 - 32.60 - 32.60 - 32.60 - 33 		Clayey GRAVEL, (GC) fine to coarse grained, poorly graded, sub-rounded to sub-angular, mottled grey-brown. (continued) CLAYSTONE, recovered on the end of the roller and barrel as clay, high plasticity, grey, stiff to very stiff. CORE LOSS. CLAYSTONE, recovered as clay, high plasticity, grey, / Stiff to very stiff. CORE LOSS (fall in of gravel from above caused washout of claystone). Casing could not be advanced further. 									
				- 39 - - -											

gINT v8.2.904. Licenced to Ove Anp. & Pathers Project: ;/j22003220422- may awyor700, site and construction/07-02\_site investigations/07-00-03\_geotechnics jan 2012/05\_gint/20120427\_summerland way\_master.gpj Libray : giviti 120 infrastructureschamtraus. Ilbray, p.gb Log: 12:1 AUGTRAUA ROTARY CORE LOG (rev fdan08 checked AB/ACP Feb 2006)

ARUP	Core Photographs	BH101
ARUP	DCATION BHIO1 DATE 9/3/2 DEPTH 22-00 to 35-00-	
hadiadia	հահահահահ	المبالمبالة
SPAC	CER A	CORE S
	CORE CORE	E LOSS
SPACER-WAS	H BORED	RE LOSS
Off Off	CORE LOSS	34-0
A WATER CONTRACTOR	22.60m to 35.00m	CONTRACTOR OF THE



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F		R	U	JP		CO	RED BOREHOLE RE	EC	ORD		В	H'	1(	)2		SHEET 4 OF 4
	CLIE	NT	r.	RMS	nlend \\//a	a Add	Viceol Clausers Diver Creasier				LOGO	GED E CKED	BY BY		RG JV	
	CON DRIL DRIL	ITRA L MC	CTOR DDEL	Ter Hyd Ter	ratest Pty Iropower ratest (D	y Ltd 5000 C)	ANGLE BEARING HOLE DIAMETER	۷ - ۲ 1	/ertical 00mm ()		GROUND LEVEL LOCATION ELEVATION DATUM COORDINATE SYST		<u>≡</u> ′EL ′UM ∕STEI	L RL 3.40m 495161 E 6715352 M Australian Height Datu TEM AMG84 Zone 56		
	DR	ILLIN	IG	5	STRATA		MATERIAL DESCRIPTION						[	DISC		IES
ate)	íQ	3N %	S, etc)			90		ŊŊ		a)	NCY (c	SF	PECIF	FIC	GENE	RAL DESCRIPTION
TCR % (Drill r	SCR / (RG	FLUSH RETUR (TYPE)	SAMPLES 2aCO <sub>3</sub> , SPT, UC	R.L.	DEPTH	GRAPHIC I	ROCK TYPE Grain Size, Texture/Fabric, Colour, Minor Components	WEATHER	ESTIMATED ROCK STRENGTH	Is 50 (MP	60 FREQUE	ТҮРЕ	ANGLE	THICKNESS (mm)	) Plar	arity, Roughness, Coating, Infill
	← 69/(69) → ← 89/(86) - 190/(100)		c <sup>2a</sup>	-20.94 -20.95 -21.02 -23.10 -2	m 		Continued from Borehole INTERBEDDED SANDSTONE / CLAYSTONE, thinly laminated at 5 to 10 degrees. sandstone is fine grained, grey, claystone is dark brown. trace inclusions of organic matter and coal on bedding planes	SW/D		D0.41 A0.49			-45 -10 -20 -25 -30 -10 -20 20 25 -70 -70 -80 -75		PL Ro3 CL PL Ro3 CL PL Ro3 CL PL Ro4 CL PL Ro3 C PL Ro2 CL PL Ro2 CL PL Ro2 CL PL Ro2 CL PL Ro2 CL PL Ro2 M PL Ro2 M	
N	) DTES	5 F 7	lole Diar 5mm to	neter 100 24.24m de	mm to 4.5 epth, wash	Om dep nbore, th	h. (Auger, then 100mm to 23m depth, washbore, then nen 52mm to 27.24m depth, NMLC)		See explanate abbreviations descriptions	ory no and b	tes for def basis of	ails of	f	J	<sup>јов</sup> 2	20422

gINT v8.2.904. Licenced to Ove Anp. & Pathers Project: ;/j22003220422- may awyor700, site and construction/07-02\_site investigations/07-00-03\_geotechnics jan 2012/05\_gint/20120427\_summerland way\_master.gpj Libray : giviti 120 infrastructureschamtraus. Ilbray, p.gb Log: 12:1 AUGTRAUA ROTARY CORE LOG (rev 16Jan08 checked AB/ACP Feb 2006)





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gINT v8.2.904 Licenced to Ove Arup & Partners Partners 1/22000220422 multicative Summeriand way Libray : 61/2000220422 multicative Summeriand way. Libray : 61/2012/101/20120427 summeriand way.meriand way.master.gpt 10/2012/101/20120421 GetterReat. BOREHOLE LOG (rev 30Junt) checked ABACP Feb 2006) and the page 22 d. 3.Made 27Apr/21443

	-					НС	DLE					OF 4
	RMS		v Add	itional (		LO — CH	GGI IECł	ed B Ked I	Y BY		RG JV	
		ratest Ptv	J td			DR					12-M	ar-12 to 13-Mar-12 77m
DRILL MODEL	Hyc	dropower (	5000		BEARING -	LC		TION	v L	-L	4954	38 E 6716883 N
DRILLER	Ter	ratest (DC	·)		HOLE DIAMETER TOUMIM ()	ELE CO	EVA1 ORD	fion e Inate	DATU E SYS	M STEM	Austra AMG8	ilian Height Datum 4 Zone 56
DRILLING		STRA	ΓA		MATERIAL DESCRIPTION			CON	DITI	ON		OBSERVATIO
			Ъ			_		~~~		TENO		
SAMPLE, TEST,	R.L.	DEPTH	SYMB	N N	SOIL TYPE	ER / IURE		00	11010			SOIL ORIGIN,
ETC.			OUP (	LEG	Plasticity / Grain Size, Colour, Minor Components	WAT MOIS <sup>-</sup>	C	OHES	IVE	COF	IESIVE	ETC.
	mAHD	m	GRG		Sandy CRAVEL (CC) fire to medium grained peoply graded		s v	ы Т С	LS I	: <b>7</b> _	205	Alluvium
		-	GC	008	<ul> <li>sub-rounded to sub-angular, brown, sand is fine to coarse grained, sub-angular, with clay. (continued)</li> </ul>	-						Anaviani
N=60*	-	-		99								
25;58/290		-		SQ3		-						
	-	- 21		29	-	-						
		-		200								
		-		220		-						
		22		2 d		-						
		- 22		220								
N-60*		-		80		-						
29;30/130		-		000	22.50m becoming Clayey, high plasticity, brown.							
	-	- 23		33	-	-						
	-	-		100		-						
	-19.83	23.60		12/2	CLAYSTONE dark arey extremely low strength recovered as CLAY							Bedrock
D N=129** 0 30/70s		-			<ul> <li>high plasticity, with gravel, fine to medium grained, tabular.</li> <li>Bereheld experiment on a Corred Drillholo.</li> </ul>	-						Bourbon
	-	- 24			- Bolenole continued as a cored Dillinole							
		-				-						
		-										
	-	- 25			-	-						
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	-	- 26			-							
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F		R	U	JP	C	CO	RED BOREHOLE RE	EC	ORD		B	H′ ⊧	10	)3	SHEET 4
	CLIE	NT	F	RMS		. Addi	tional Clarance Diver Crossing				LOG CHE	GED I CKED	BY BY		RG JV
	CON DRIL DRIL	TRA L MC LER	CTOR DDEL	Ter Ter Ter	ratest Pty Iropower ratest (D	/ Ltd 5000 C)	ANGLE BEARING HOLE DIAMETER	V - R 1	′ertical 00mm ()		GROUND LEVEL LOCATION ELEVATION DATUM COORDINATE SYST			E ′EL ′UM YSTEN	12-Mar-12 to 13-Mar-12 RL 3.77m 495438 E 6716883 N Australian Height Datum M AMG84 Zone 56
	DR	ILLIN	IG	5	STRATA		MATERIAL DESCRIPTION						۵	DISCO	ONTINUITIES
TCR % (Drill rate)	SCR / (RQD)	FLUSH RETURN % (TYPE)	SAMPLES aCO <sub>3</sub> , SPT, UCS, etc)	R.L.	DEPTH	GRAPHIC LOG	ROCK TYPE Grain Size, Texture/Fabric, Colour, Minor Components	WEATHERING	ESTIMATED ROCK STRENGTH	ls 50 (MPa)	FREQUENCY (per m)	SF	ANGLE	HICKNESS 7 (mm)	GENERAL DESCRIPTION Planarity, Roughness, Coating, Infill
	← 94/(73) →  ■ 74/(60)  63/(38) >	- (mud) 90 % 🚽 (mud) 90 %		-20.13 - - -20.33 - -20.33 -20.35 -20.33 -20.35 -20.33 -20.35 -21.23 -21.23 -21.23 -21.23 - -21.23 - -21.23 - - -21.23 - - - - - - - - - - - - - - - - - - -	m - 21 - 22 - 23 - 22 - 23 - 24 24.00 24.10 24.12 - 24.50 24.63 - 24.63 - 26.32 - 27.700 - 28 - 28 - 28 - 28 - 28 - 28 - 28 - 29		Continued from Borehole CORE LOSS. CLAYSTONE, thinly laminated, well developed bedding dipping at 5 to 10 degrees, dark grey-brown. CORE LOSS (due to core rotating inside barrel). CLAYSTONE, thinly laminated, well developed bedding dipping at 5 to 10 degrees, dark grey-brown. CORE LOSS. INTERBEDDED CLAYSTONE/SANDSTONE, Claystone, is dark grey, organic, Sandstone is fine grained, thinly laminated, very well developed bedding, dark grey. 25.00m organic fragments on bedding plane. INTERBEDDED CLAYSTONE/SANDSTONE, Claystone, is dark grey, organic, Sandstone is fine grained, thinly laminated, with very well developed bedding, dark grey. 25.90m - 26.00m recovered as Clayey GRAVEL, fine grained, angular. 26.15m - 26.30m dark grey-brown, increasing clay content. INTERBEDDED CLAYSTONE/SANDSTONE, Claystone, is dark grey, organic, Sandstone is fine grained, thinly laminated, with very well developed bedding, dark grey. 26.10m slickenslides on joint plane dipping at 70 degrees. 26.15m - 26.30m dark grey-brown, increasing [clay content. [CORE LOSS] INTERBEDDED CLAYSTONE/SANDSTONE, Claystone, is dark grey, organic, Sandstone is fine grained, thinly laminated, with very well developed bedding, dark grey. End of Borehole at 27.00m	S - - - - - - - - - - - - -		D0.51 A0.90			-40 -45 -20 -45 -40 -10 -30		PL R02 C PL R04 C.G PL R03 C PL R03 CL PL R01 CL PL R02 CL PL R02 CL PL R02 CL
N	DTES	3 F 7	lole Diar '5mm to	neter 100 23.9m dej	mm to 4.50 pth, washt	Om dept bore, the	h. (Auger, then 100mm to 21m depth, washbore, then in 52mm to 27m depth, NMLC)		See explanato abbreviations descriptions	ory no and b	tes for de asis of	tails of	f	J	ов 220422

gINT v8.2.904 Licenced to Ove Arup & Partners Project: 1/220032022-0 mices summeriand vax/07-00 site and construction/07-02\_site investigations/07-00-03\_geotechnics jan 2012/05\_gint/20120427\_summeriand way\_master.gpj Library: st/uif\_120 infrastructureletengintius... library.pglb Log: 1.2.1 AuSTRALIA ROTARY: CORE. LOG (rev 16.3an08 checked AB/ACP Feb 2006)





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gINT v8.2.904 Licenced to Ove Aup & Partners Provent: 1/L2000/224022- must be summertand way Library: 1/1.1/L20124022- must bottened by more and construction(07-02\_site investigations(07-00-03\_geotechnics jan 2012(05\_gint20120427\_summertand way\_master.gp) Library: 1/1.1/L211241A GENERALA DORENDELDELDG (rev 30Junt) checked ABACP Feb 2006) Alon Toubut page 2/2. Made 27Apr12.14:44

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CLIENT PROJECT	RMS	rland Wa	v Addi	itional (	Jarence River Crossing		GGED BY ECKED BY	JV AB	- 10 Is 01 May 10
CONTRACTOR DRILL MODEL DRILLER	Ter Hyc Ter	ratest Pty Iropower s ratest (DC	Ltd 5000 C)		ANGLE Vertical BEARING - HOLE DIAMETER 100mm ()	GF LO ELE CO	ROUND LE CATION EVATION DA ORDINATE S	VEL RL 6.7 49472 TUM Austral SYSTEM AMG84	70m 0 E 6718301 N ian Height Datum
DRILLING		STRAT	ГА		MATERIAL DESCRIPTION		CONDI	TION	OBSERVATIO
Sample, test, Bit, support, Etc.	R.L.	DEPTH	<b>ROUP SYMBOL</b>	LEGEND	SOIL TYPE Plasticity / Grain Size, Colour, Minor Components	WATER / MOISTURE	CONS		SOIL ORIGIN, STRUCTURE, ETC.
	mAHD - -		L L		Silty CLAY, (CL) low to medium plasticity, dark brown, trace sand, fine grained, trace root fibres.	D - -	S S T S S S S S S S S S S S S S S S S S	Kogrki	Alluvium
	5.80	- 0.90 - 1	SP		- _ Silty SAND, (SP) fine to medium grained, sub-angular, poorly graded, yellow-pale brown, with silt.	- D - D			Alluvium
N=5 2;2,3	-	- - 2 -			-	- M - -			
	-	- 3			-	-			
N=5 2;2,3	-	- - - <b>4</b>			-	-			
	-	-			- - 4.50m becoming Clayey, brown. -	-			
N-5		- <b>5</b> - - 5.50	СН		- - - CLAY (CH) high plasticity, grey mottled brown, trace organic lenses	M-W			Alluvium
0;3,2	-	- 6			- -	_			
	-	- 7			6.50m becoming dark brown mottled brown. - -	-			
N=5 2;1,4	-0.80	7.50	SP		7.20m becoming brown.	- - - M-W			Alluvium
	-1.40 -1.40	- <b>8</b> 8.10	СН		- - CLAY, (CH) high plasticity, brown. -	- - M-W -			Alluvium
	-2.00 -	8.70 - - <b>9</b>	SP		- Silty SAND, (SP) fine to medium grained, poorly graded, grey-dark grey. -	- - M-W -			Alluvium
N=8 4;5,3	-	-		· · · · · · · · · · · · · · · · · · ·	-				

gINT v8.2.904 Licenced to Ove Arup & Partners Project : j/22000/220422 - mmd5 summerland vay/07-00 site and construction/07-02\_site investigations/07-00-03\_geotechnics jan 2012/05\_ginf/20120427\_summerland vay\_master.gpj Library : givin 120 infrastructureitechignitates. Ibrary p.gbj Logr : 10,1 AUSTRALIA GENERAL, BORFHOLE LOG (rev 30Jun10 checked ABIACP Feb 2006)



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gINT v6.2.904. Licenced to Ove Arup & Partners 1. Control 2: 1/12:000222422: minis summerland way/07-00\_site and construction/07-02\_site investigations/07-00-03\_geotechnics jan 2012/05\_gint/20120427\_summerland way\_master.gpj Libery: 0:1.015/07:101 infrastructureterbyInitiaus. Iberay-0.910 Libery: 0:1.015/17:201 infrastructureterbyInitiaus. Iberay-0.910 1. Dispective of the offending of the offending of the offending of the offending of the offending of the offending of the offending of the offending of the offending of the offending of the offending of the offending of the offending of the offending of the offending of the offending of the offending of the offending offending of the offending offending of the offending offending of the offending of the offe



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	RMS					LO CH	GGED BY IECKED BY	JV AB	
CONTRACTOR DRILL MODEL DRILLER	Summe Ter Hyc Ter	ratest Pty dropower st ratest (D0	y Add Ltd 5000 C)		ANGLE Vertical BEARING - HOLE DIAMETER 100mm ()	DR GF LC ELE CO	ILLED DAT ROUND LEV OCATION EVATION DAT ORDINATE S	E 21-N /EL RL 4 4959 TUM Aust YSTEM AMG	Aar-12 to 23-Mar-12 .79m 204 E 6716405 N ralian Height Datum 84 Zone 56
DRILLING		STRA	ТА		MATERIAL DESCRIPTION		CONDI	ΓΙΟΝ	OBSERVATION
Sample, test, Bit, support, Etc.	R.L.	DEPTH	OUP SYMBOL	LEGEND	SOIL TYPE Plasticity / Grain Size, Colour, Minor Components	WATER / MOISTURE	CONSI	NON COHESIV	SOIL ORIGIN, STRUCTURE, E ETC.
N=55	mAHD -15.21 -	m 20.00	й GW		Sandy GRAVEL, (GW) fine to coarse grained, sub-angular to angular, - black, white, sand is fine to coarse grained, sub-rounded to angular, brown, black, white, with clay, brown.	M-W	VS ST ST VS VS	ΩΩLK	Alluvium
29;25,30	-	- 21 			-	-			
	-	- 			21.50m decreasing clay proportion. - -	-			
N=90** 30/100s	-17.71 - -	22.50 	GW		<ul> <li>GRAVEL, (GW) fine to medium grained, sub-angular to angular, black, brown, white, red, with sand, medium to coarse grained, sub-rounded to angular, black, brown.</li> </ul>	- - M-W -	-		Alluvium
N=50 27;24,26		- - - - <b>24</b>			- - 23.70m becoming fine to coarse grained, trace clay. -	-			
	-	- - - 25			- - - -	-			
N=113** 30/80s	-20.71	25.50 			CLAYSTONE fine grained, thinly laminated at 5 degrees, grey. Borehole continued as a Cored Drillhole	-	-		Bedrock
		- 27			- - - -	-			
	-	- 28			- - - -	-			
	-	- 29			-	-			
	-	+ +			- - -	-			

gINT v8.2.904 Licenced to Ove Arup & Partners Project : j/22000/220422 - mmd5 summerland vay/07-00 site and construction/07-02\_site investigations/07-00-03\_geotechnics jan 2012/05\_ginf/20120427\_summerland vay\_master.gpj Library : givin 120 infrastructureitechignitates. Ibrary p.gbj Logr : 10,1 AUSTRALIA GENERAL BORFHOLE LOG (rev 30Jun10 checked ABIACP Feb 2006)

CI PF CC DF	LIE RO ON RILI	NT JECT TRAC	CTOR	RMS Summe Ter Hyo	erland Wa ratest Pty Iropower	ay Addit / Ltd 5000	tional Clarence River Crossing ANGLE BEARING	V -	ertical		LOGO CHEO DRILI GRO LOC	GED CKED LED I UND ATIO	BY ) BY DAT ) LE\ N	E /EL	JV AB 21-Mar-12 to 23-Mar-12 RL 4.79m 495904 E 6716405 N
				Ter				<u> </u>	oomm ()		ELEV/ COOR	ATION DINA	I DAT	TUM YSTE	Australian Height Datum M AMG84 Zone 56
			0 0				WATERIAL DESCRIPTION	1				6			
	SCR / (RQD)	FLUSH RETURN % (TYPE)	SAMPLES CaCO <sub>3</sub> , SPT, UCS, et	R.L.	DEPTH	GRAPHIC LOG	ROCK TYPE Grain Size, Texture/Fabric, Colour, Minor Components	WEATHERING	ESTIMATED ROCK STRENGTH STRENGTH	30 10101	() FREQUENC	TYPE	ANGLE	THICKNESS (mm)	Planarity, Roughness, Coating, Infill
					- 22 - 22 - 22 - 22 - 23 23 23 										
- //>	70/(40)			-20.81 -20.96 -21.31 -21.41	25.60 25.75 - <b>26</b> 26.10 26.20		Continued from Borehole CORE LOSS. SILTSTONE, fine grained, poorly developed bedding, grey. CORE LOSS. INTERBEDDED SILTSTONE/SANDSTONE,	FR/SW				86 66	80  / 15  /60	00	-ST R03 C NPL R02 C -PL R04 G -PL R04 G
()00	93/(93)		С		- <b>27</b> <b>27</b> 		sandstone, fine grained, pale grey, siltstone, fine grained, grey, thinly laminated.	-	D0.5 A0.8 A0.6	i6 i5 i2 i5		200 200 200 200 200 200 200 200 200 200	20 5 5 8 7 1 8 7 1 1 7 1 8 7 1 1 7 1 8 7 1 7 1		NPL Ro2 c, G PL Ro4 c, G -PL Ro1 C -PL Ro3 G NPL Ro2 CL -PL Ro2 CI -PL Ro4 CL -PL Ro3 CL -PL Ro3 CL -PL Ro3 Pyrite
,			С	- 	- 28 - - - - 28.80 - 29 - -		End of Borehole at 28.80m	-	D04	08		19990 1/7 1	130 15 15 10	_0  /0  /70 _0	PL Ro2 GL PL Ro3 G R Ro5 G PL Ro5 G PL Ro2 G

gINT v8.2.904 Licenced to Ove Arup & Partners Project : j:\2220000220422 - mf83 summerland way/07-00\_site and construction/07-02\_site investigations\07-00-03\_geotechnics jan 2012\05\_gint20120427\_summerland way\_master.gpj Licent : j:\14.DETReatLink AFOCORE Licent (stands decked AB/ACP Feb 2006) Licent : J:\41.DETReatLink FOTARY CORE LICG (rev (stands decked AB/ACP Feb 2006)



Appendix C

Laboratory Tests

# **TEST CERTIFICATE**



Accreditation No. 2418

SGS Australia Pty Ltd Unit 15, 33 Maddox Street (PO Box 6432) Alexandria NSW 2015 Australia

# **POINT LOAD STRENGTH INDEX**

## CLIENT: Arup PO Box 76 Millers Point NSW 2000 PROJECT: Summerland Way, Grafton (220422)

LAB.	SAMPLE	LITHOLOGY	PL/	ATEN	TEST	POINT	POINT	Туре
NO.	SOURCE		SEPA	RATION	ORIENTATION	LOAD	LOAD	OF
			DIAM	HEIGHT		STRENGTH	STRENGTH	FAILURE
			(mm)	(mm)		ls (MPa)	Is <sub>(50)</sub> (MPa)	
71494	BH102 25.41- 25.53m	Siltstone	50.3	28.5	Diametral Axial	0.41 0.53	0.41 0.49	FB FOB
71495	BH103 24.88- 25.00m	Siltstone / Sandstone	51.5	28.9	Diametral Axial	0.51 0.96	0.51 0.90	FB FOB
71496	BH103 26.70- 26.87m	Siltstone	51.6	31.7	Diametral Axial	0.83 2.09	0.84 2.01	FB FOB
71497	BH106 26.57- 26.60m	Siltstone	51.2	34.5	Diametral Axial	0.55 0.87	0.56 0.85	FB FOB
71498	BH106 28.68- 28.80m	Siltstone	51.6	30.6	Diametral Axial	0.40 0.51	0.40 0.48	FB FOB
71499	BH106 27.44- 27.51m	Siltstone	51.6	30.8	Diametral Axial	0.32 0.68	0.32 0.65	FB FOB
NOTES	TO TESTING							
Testing	Device	ELE Point Load Tester	Failure <sup>-</sup> FOB	Type Fracture	through fabric of s	specimen obl	ique to beddi	ng
Sample	HISTORY	Unsoaked	<b>FD</b>		enced by weak pla	nes		
Sample	d By:	Client	FB FIP	Fracture Fracture vein. che	along bedding influenced by pre- mical alteration	-existing plan	e, microfractu	ure,
Job Nu	mber:	007-272	CPF	Chip or p	artial fracture			
Date Te	ested:	28.03.12						
Test Me	ethod:	AS 4133.4.1 2007					Page 1 of	1
Approv	ved Signatory:	Chris Lloyd			<b>Date:</b> 28	3.03.12		_
1	MRA N	This document is issued in accord	dance with NA	TA's accredi	tation requirements			



Brisbane 346A Bilsen Road, Geebung QLD 4034 Ph: +61 7 3265 5656

Perth 2 Kimmer Place, Queens Park WA 6107 Ph: +61 8 9258 8323

Client	Arup Geo	otechnics I	Ltd Report No.	12031187-G
Project	Summerl	and Way,	afton GI Test Date	11-13/04/2012 4/5/2012
Client ID	BH101		Depth (m)	2.50-2.95
Sieve Size	Passing			
(mm)	%	100		
150.0				
75.0		90		
53.0				
37.5				
26.5		80		
19.0				
9.5		70		
4.75		10		
2.36	100			
1.18	99	60		
0.600	97	(%)		
0.425	87	sing		
0.300	58	se 50		
0.150	30			
0.075	22	40		
0.075	22			
0.053	19			
0.038	18	30		
0.027	1/			
0.02	15	20		
0.014	14			
0.0102	13			
0.0072	0	10		
0.0001	9 Q			
0.0042	7	0		
0.003	5	0.0	0.01 0.1	1 10
0.0026	4		Particle Size (mm)	
0.0015	4			
-	- <b>. .</b>			
)TES/REMARKS	<u>5:</u> - N	Moisture Cor	t 25.6% -2.36mm Soil Particle Density(t/m <sup>3</sup> )	2.60
This docume requirement results of the document a	ent is issued in a is. Accredited fo e tests, calibratio re traceable to A	ccordance with r compliance w ons, and/or mea ustralian/Natio	Authorised Signatory SO/IES 17025. The ements included in this Standards. J. Russell	

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	COMPRESS	SIVE STRE		SOIL TEST RE	PORT	
Client	Arup Geotechnics I	Pty Ltd	1100. AS 1269.0.4.1 -	Sample No.	12031188-QU	
Project	Summerland Way,	Grafton GI		Test Date	12/04/2012	
				Report Date	20/04/2012	
Client ID	BH104			Depth (m)	1.00-1.30	
Description	Silty Sandy Clay - N	/lottled Brown/C	)range/Grey			
300						
250						
200						
ess (kPa)						
Ssive Str 120						
00 Umbre Compo Compo						
50						
0	2	4	6 E	3 10	12 14	
Avorago Sam	nlo Diamotor (mm)	18.6		vinum Principal St	ross (kPa) 261	
Average Sall		40.0				
Average S	ample Height (mm)	101.2			allure (%) 13.3	
Heigr		2.1		Average rate of Stra	in (%/min) 1.5	
	Wet Density (t/m <sup>3</sup> )	1.83		Moisture C	ontent (%) 21.6	
	Dry Density (t/m <sup>3</sup> )	1.50				
Mode of F	ailure of Specimen	Shear				
votes/Remarks:	-					
Sample/s supplied	by the client				Page 1 of 1 REPO	0220
This docume requirements results of the this documer	nt is issued in accordance with Accredited for compliance wi tests, calibrations, and/or mea t are traceable to Australian/Na	NATA's accreditation th ISO/IES 17025. The surements included in ational Standards.		Authorised Signatory		

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		<u>OEDO</u>		A S1289 6 6	REPORT						
Client:	Arup Geotechnics	Pty Ltd		Rep	port No.: 12031	188-OED					
Project:	Summerland Way,	Grafton GI		Test Date: 12/04/2012 Report Date: 24/04/2012							
Client Id.:	BH104			Depth (m): 1.00-1.30							
Description	: SANDY CLAY - mo	ottled yellow red	brown gre	ey							
			TEST I	RESUL	<u>TS</u>						
Stage	Load	Cc	Cv (	m²/yr)	Mv (kPa⁻¹x10⁻³)	C <sub>a</sub> x 10 <sup>-3</sup>	% Consolidation				
	(kPa)		t <sub>50</sub>	t <sub>90</sub>							
1	100-197	0.077	2.62	211.29	0.136	1.00	1.3				
2	197-73	0.038	2.65	2.08	0.078	0.55	0.4				
3	73-26	0.005	0.95	70.33	0.029	1.78	0.2				
4	26-73	0.019	3.53	29.11	0.106	0.29	0.7				
Remarks:	Tested as Received			1			Page 2 of 2				



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ent Arup Geo	otechnics Pty L	td		Report No.		12031189-/	٩L
<b>oject</b> Summer	and Way, Graf	ton Gl		Test Date Report Dat	e	19/04/2012 20/04/2012	
Sample No.	12031189	12031190	12031194	12031195	-	-	]
Client ID	BH103	BH102	BH106	BH106	-	-	1
Depth (m)	0.50-0.95	4.50-4.95	2.50-2.95	12.50-12.95	-	-	1
Liquid Limit (%)	39	30	39	24	-	-	1
Plastic Limit (%)	19	24	17	21	-	-	
Plasticity Index (%)	20	6	22	3	-	-	1
Linear Shrinkage (%)	6.5+	2.5*	9.5	0.5	-	-	]
Moisture Content (%)	29.1	47.4	24.5	32.2	-	-	]
Client ID	-	-	-	-	-	-	-
Depth (m)	-	-	-	-	-	-	_
Liquid Limit (%)	-	-	-	-	-	-	-
Plastic Limit (%)	-	-	-	-	-	-	
Linear Shrinkage (%)		-	_	_	-		-
Moisture Content (%)	-	-	-	-	-	-	-
S/REMARKS: The sampled by the client This document is issued in accord accreditation requirements. Accred ISO/IES 17025. The results of the	es were tested over lance with NATA's edited for compliance e tests, calibrations, a	en dried, dry si <u>* Crumbling c</u> with nd/or	eved and in a occurred Authorised	125-250mm moul + Curling occur Signatory	ld. rred	Page 1 of 1	RE
Australian/National Standards.	cument are traceable		J. Rus	sell		TE	MPETE



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lient	Arup Geotech	nnics Pty Lt	td		Report No	<b>)</b> .	12031190-	G			
roject	Summerland	Way, Graf	ton GI		Test Date Report Da	ate	19/04/2012 20/04/2012				
Sample No.	12031190	-	-	-	-	-	-	]			
Client ID	BH102	-	-	-	-	-	-				
Depth (m)	4.50-4.95	-	-	-	-	-	-				
Moisture (%)	47.4	-	-	-	-	-	-				
AS SIEVE SIZE (mm)		PERCENT PASSING									
150		-	-	-	-	-	-				
75		-	-	-	-	-	-				
53		-	-	-	-	-	-				
37.5		-	-	-	-	-	-				
26.5		-	-	-	-	-	-				
19		-	-	-	-	-	-				
9.5		-	-	-	-	-	-				
4.75		-	-	-	-	-	-				
2.36		-	-	-	-	-	-				
1.18	100	-	-	-	-	-	-				
0.600	98	-	-	-	-	-	-				
0.425	97	-	-	-	-	-	-				
0.300	91	-	-	-	-	-	-	1			
0.150	68	-	-	-	-	-	-				
0.075	53	-	-	-	-	-	-				
<u>=S/REMARKS:</u>											
	Sample/s suppli	ed by the clie	ent				Page 1 of 1	RE			
This document is i accreditation requi ISO/IES 17025.	ssued in accordance v rements. Accredited he results of the tests	with NATA's for compliance v , calibrations, ar	with nd/or	Authorised	i Signatory	/	ļ				

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Client	Arup Geo	technics I	Pty Ltd						Rep	ort N	о.		120	311	91-0	G
Project	Summerl	and Way,	Grafton	GI					Tes	t Date	9		11-	13/0	4/2	012
									Rep	ort D	ate		17/-	4/20	12	
Client ID	BH105								D	epth (	(m)	3.5	50-3.	95		
Sieve Size	Passing	100	<b>.</b>				_									
(mm)	%															
150.0																
75.0		90				++-						-				++-
53.0																
37.5																
26.5		80	1									1				
19.0												/				
9.5		70	┫───┤			++			_	+++	/				++	+++
4.75											/					
2.36											/					
1.18		60	┫ ┤			++					/-					
0.600		(%) B														
0.425	100	uss 50														
0.300	100	Ба														
0.150	83										/					
0.075	40	40	-			++				++						++
0.071	30															
0.027	20															
0.037	20	30														
0.020	10															
0.017	17	20														
0.014	17															
0.0077	17					$\parallel$										
0.005	11	10	1 †	$\rightarrow$	$\square$	++										$\left  \right $
0.0041	10															
0.0036	9	0									Щ					
0.0029	8	0.	001			(	0.01				0.1					1
0.0025	7						Р	article	Size (m	m)						
0.0015	4															
0.0015	4															
<u>)TES/REMARKS</u>	<u>S:</u> - N S	/loisture Co Sample/s su	ntent 16.2 pplied by t	2% the clie	ent	-2.3	36mm \$	Soil Pa	article	Densit	y(t/m <sup>3</sup> )	2.66	I	Page 1	of 1	REF
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		<u>OED</u>	OMETER	RTEST	REPORT						
			Test Method:	AS1289.6.6	.1, 3.5.1						
Client:	Arup Geotechnics	Pty Ltd		Rej	oort No.: 12031	192-OED					
Project:	Summerland Way,	Grafton GI		Test Date: 13/04/2012 Report Date: 24/04/2012							
Client Id.:	BH105			Depth (m): 6.00-6.45							
Descriptior	1: SILTY CLAY - mo	ttled yellow red	brown grey	/							
			TEST	RESUL	TS						
Stage	Load	Cc	Cv (	m²/yr)	M∨ (kPa <sup>-1</sup> x10 <sup>-3</sup> )	C <sub>a</sub> x 10 <sup>-3</sup>	% Consolidation				
	(kPa)		t <sub>50</sub>	t <sub>90</sub>							
1	25-43	0.000	50.44	47.91	0.000	0.00	0.0				
2	43-79	0.038	5.06	175.78	0.160	1.21	0.6				
3	79-120	0.064	3.02	303.36	0.163	1.32	1.2				
4	120-240	0.106	5.27	84.52	0.154	1.50	3.1				
5	240-79	0.061	5.22	15.12	0.108	0.40	1.4				
6	79-43	0.030	1.15	166.33	0.127	0.77	0.9				
7	43-79	0.097	6.21	258.24	0.412	0.23	2.4				
Remarks:	Tested as Received		1	1	<u> </u>		Page 2 of 2				



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Client	Arup Geo	technics I	Pty Ltd					Re	eport	No	-	12	2031	193-	G
Project	Summerla	and Way,	Grafton (	GI				Te	st Da	ate		11	11-12/04/2012		
								Report Date		17	17/4/2012				
Client ID	BH105								Dent	– <u>– –</u> h (n	<u>יי</u> ו) 1	1 50	_11	95	
Sieve Size	Passing								Jopt	. (	<u>'</u>	1.00		00	
(mm)	%	100	1											-	
150.0															
75.0		90													
53.0		50													
37.5															
26.5		80			++							+			++-
19.0															
9.5		70													
4.75		10													
2.36															
1.18		60			++										
0.600	100	(%)													
0.425	99	sing													
0.300	94	ଞ୍ଚ 50 ଜ													
0.150	27														
0.075	14	40													
0.075	14														
0.054	13														
0.038	12	30													
0.027	12														
0.02	12	20													
0.014	12														
0.0101	12									$\mathcal{H}$					
0.0071	10	10		$\pm$	+	ΠH									++
0.003	Q														
0.0036	8	0													
0.0029	8	0.0	001			0.01					0.1				1
0.0025	8						Partic	le Size (	mm)						
0.0015	6														
	-														
)TES/REMARK	<u>5:</u> -	Anisture Cor	ntent 25.6º	/		-2.36r	nm Soil	Particl	e Den	sitv/	t/m <sup>3</sup> ) 26	7			
	S	Sample/s su	pplied by th	e client	t	2.001				Sity(			Pag	e 1 of 1	REP
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results of th	e tests, calibratio	ns, and/or mea	asurements ir	icluded ir	ne this			Į.		$\square$	100	//			
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Client	Arup Geo	technics F	Pty Ltd			F	Report	No.	1	203119	4-G	
Project	Summerla	and Way,	Grafton GI			<sub>1</sub>	Fest Da	te	1:	12-19/04/2012		
						F	Report Date		23/4/2012			
Client ID	BH106						Depth	(m)	2 50-	2 95	_	
Sieve Size	Passing							()	2.00	2.00		
(mm)	%	100 -						/				
150.0												
75.0		90 -										
53.0												
37.5												
26.5		80 -								+++		
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**Perth** 2 Kimmer Place, Queens Park WA 6107 Ph: +61 8 9258 8323

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Liquid Limit (%)	54	39	30	65	39	24		
Plastic Limit (%)	28	19	24	29	17	21		
Plasticity Index (%)	26	20	6	36	22	3		
Linear Shrinkage (%)	13.0+	6.5	2.5	16.5	9.5	0.5		
Moisture Content (%)	25.3	29.1	47.4	28.1	24.5	32.2		
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Plastic Limit (%)	-	-	-	-	-	-		
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**Appendix D** Gravity Field Survey



Report prepared for

## ARUP

On behalf of

# **Roads and Maritime Services of NSW**

# GRAFTON SUMMERLAND WAY GRAVITY SURVEY

April 2012 ETS Job No. ET403

Report Prepared By: Earth Technology Solutions Pty Ltd ACN 078 325 658

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Figure 2

Figure 3 Figure 4

Figure 5

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Interpreted Rock Levels - Contour Plan

3D View - Interpreted Rock Levels

APPENDIX A Gravity Method, Instrumentation & General Assumptions of Interpretation

Interpreted Rock Levels (Aerial Photo Site Plan)

Bouguer Gravity Data & estimated Regional Gravity Gradient



#### 1.0 INTRODUCTION

Earth Technology Solutions Pty Ltd (ETS) was commissioned by ARUP on behalf of the Roads & Maritime Services of NSW (RMS) to carry out a gravity survey adjacent to the Clarence River at Grafton for the proposed Summerland Way road project.

The gravity profiling was undertaken as part of a preliminary level study to provide interpreted bedrock profiles in the region of two potential road alignments to aid the assessment of foundation conditions for a proposed bridge and elevated roadway.

Borehole results from a number of previous investigations in the area had indicated a palaeochannel in the region of the current river however access to land for a drilling investigation was limited.

The gravity method was recommended as the most effective non-invasive method to delineate the general rock profile and provide information on the bedrock depths given the site conditions.

The fieldwork was carried out from 13<sup>th</sup> and 14<sup>th</sup> March 2012 in accordance with standard practice as detailed below.

### 2.0 SCOPE OF WORK

Four (4) individual gravity lines were completed, totalling approximately 3500m in length. The locations of the gravity lines are shown on the general site plan Figure 1. This site plan has been generated from an aerial photo plan provided by ARUP showing proposed road alignments, previous borehole locations and the proposed location of the gravity stations.

Line 1 extended from the Pacific Highway along Eggins and Moana Lanes. Line 2 was positioned along the western and northern extension of Eggins Lane. Line 3 was positioned along a public access laneway further to the south and the southern Line 4 was positioned along McClaers Lane.

#### 3.0 EQUIPMENT

A Lacoste & Romberg G-Model gravimeter was used to acquire the gravity data. This instrument measures the Earth's gravitational field very accurately by balancing or "nulling" the gravitational force on a proof mass, with a restoring force provided by a series of levers activated by turning a high precision screw.

Gravity readings are taken by levelling the instrument on a base plate and manual reading of the "null" position.



Further details of the specifications of the Lacoste & Romberg gravimeter are provided in Appendix A.

#### 4.0 FIELD PROCEDURES

A description of the field procedures is provided below. Some further background information of the micro-gravity method is also provided in Appendix A.

Gravity readings were taken generally at 20m intervals along the survey lines. The position of each station was located using a 100m tape laid along the ground surface and marked with marker paint.

The surface elevations for each gravity station were measured by the geophysical crew, using an ATG-6 Automatic level, whilst undertaking the gravity measurements for each area.

The horizontal position of the start and end of each of the gravity lines was determined with a Differential GPS system.

A number of base station were established in relatively quite locations and repeat readings were taken at these base station and a number of other secondary base points at approximately 30 to 45 minute intervals, to allow determination of the residual drift of the gravity meter, in accordance with accepted practice.

The ground surface was generally very stable comprising gravel roadways over the majority of stations with some of the survey points on grass surface. In general the data was considered of good quality and repeat measurements indicated a survey accuracy of approximately 10 microgals.

A number of outlier gravity points were taken to the south of the Pacific Highway where rock is expected to be very shallow, and at Borehole locations to the South and North of the river with known rock levels, to allow an estimation of the regional gravity gradient across the area of interest.

### 5.0 INTERPRETATION PROCEDURES

### 5.1 Survey Co-ordinates

The Relative Levels for each gravity survey point was measured during the gravity survey relative to the start of each line.

Listing of the corrected Easting and Northing coordinates to AMG-56 for each of the gravity stations were provided to ARUP and ground surface levels to AHD were then derived from the LIDAR survey. These levels were used to provide a shift of the ground surface for each gravity line to AHD



datum. It is expected that overall the surface levels would be accurate to within approximately +/-0.1m.

## 5.2 Gravity Data Processing & Corrections

The **Earth Tide corrections** and the **short-term residual gravity meter drift** were removed using repeat base station readings. Approximately 150 microgals of drift was observed over the course of each day of the survey, which was effectively removed by curve fitting of the base station data.

A **latitude correction** was applied to the data using the surveyed station coordinates, assuming a datum point to the south of the site. A Free Air correction was applied using the elevations provided for each station.

**Bouguer Corrections** were applied to the Free Air gravity data using a range of densities from 1.6 to 2.4 tonne/cubic metre, and plotted against elevation to determine the most appropriate density of the near-surface rocks using Nettleton's Method. A value of 2.2 t/cu.m was chosen as the most appropriate density for the near surface to derive a final Bouguer Gravity Data.

**Terrain corrections** were not applied as the ground surface was relatively flat and there were no obvious areas where irregularities in the surface elevations would have resulted in errors in assumption, which would cause a reduction in gravity due to upward pull. The river and subsequent drop in river bed surface may have an effect on the data within approximately 50m of the river's edge.

### 5.3 Regional Gravity Gradient

The regional gravity gradient is a longer wavelength gravity anomaly due to large and deeper structures such as the sedimentary basin structure or other large scale changes in bedrock density. Typically this gradient would be sub-planar over a survey area of this size and may be identified by taking gravity readings at locations where rock outcrops ie the contribution of the alluvium is nil. However rock outcrops in the vicinity of the site were limited.

A number of spatially diverse locations where the rock level was relatively shallow as provided by the borehole data, were used in conjunction with 2D modelling of the gravity response for these known depths to rock, to best approximate the region gravity gradient. This is shown in Figure 2 where the contoured Bouguer gravity data and estimated regional gradient is shown as a 3D perspective view.

### 5.4 Gravity Modelling

This Regional Corrected Bouguer gravity data was used as the input data to



2-Dimensional modelling, using Grav2D Gravity Interpretation package. The gravity modelling is based on a simplified earth-model with the following assumed densities for the soil and rock units.

Alluvium	1.8 t/cu. m wet
Rock	2.35 t/cu. m wet

As the water table and moisture levels would be considered relatively shallow and sub-parallel with the ground surface, separate regions of density variations due to moisture content were not included in the gravity model. It was assumed that the water table was fairly shallow and the shallow soils were generally moist.

Gravity modelling was undertaken assuming a soil layer, of generally uniform density contrast of -0.55 t/cu.m compared to the underlying bedrock. The depth to rock indicated at the boreholes nearest the gravity lines were used to calibrate the gravity modelling.

Sections of the gravity lines with varying depths to rock were modelled to obtain a "best approximation" between the corrected Bouguer gravity data and known depths to rock. An approximate correlation factor of 0.038 milligals per meter depth to rock was determined. This was used then used to calculate an interpreted depth below ground surface which when subtracted from the measured ground surface provided an interpreted rock level to AHD datum.

Further details of the gravity data corrections and interpretation are provided in Appendix A.

#### 6.0 <u>RESULTS</u>

A contour plan of interpreted rock RL (AHD) has been provided on Figure 3. The Interpreted Rock Contour Plan is interpreted to represent the bedrock mass as defined by the assumed two layer model. The gravity station locations, interpreted rock RL's and contours of the interpreted rock levels from the gravity data labelled at 5m depth intervals are shown. The location and RL of the bedrock from the nearby boreholes provided are also shown.

These same interpreted rock contour levels derived from the gravity survey are shown overlain on the aerial photo base map provided by ARUP in Figure 4.

The interpreted rock profile is observed to vary from approximately RL 0m depth to RL-22m over the regions tested.

There may be some significant variation in densities along the lines due to variable thickness of gravels or dense sediments. Such density variations



may affect the interpreted levels. If the sediments contain an increased percentage of gravel, then the density contrast used in the modelling (-0.55 t/cu.m) may have been overestimated resulting in an underestimation of the depth to rock. Similarly if some areas contain relatively less dense sediments then the depth to rock may be overestimated.

Density variations within the bedrock are also possible. Due to variations in the weathering profile across site the interface of the relatively "dense" rock surface on which the gravity interpretation is based may vary slightly.

It was not possible to account for these variations systematically based on the limited spatial information available and the single gravity profiles.

Listings of the gravity station coordinates and interpreted rock levels along the gravity profiles from which the contour plans have been derived will be provided in electronic format.

#### 7.0 CONCLUSIONS

Gravity survey was successfully completed along the designated profiles. The gravity data acquired was considered to be generally of good quality.

The gravity testing has allowed modelling of an interpreted rock profile along each of the surveyed lines based on a relatively simplistic subsurface model of uniform sediment density overlying a uniform rock mass.

This interpreted rock profile is observed to vary from approximately RL 0m to RL-22m depth over the regions tested.

Whilst the actual rock level may vary from the interpreted rock level for a number of reasons as detailed in this report it is considered that the interpretation included is a good approximation of the overall bedrock topography and trends given the scope and objectives of the survey.

Appendix A – Gravity Method, Instrumentation & General Assumptions of Interpretation, is provided to offer some general information on the gravity method including the precision and accuracy of results and the possible effect of variations to the assumptions on which the method and interpretation procedure is based.













## APPENDIX A

## GRAVITY METHOD, INSTRUMENTATION & GENERAL ASSUMPTIONS OF INTERPRETATION

The results of gravity surveys are presented as interpreted rock profiles beneath the line of traverse. These outputs are a two-dimensional model, which have been interpreted from corrected gravity data obtained in the field.

The following background information is intended to assist in the understanding of the gravity instrumentation and method, and the interpreted gravity sections provided.

#### A1 <u>The Earth's Gravitational Field and its Variations</u>

The Earth is essentially a spheroid, with slight flattening at the poles. The mean value of gravity reduces at the equator and increases at the poles. Due to lateral variation in density the Earths gravitational field (g) is not a simple spheroid.

A **Latitude Correction** is applied using an equation, which approximates the Earth spheroid and includes the Newtonian attraction of the Earth as a spheroid and the centrifugal force caused by rotation about its axis.

The Free-Air Effect is the mean vertical gradient of **g** above the surface of the Earth. As one increases in elevation above sea level, the gravitational attraction will decrease as the inverse square of the distance to the centre of the Earth. A **Free-Air Correction** is applied using the measured elevation for each gravity station.

When one increases elevation on the Earth, it usually implies that there is an additional mass, which will exert a positive gravitational attraction, which acts to reduce the Free-Air gravity change. The **Bouguer** gravity effect is calculated on the basis of the gravitational attraction of a horizontal slab, of infinite extent and of thickness equal to the elevation difference assuming a mean density of the slab. Nettleton's Method for determining the density of near-surface rocks is based on applying the Bouguer correction to the Free-Air gravity data over a broad topographic feature using a range of assumed densities. The correct density is indicated by the profile which least correlates with the topography.



Local irregularities in the topography around a gravity station may give rise to significant **Terrain Effects**. Embankments or dense structures rising above a station will cause a reduction in gravity, due to upward pull. Road cuttings or embankments falling below the station will also cause a reduction in gravity due to the deficit of mass that would be included in the Bouguer assumption of an infinite slab. As the ground surface surrounding the areas tested was relatively flat and the distance to the river was approximately constant, no terrain corrections were attempted for this data.

The final correction to the gravity data is the removal of the **Regional Gradient**, which are longer wavelength anomalies due to large and deeper structures such as the sedimentary basin structure. These are typically observed as sub-planar gradients over a relatively short profile, and are defined by comparing the corrected gravity values at a number of regions around the site of constant depth to rock. Ideally we would take gravity readings at a number of points around the site where rock outcropped (ie the contribution of sediments/alluvium nil) to determine the regional gradient. However as rock was not outcropping at this site a number of locations of relatively shallow rock were used to attempt to best define this gradient.

#### A2 Gravity Instrumentation – Lacoste & Romberg G Meter

The Lacoste & Romberg is a gravimeter which measures the Earth's gravitational field very accurately by measuring the gravitational force on a proof mass. The beam is supported from a point just behind the mass by a " zero length" spring. The spring is at an angle of approximately 45 degrees from horizontal.



The meter is read by nulling the mass position, that is, adding or subtracting a small amount of force to the mass to restore it to the same " reading" position. This is accomplished by lifting up on the top end of the zero length spring. This must be done with great accuracy and is accomplished with a series of levers. In turn, the levers are moved by a high-precision screw which in turn is rotated by a gear box with considerable reduction.





The instrument is placed on a tripod base plate, which contains levelling screws and tilt meters to allow very accurate levelling of the meter in the vertical plane.

#### A3 Assumptions Of Interpretation

Two-dimensional modelling of the corrected gravity profile data (Bouguer Profile) enables an interpretation of the rock profile assuming a density distribution of the shallow subsurface.

The gravity interpretation provides a simplified model of the subsurface densities and is based on a number of assumptions about its nature. The major assumptions are:

i) the subsurface essentially consists of two layers of uniform density ie alluvium overlying rock,

ii) the cross section of the density model is assumed to be constant in the direction orthogonal to the direction of the gravity profile.

There is no unique interpretation to any observed gravity data as the densities or density contrasts of the subsurface materials must be assumed. Thus the depth to the source of a specific gravity anomaly cannot be precisely determined.

The interpreted rock levels provided in this report are based on 2dimensional modelling of the gravity data assuming a uniform density contrast of -0.55t/cu.m between the sediments and underlying bedrock.

If the assumed density contrast varies along the gravity lines the interpreted depth to rock will be in error. If the actual density of the shallow subsurface is 10% higher than the assumed density, this will result in an interpreted bedrock model which is approximately 10% shallower than the actual depth to rock.