University of Southern Queensland
Faculty of Engineering and Surveying

Estimating rippability of Brisbane Tuff using quantitative and qualitative characteristics and a modified approach to an existing rippability rating method

A dissertation submitted by
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CERTIFICATION

I certify that the ideas, designs and experimental work, results, analysis and conclusions set out in the dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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ABSTRACT

The aim of this research paper is to assess the rippability of Brisbane Tuff (welded ignimbrite) using both quantitative and qualitative information collected from geotechnical borelogs and rock strength testing for the North – South Bypass Tunnel (NSBT) project in Brisbane. Rock properties were quantified into specific ratings and used in an existing rating method ("The Estimation of Rock Rippability" F. MacGregor et al. 1994) to estimate productivity of rippability for general bulldozer types, using regression equations. Some qualitative classifications such as 'weathering / staining', were modified for the Brisbane Tuff based on interactions between weathering characteristics and strength for this rock type. These modified ratings were then re-entered into F. MacGregor et al. 1994 equations, to give an alternative estimation of rippability based on these proposed variable dependencies.

Correlations between point load index (PLI or Is 50) and unconfined compressive strength (UCS) were also determined specific to the data set used for this research, and compared to findings with existing literature on Brisbane Tuff. This UCS / PLI correlation enables use of the much faster, cheaper point load index test Is (50) to correlate a UCS (MPa) value, which forms the backbone in several F. MacGregor et al. 1994 regression equations used in estimating rippability of rock.

Results and information collected were part of a data set collected by the author whilst working for Golder Associates, and is a stand alone assessment of rippability unique to the limited data set used, and not necessarily relevant to any advice given to the client for the North-South Bypass Tunnel (NSBT).

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CHAPTER 1 INTRODUCTION

1.1 Outline of Study

This research presents the analysis of rippability for Brisbane Tuff, or welded ignimbrite, by standard bulldozers. A number of boreholes were used for the analysis, which were drilled for the NSBT (North South Bypass Tunnel) project in Brisbane Australia. The boreholes used in analysis were chosen out of a larger sample of boreholes drilled in various geologies. The holes specifically targeted were drilled in several locations which possessed deep fresh to highly welded ignimbrite deposits (0-50m) with no 'major' faulting and similar weathering profiles. This was done to keep the data comparable between sites, which were spread over the alignment of the proposed tunnel.

On a project such as NSBT, where huge quantities of rock are to be excavated, it is crucial to investigate the economics of rippability in regards to using bulldozers opposed to drilling and blasting. Guides are available from both manufacturers of earth moving equipment (e.g. Caterpillar), or using methods such as those proposed by authors such as Franklin, Broch & Walton (1971), Weaver (1975), Kirsten (1982) and Minty and Kearns (1983). (F. Macgregor et el. 1994). Macgregor et al. also states these methods and others summarized by Braybrook (1988), have proved to be inaccurate and subsequent contractual disputes are common, arising from a contractors inability to rip rock assessed to be rippable, or from unexpected low rippability.

This research project evolved from the concept of incorporating a bulk of field logs (logged by the author) and testing conducted by Golder Associates for the NSBT project, and attempting to assess an approximate rippability / or productivity of ripping, for different machines based on information obtained from the geotechnical borelogs and test results. Information obtained from logs and testing included material classification (e.g. rock type and grain size), strength classification (either based on qualitative assessment using Australian Standard guidelines, weathering, or quantitative measurements such as Point load index [Is 50], UCS : Unconfined Compressive Strength, rock defect type, defect planar properties (e.g. roughness), joint spacing and geophysical properties. The broad aim of this research is to utilize both the maximum and cheapest information available which can be recovered from a 'limited' geotechnical borehole survey, and applying the obtained data to regression equations to formulate a rating system specific for Brisbane Tuff and other rock types. It is also proposed that the methodologies adopted can be used to formulate rating systems for other rock types.

Brisbane Tuff was chosen for several reasons as it is a massive rock type with no bedding (being an ash deposit), and is easier to handle and prepare for testing which would minimize time constraints for this research project. Other rocks in the Brisbane area such as the Neranleigh – Fernvale Metamorphics or Aspley Conglomerates can give more variable test results due to bedding and weathering characteristics and take more time to log and interpret results.

Also investigated are some weathering properties observed in the material such as limonite staining adjacent joints, colouring, and also the strength and welding / alteration properties of the Brisbane Tuff in proximity to contact zones with the underlying 'permeable' conglomerates. This effect on the rock strength and properties will be touched on, as it gives an idea of the variability of the rock mass properties and may be worth considering when developing a broad cross section of a Tuff formation.

In summary, Brisbane Tuff is a homogeneous rock to not only work with, but also ideal for testing preparation (i.e. gives less test result variability), and is a targeted rock type in Brisbane in regard to tunneling and excavation due to its strength and stability properties. A clearer summary of rationale and objectives which were attempted to be met are listed below.

1.2 Project Rationale and Objectives

To successfully maintain direction for this project, both semi-flexible **broad outcomes** and **specific objectives** were devised which defined the original project specification. The broad outcome was semi - flexible as specific tasks or outcomes were either satisfied, inconclusive or gave an unexpected outcome. An attempt was made to also identify limitations of results or methodologies, based on the amount of data available and the way it was tested or collected. At all times during this research there was an obligation to adhere to Golder Associates confidentiality and intellectual property clause, as the data used in this research was originally collected for Golder's client LBBJV. (Note: Golder Associates was engaged to carry out the geotechnical investigation and design for the NSBT project).

Therefore, it must be understood that the analysis in this paper does not pertain to or represent findings by Golder Associates for the NSBT project, and is a stand alone analysis for the purpose of this paper based on a limited sample of the data. Summarized below are the research project's broad aims and specific objectives.

i) **Broad Aims**: To assess a rippability or productivity rating using a modified approach to the regression equations developed by F. MacGregor et al. 1994.al 1994. Parameters used were qualitative and quantitative rock properties such as strength, weathering characteristics, rock defect type and joint spacing obtained from borehole logs and test results during the geotechnical investigation for the North-South Bypass (NSBT) tunnel project in Brisbane. Australian Standards list general weathering descriptions of rock such as XW – extremely weathered / DW distinctly weathered / SW – slightly weathered & FR – fresh rock. These weathering descriptions are based on staining, decomposition and strength properties, and often the classification given to the rock is inconsistent between field geologists. From logging experience in Brisbane Tuff it is observed that the relationship between an AS weathering descriptions and rock strength do not necessarily follow the rule of thumb in that the degree of limonite staining or colour comparison to the parent rock greatly influences the rock strength as it does for other rock types in Brisbane. It was initially a broad aim to analyse rock property relationships discovered (listed in the specific research objectives below), and possibly formulate a more relevant 'weathering rating' for this rock type, rather than a general 'igneous' one. It was decided after initial research however, to simply numerically '**modify'** the upper and lower bounds of this semi-quantified variable as used in MacGregor's rippability rating system, and then compare the variation in rippability for different machines opposed to MacGregor's values. F. Macgregor et al. 1994 for example, semi-quantifies weathering descriptions from (1 – 10), (1) being the highest for Fresh Rock (FR), (4) being for slightly weathered rock (SW), and (10) being for extremely weathered rock (XW). A broad aim of this research was to show there is little evidence of significant numerical variation in Is (50) and UCS results from weathering grades (FR) to (SW-DW) alone, especially where a section of core will often be described by a field geologist as (SW) simply due to limonite staining adjacent joints. Staining, as seen from observing core photos, is an indicator of water ingress through fractures, and generally the amount of staining on the rock is dependant on fracture spacing (i.e. joints per metre). The MacGregor regression equations treat weathering / staining and defect spacing as independent variables within the regression equations, so a second broad aim was to not only converge the numerical values of the MacGregor weathering rating at the lower end of the weathering scale (where staining may have little influence over rippability), but also derive an interaction between the amount of staining on rock core and likely defect spacing. This aimed to change the shape of the productivity vs. mass of ripper polynomial curves. This modified approach may give a better representation of rippability, as the weathering and defect spacing parameters are weighted heavily (mathematically) in the MacGregor et al. 1994 equations. It was also a third broad aim to show that Rhyolitic Tuffs can have variable degrees of 'welding' and alteration which influence the overall strength. These variations in welding will be discussed when looking at Is (50) results and literature on cooling units within the deposition. Another factor also investigated was a loss of strength (at depth) due to proximity of contact zones with the underlying Brisbane conglomerates.

ii) **Specific Objectives**: To find correlations between specific quantitative and qualitative properties observed in Brisbane Tuff core sampled from specific sites. Quantitative properties include unconfined compressive strength [UCS] & Point Load Index [Is50] (and a correlation comparison literature to findings), rock density, grain size and depth. The first relationship between Point Load Index and Unconfined Compressive strength was seen to be the backbone of data validity, as the aim of this research was to use the simplistic test (Point Load Index – Is [50]), and correlate UCS from the Is (50) value to then apply in MacGregor's regression equations. Limitations of point load testing are thus discussed in later chapters as well as overall interpretive limitations due to data sample size and methodologies used. Other qualitative properties included a derived 'degree of staining' classification, colour, defect type, defect condition and defect spacing. Mineralogy and weathering interactions in Brisbane Tuff are also discussed briefly in this research. This interaction between mineralogy and weathering may need to be understood further as 'degree of staining' suggests some form of iron oxidation influencing strength due to leaching or localized water migration. It is noted that Tuff tends to exhibit various colouring from pinkish purple, grey, green, cream to an almost bleached white. Bleaching effects and other chemical alterations were initially mentioned in this research, as Guan et al. (2000) states that in respect to mineralogy, bleaching (due to oxidization of FeO) in rhyolitic Tuffs can be observed in the iron-bearing rich minerals such as biotite. Some sections of core tested for this research were observed to be 'bleached' to a pale grey or white. In the end, it was considered chemical alteration of rhyolitic Tuff was related to the rock geo-chemistry and beyond the scope of this research project. Alteration of the rock mass influences overall strength of the rock which is taken account anyway, so this specific objective was steered back towards a geotechnical problem.

CHAPTER 2 LITERATURE REVIEW

2.1 Background Information

2.1.1 Brisbane Tuff (welded Ignimbrite)

Brisbane Tuff is an ash-flow Tuff formed by a mud mixture of precipitated steam and volcanic ash, deposited during several short Triassic volcanic periods. After initial pyroclastic deposition, the ash-flow experienced deformation due to welding and compaction, and then cooled to form welded 'ignimbrite' Tuff. (Roach, 1996 – Sheridan & Wang 2005). The term 'ash-flow' is a lithologic term that refers to a rock consisting primarily of volcanic particles finer than 4mm diameter. (Sheridan & Wang 2005).

At deposition, the giant steam clouds were some distance away from the volcano giving a finer grained texture to the rock as the particles were sorted whilst falling through the air. This is in contrast to the igneous rocks and coarser volcanic agglomerates closer to the vent. (Scott, 1996)

On closer inspection of Brisbane Tuff, it is observed to contain fine glass particles and is thus classified as a 'rhyolitic' Tuff. Some Tuffs are observed to have large isolated crystals within the rock structure called phenocrysts, and therefore classified as having a porphyritic texture. (Scott, 1996). Brisbane Tuff can be of both rhyolitic and porphyritic texture. (Roach, 1996).

2.1.2 Welding Compaction and Degree of Welding

Welding compaction of rhyolitic Tuff begins as soon as the hot ash-fall comes to rest, and is the result of slow viscous deformation of glassy fragments at high temperature and pressures. The controlling factor for the welding process is the residence time at temperatures above the threshold for welding. Threshold temperature is dependant on composition of the material, and rhyolitic threshold temperatures for welding compaction have been estimated by Riehle (1973) & Sheridan & Ragan (1976) to be in the range of 550 – 625 ° C. (M.F Sheridan & Y. Wang 2005).

Rhyolitic Tuff such as Brisbane Tuff exhibits varying degrees or 'intensities' of welding in either single or compound cooling units which have been previously quantified and ranked by numerous schemes such as those developed by Smith 1960b, Smith and Baily 1966, Sheridan and Ragan 1976, Peterson 1979, Streck and Grunder 1995, Wilson and Hildreth 2003, as cited in Quane & Russell, 2004.

Cooling and welding of ash-flow Tuff occurs after sub-aerial eruption and emplacement of gravity-driven density currents of hot air and gas. The deposition and subsequent deformation of an ash-flow Tuff, as it cools, can be considered as a series of partially overlapping events. These events include: deflation of fluidized clouds, degassing of fluidized stationary beds, mechanical compaction (rotation and compression of particles), welding compaction of ash-flow, and equal volume deformation with or without shear. (Sheridan & Ragan 1976, as cited in Sheridan & Wang 2004).

Friedman et al. 1963, as cited in Sheridan & Wang 1976 states that the process of welding in Tuff is controlled by the viscous deformation of the glass fragments. This process is further dependant on the temperature and pressure distribution within the ash-fall 'sheet', and the maximum density or highest degree of welding in Tuff occurs in the lower central part of the sheet. These highly welded zones occur because the lower central zones retain heat for longer periods. J. R Riehle et al. 2005, states that rainfall can cause heat loss at the upper boundary of the cooling unit, which can subsequently effect the heat distribution at the upper boundary and upper central zone. J. R. Riehle et al. 2005 also states that compaction and welding can continue for weeks to several years, and near emplacement temperatures can persist for over 10 years in the interiors of thick deposits.

The Tuff sampled for this research likely falls into the 'highly welded' category, which is prominent in the Brisbane Tuff formation. Degree of welding, for the purpose of this research paper will be mentioned only in that it influences the strength of rhyolitic Tuff, and may explain strength variance at depth within the Tuff deposit itself, as data shows later with plots of UCS and Is (50) vs. depth.

Air-fall Tuff deposits at depth can often exhibit bedding, and underlay the main ignimbrite body. These air-fall Tuffs are usually crystal rich, and are commonly silicified or stratified. (Roach, 1996). This coarser, more stratified (unwelded) Tuff has been observed whilst drilling for this research, overlying the 'Aspley Formation' Conglomerates at several sites. This Tuff tends to possess less limonite staining and is a 'green to creamy' colour, founding near the contact zones with underlying older deposits. Core tends to possess stratified layering with some fine to coarse fragments at times grading into a relatively unwelded conglomerate groundmass. It is quite weak with a point load index mostly from 0.1 – 1.0

MPa as shown in Appendix A for borehole NST257. Borehole NST257 was drilled in a specific area at Kangaroo Point to target the Brisbane Tuff / Aspley conglomerate contact zone as this weaker, water bearing zone has implications when tunneling. This is of some interest as the ash-flow Tuff has undergone minimal welding as it settled on the underlying conglomerate due to possible water flow.

The core photo for NST257 is shown below;

Figure 1 : NST257 – Core Photo

Observing **Figure 1**: Brisbane Tuff is extremely to distinctly weathered and highly fractured to 6.64m. Limonite staining is evident adjacent fracturing to 12.5m depth giving an oxidized appearance. The Tuff is somewhat stratified below 6.64m depth ranging from very low to medium strength (Is [50] 0.06 – 0.9MPa), as shown in attached point load test results for NST257 in the Appendices. At about 23m depth the Tuff is grading to a conglomerate with coarse sub-angular and angular fragments cemented in a Tuffaceous claystone, before becoming high strength conglomerate at about 32m to 34m at the end of the borehole. In the research this was the only borehole which documented the stratification and grading between ash-fall Tuff and underlying conglomerate. Noted are the inconsistencies in strength shown in attached test results compared to other boreholes logged in the data set. Borehole NST257 shows the unique Brisbane Tuff contact zone geology and may explain a trend showing loss of rock strength at depth when in close proximity to a contact zone (as shown later in the Is(50) and UCS vs. Depth plots). These contact zones will produce the lower end UCS values when estimating rippability, as the Tuff is unwelded and more readily ripped. Some knowledge of the Brisbane geology would be beneficial to identify Tuff deposits with shallow contact zones, as other geotechnical issues such as water ingress while excavating or instability may cause problems during excavation.

2.2 Specific Literature

Dearman et al; Lee and De Freitas; anonymous (cited in Guan et al. 2000) state that the process of weathering modifies the chemistry, texture and strength of rocks within the shallow domain where engineering projects are founded. Various grading systems for the classification of weathered material have been proposed.

In this research an attempt will be made to quantify rock mass properties, including a ‘degree of staining / defect spacing’ specific to this rock type. Guan et al. (2000) theorizes that it may be useful to quantify weathering effects as index values which will lead to consistent and objective material descriptions, particularly for the non-specialist users. Guan et al. devised ‘decomposition indices’ as opposed to ‘weathering indices’ for various rock types in Hong Kong, including rhyolitic Tuff. Guan’s indices categorize rock into decomposition grades I, II, III, IV, V and VI, where grades I – III relate to Rock and IV – VI relating to soil. The idea behind developing decomposition indices was that ‘weathering’ was seen to be too general a term to quantify an index value. Vaughan, 1988; Anonymous 1990, cited in Guan et al. 2000 states that;

“Engineering characteristics of rock are governed by a number of factors such as physical properties of the material and discontinuities within the rock mass. For an intensely weathered rock, the influences of discontinuities are greatly reduced and it is the mineralogy, grain size, micro-fabric, and secondary bonding characteristics which control its physical properties and in turn its engineering characteristics”.

The decomposition grades developed by Guan were devised and quantified primarily on chemical and mineralogy characteristics of rocks which is beyond the scope of this research project. The research however, identifies that study has been done to quantify weathering or decomposition grades specifically for rock mass rating systems based on unique characteristics of specific rock types due to location, mineralogy, chemistry, porosity, grain size, oxidization and more general weathering characteristics.

As was mentioned under the specific objectives, mineralogy and colour of rhyolitic Tuff may or may not play a role in influencing weathering and strength characteristics. Research by Topal & Sozmen (2001) was done to assess weathering characteristics of Tuff in the Midas Monument, where mineralogy and strength tests on “white” and “pink” ignimbrites found differences in the relative strengths of the (2) colour categories. Amongst the indications from the study were that the pink Tuffs tested were stronger than white Tuffs, less susceptible to weathering and alteration, and slightly denser and less porous due to mineralogy. Topal & Sozman (2001) also interestingly found there was no decrease in rock density across weathering zones of the Tuff they sampled, however there was a degree of fracturing or breakdown of the feldspar minerals across weathering zones which potentially weakens the rock.

For the purpose of this paper, the colour will only be mentioned as a function of its mineralogy where the red , pink and purple Tuffs tend to be more oxidized than the other lighter colours where little oxidzation probably occurs. As is seen in the laboratory results for Is (50) tests, all colours tended to possess high strength values well in the upper and lower bounds of each strength description, except the green and pale green / grey samples which were unwelded and gave the lower strength values. The pink Tuff, as Topal & Sozmen suggest may be stronger than the other coloured Tuff, but insignificantly for the purpose of this research paper. Guan et al. 2000, as mentioned earlier, investigated in greater detail the mineralogy of rhyolitic Tuff and the influence of mineralogy vs. weathering and decomposition of this rock type. Guan refers to the geo-chemical process of mineralogy vs. weathering in detail with reference to leaching over time of elements contained within the groundmass of the Tuff, and the role such elements potassium, calcium, magnesium, iron, oxygen, sodium, manganese as well as compounds found in rock. It is discovered through their work that each element behaves in its own ‘complex’ way during the weathering process and influences the engineering properties of the altered rock in different ways.

Mineralogy of Brisbane Tuff was not investigated any further, and the quantitative Is (50) and UCS test results show that the amount of strength variation between the different coloured Tuffs is not significant enough to be considered a major influence in quantifying a weathering rating with colour as a variable.

2.2.1 Rippability

As mentioned in the introduction, many methods are available to estimate rippability based on geotechnical and geological mass rock rating systems. It is imperative that the rate in which a site can be excavated is assessed so that civil works can be priced and planned accordingly. Rock excavation, ripping, blasting can be seen as the first part of a major planning process incorporating loading and haulage / transportation.

G.S Pettifer & P.G Fookes, 1994 state that the excavatability of rock depends on the geotechnical properties of the material, on the method of working, and on the type and size of the excavation equipment used. As cutting parts of the equipment must be forced into discontinuities in the rock mass it is generally accepted that discontinuity spacing (or fracture spacing), effective planes of separation (defect properties) and the strength of the intact rock are particularly important factors. They also state that the joint characteristics define the individual rock ***‘block size’*** characteristics which need to be considered as a parameter when estimating rippability. This block size, they state, can be determined simply from the fracture spacing index along a section of drill core. The index can be expressed either as a frequency (i.e. fractures per metre), or the mean spacing of fractures per metre.

This research project will therefore weigh heavily on those factors (among a few others) in applying an estimation of rippability method specifically to Brisbane Tuff samples taken during the NSBT project. These are also specific parameters which are logged whilst on site by a geologist or engineer and the information normally noted on borehole logs. Some examples of borelogs used for this research can be seen in Appendix A.

F. MacGregor et al. 1994 developed multi-variable regression equations which predict rippability using individual factors such as those listed above, using a large database of detailed ripping and geological data gathered from highway and mine sites in new South Wales, Australia. The data collected by Macgregor et al. was obtained from areas where ripping had been observed (using standard machines) and its operations recorded. Representative samples were taken from sites and exposed surfaces or outcrops were geologically mapped. Nineteen different rocks were observed in their research including **'porphyry', as is Brisbane Tuff.**

F. MacGregor et al. 1994 also collected other geological data such as rock type, colour, grain size, weathering, ***'estimated unconfined compressive strength (UCS)'***, defect spacing/ waviness/ roughness/ defect weathering/ defect description/ defect wall strength and type of defect infilling. This is information readily available once again on borehole logs, and further explained later in this research under individual headings. Macgregor et al. 1994, assessed available methods of estimating rippability including those proposed by Caterpillar, Komatsu, Fiat Allis, Franklin (1970), Franklin et al (1971), Weaver (1975), Chevassu (1978), Kirsten (1982), Minty & kearns (1983), Scoble & Muftuoglu (1984), Pells (1985), Smith (1986), Singh, Denby & Egretli (1987) and Hadji-georgiou & Scoble (1990), in relation to their observed ripping database. MacGregor et al., after correlating observed rippability data from their database with all of the above rating systems concluded that;

'the analysis indicates that none of the rating methods is a useful predictor of productivity, all have very poor correlation coefficients, and the correlation coefficients are not greatly influenced by considering bulldozer model, i.e. D10'.
(F. MacGregor et al. 1994).

G.S Pettifer & P.G. Fookes also assessed each rating method shown above and point out some individual deficiencies in the available methods such as lack of parameters (Franklin et al. 1971 : 2 parameters), incorrect correlations of strength parameters and incorrect development of weathering parameters, and the dissolving of discontinuity spacing in a broad weathering parameter (i.e. Singh, Denby & Egretli 1987).

Both F. Macgregor et al. 1994 and Pettifer & Fookes 1994 determined the strength of intact rock using the point load test or irregular lump test to give an Is (50) value for different

sample sizes and shapes. Both authors then correlated linearly a UCS value from the Is (50) values and determined a correlation of (**24)** (Pettifer), and (**20.6)** (MacGregor). These were broad correlations incorporating all rock types for Pettifer, and all igneous rocks for

MacGregor. As is shown below for this research project, a correlation of **(17.6)** between UCS and Is (50) was determined from the data sample used for this analysis, which was specific for Brisbane Tuff. This agrees with Look & Griffiths (2001), who assessed the correlation specifically for Brisbane Tuff and determined it to be **(18)** using a large sample of data, testing both axially and diametrally.

F. MacGregor et al. 1994 developed (11) multi variable regression equations based on combinations of parameters obtainable in geotechnical and geophysical investigations, each with their own (R^2) correlation coefficient of regression between 0.4 and 0.85. These equations generally calculated either *'Productivity (m^3 / hr)', 'Productivity (m^3 / hr) / MASS of bulldozer machine including ripper', 'square root of Productivity (m^3 / hr)' or the 'square root of Productivity (m^3 / hr)/ MASS of bulldozer including ripper.'*

In each unique equation, (1) or more parameters are either included or omitted, giving a closer estimate of productivity comparable to the database made from records of observed rippability data. For this research, (2) regression equations from MacGregor et al. 1994 were initially considered, one weighting heavily on using seismic velocity data and the other weighted heavily on UCS (Unconfined Compressive Strength) values. The equation using seismic velocity (Equation 10) data gives the best correlation coefficient of regression of (0.85), specific to igneous rocks and the other equation weighting on UCS gives a correlation coefficient of regression of (0.53) based on all rock types. The latter equation with the lowest of the two coefficient of regressions, however, was used in this research as it incorporates the UCS value, which can easily be correlated from the Is (50) test as stated earlier.

Considering the difference in the coefficient of regressions between the two equations, and the ease and speed in which an Is (50) value can be obtained (sometimes on site whilst logging), equation (6) it is considered favourable when estimating rippability. This is because seismic velocity data is not only expensive and tedious to obtain (maybe AUD$3000- $10000+), but also takes time in interpretation of results.

MacGregor et al. 1994 Equation (6) is as follows;

Table 1 : MacGregor et al. 1994 Eq (6) – Rippability Productivity all Rock Types

Equation No. (6) Factor omitted : Seismic velocity	
√PRODUCTIVITY / MASS Note Mass = mass of Bulldozer inc. Ripper)	
Constant	+0.481
UCS (MPa)	-0.00376
Weathering Rating	+0.0231

Grain Size Rating	-0.211
Roughness Rating	+0.0623
Defect Spacing (mm)	-0.000065
Structure Rating	+0.00892
R^2	*0.53*
S (standard error of estimate)	*0.19*

F. MacGregor et al. 1994

As can be seen above, MacGregor et al. uses quantitative parameters (i.e. UCS / Joint Spacing) and semi- qualitative parameters derived from qualitative judgements made by classification of rock characteristics. (I.e. Structure Rating / Weathering Rating etc) Rating of these parameters, as well as the modification and interaction of parameters such as 'weathering rating' and defect spacing will be discussed later.

This research paper aims to produce general productivity curves, as well as curves more specific to this research by 'tweaking' parameters and interactions between parameters.

CHAPTER 3 PROJECT METHODOLOGY

Research project methodology at this present time can be subdivided into several categories. These will be listed down the page under the relevant subheadings. Methodologies range from being 'collective', 'collative tasks', 'data analysis' and 'conclusions'.

3.1 Data Collection

Several sites were chosen specifically for the bulk of this research, as the risk analysis for the sampling, drilling supervision, core and defect logging as well as rock property testing had been conducted recently as 2006 – 2007.

Criteria for suitable rock core depended on the location of specific sites which ideally was to be limited, and secondly dependent on whether the rock was of similar geology and weathering profiles. In adhering to this criteria, several sites were chosen at Bowen Hills

(Sneyd & Campbell street), Shaftston Avenue (East Brisbane) and Kangaroo Point, where the Brisbane Tuff is quite shallow and subsequently without much overburden or folding. These sites also have a deep Brisbane Tuff profile which was useful in observing a full weathering profile. The site at Kangaroo Point differed slightly from the other two in that it had a shallower contact with the underlying conglomerates (i.e. NST257).

Information collected both in the field, laboratory or existing reports was categorized as either **quantitative** or **qualitative** in stature. How these interacted will be understood later in this research paper when formulating quantitative or semi - quantitative ratings to be applied in an existing rippability rating method.

Examples of **quantitative** data collected include depth, Unconfined Compressive Strength - USC, Point Load Index – Is(50), grain size and defect spacing.

Examples of **qualitative** data collected included joint and defect type, joint surface properties and a proposed 'degree of staining' description on the area of core tested, which is used to derive part of a semi-quantitative 'degree of staining and fracturing' weathering index. The justification for this 'degree of staining' was explained in the broad objectives, however, the symbols and parameters are listed below and sections of core were classified by viewing either from core boxes or core photos where available. It is proposed the 'degree of staining' will be judged by the percentage (%) of iron staining on the "whole" core surface that was point load tested, and not the amount of staining at localized defects where testing cannot be done. Defects were treated separately.

Table 2: Symbols Legend and (%) staining for classification of ***'degree of staining'***

Degree of staining on TOTAL core surface not relating to local defect: **XS (70 -100%)**
DS (40-70%), SS (5-40%), TS (0-5%)
Where XS (Extreme Staining) / DS (Distinct Staining)
SS (Slight Staining) / TS (Trace to NO Staining)

Collection of data and laboratory testing was done strictly to Australian Standards except for the 'degree of staining classification'. This degree of staining will replace to more standard subjective descriptions for weathering, and also be assigned minimum values of associated likely defect spacing. This will form an interaction between defect spacing and 'degree of staining', and the two parameters will become semi-dependant variables opposed to independent variables, as they are in the regression equations derived by F. MacGregor et al. 1994.

3.2 Rock Core Recovery

Recovery of Rock Core on site was achieved using a 50mm diamond NMLC core bit and 3m length core barrel. The core barrel is inside a HW casing sealed in the Tuff at the top of the rock profile using a second diamond bit. The fluid used to lubricate the drilling process is circulated in a closed system and recycled, except where water losses due to fracturing occur. Packer Testing (Luzon Testing), is normally conducted at specified intervals while drilling to ascertain loss / or discharge of water through fractures, however, these results are not included in this project, but only mentioned as part of the drilling procedure.

Rock is extracted from the core barrel, and placed in PVC splits to limit movement and damage of rock core, then stored in tin core boxes designed to hold 6m sections. Rock is normally logged on site to Australian Standards, including all defects. The onsite logging minimizes double handling of core boxes back in the laboratory (i.e. from storage to logging bench). Core boxes are photographed on site before some sections of core are wrapped to maintain field moisture content for specific rock property testing. Point load testing (Is 50) is conducted at a specified frequency of about (1) test every (2 or 3) metres, or where a change in either weathering, strength or rock classification occurs.

Appendix A shows core photographs of Brisbane Tuff, which is a typical of the way core is presented in the core boxes after drilling. As the core may be checked by senior geologists many times against the defect logs done onsite, the depths at the beginning of each line in the tray start at ‘whole’ metre intervals. This is so a defect can be easily related quickly to a depth by eye when viewing the photo.

Note also when observing the photo of NST207 the distinct changes in (%) of staining on the rock core, and associated degree of fracturing for each distinct weathering region. This is merely pointed out to show to that limonite staining is due to water ingress through fractures, and the top region with joint spacing up to 200mm shows the higher bounds of ‘degree of staining categories’ (i.e. XS – DS). It is proposed that it would be less likely to

have a fracture spacing of say 2.5m, and 70% to 100% of the core stained, simply due to the proximity of the nearest defect.

3.3 Rock Property Testing

All rock property testing is done to Australian standard and listed below.
AS4133 4.1 - Determination of point load strength index
AS4133 4.2 - Determination of uni-axial compressive strength
AS4133.2.1.2 - Determination of rock density

3.3.1 Is (50) MPa – Point Load Index (AS4133 4.2)

Point Load Index (Is 50) is a common test used to assess strength of rock core, where a piece of core, usually of length twice its diameter, is tested. Is (50) data used in this research was the result of both axial and diametral tests performed on the rock core. Testing was conducted on specimens at regular intervals where there were no discernable defects, or where there was a noticeable change in strength or weathering. The idea behind the point load test is to back up the AS log description for strength, which may have been assessed simply from drill rates, a geological pick, by hand or finger nail as per Australian Standards. Usually rock strength is usually logged by means of a qualitative approach in the field, then confirmed by Is (50) results or UCS results. It is not unusual to reassess strength designation on logs after doing Is (50) tests and quite often the Is (50) result may not be representative of the strength of a profile of core in hindsight, but of a localized section. Care must be taken, and experience used to assess rock strength using a combination of both qualitative and Is (50) results, therefore a feel for how the samples represent the total rock profile is imperative.

A major limitation of the Point Load Index, as stated above, is that the strength of the rock mass as a whole may be weaker due to rock defects such as bedding and localized defects within the specimen, which may not be totally representative of the rock mass. This problem is amplified somewhat more when testing the bedded phyllites in Brisbane for example, where failure may occur along a bedding plane rather than in the rock mass itself. In this case a rock core should be tested in both its weakest and strongest direction, and mode of failure noted or sketched to determine if the failure plane intersected a bedding plane. Usually if failure along a bedding plane is observed the test result would be rejected.

It is noted that tests conducted by the author, the failure plane was noted or the result completely rejected if failure or crushing occurred due to a localized defect. It is unclear if the other results from point load tests conducted by James Cook University and Brisbane City Council mirrored the testing methodology used for Golder Associates internal testing and vice versa. From experience results can vary significantly between technicians and laboratories.

A second limitation of the point load test is that it is ideal that the two surfaces should be parallel and flat to obtain an accurate result. This is not always possible in Tuff unless cutting machinery is available. Some of the accuracy may at times have slightly suffered due to inadequate preparation of rock core samples, especially in the higher strength Tuff.

At times, due to the amount of testing which is required on this type of project (NSBT), and the lack of laboratory resources or personnel, samples may have been prepared more crudely by way of breaking length of core with a geological pick on site to obtain the sample. This is sometimes deemed to be acceptable in a massive rock such as Tuff if the resulting surface is near perpendicular to the core axis, as the Is (50) result is used as a secondary rock strength description to the qualitative rock strength description based on more ‘observed’ properties. The same limitation applies to the UCS test where the mode of failure is not always noted, possibly giving rise to varying results. However, USC samples are more likely to be cut and prepared more thoroughly, as the test is more likely to be conducted in a geotechnical laboratory.

3.3.2 Diametral Is (50) vs. Axial Variation in Brisbane Tuff

B.G Look & S. G Griffiths 2001, studied the possible variations in results for Brisbane Tuff (as well as for Argillite / Greywacke/ Arenite / Phyllite) when tested in both axial and diametral directions. Results were tabulated that were within 100mm of each other, before a statistical analysis was done to assess variations. As shown below, it was found that Brisbane Tuff had an axial / diametral ratio of about (2) or greater in the ‘low - medium strength’ range. Brisbane Tuff exhibited the least statistical variation in axial / diametral ratio than the other Brisbane rocks tested, and the bedded phyllite exhibited the greatest ratio of 4.4. Look & Griffiths then went on to conclude that for Brisbane Tuff, results for axial and diametral tests are approximately equal after the low to medium strength range. It is noted on point load test sheets used for this research whether a particular test is performed axially or diametrally.

Table 3 : Axial / Diametral Test *Is (50)* Variation for Brisbane Tuff Samples

Rock	**Axial / Diametral Relationship for Point Load Tests (Look & Griffiths 2001)**	
	Extremely low to medium strength	*High to extremely high strength*
Brisbane Tuff	**2**	**~ equal value whether done diametral or axially**

Shown below is a diametral point load index test being conducted on a piece of Brisbane Tuff core.

Figure 2: Pointload Testing on Brisbane Tuff

Figure 3: Point Load Tester

3.4 Data Collation (Quantitative and Qualitative)

Data is described as either quantitative or qualitative, as mentioned previously. Test result data is collated individually and referenced to the depth tested / borehole number. An example of the simplicity of collating such data is NST207 1.85m Is (50) = 2.31MPa. Qualitative data was described subjectively based on experience. For example, referring to the core photo of NST207 in Appendix A again, it can be seen when looking at the photograph there are (2) or (3) distinct degrees of staining which were categorized. This project initially strayed somewhat from the log descriptions which strictly follow Australian Standards for descriptions of weathering (XW – extremely weathered / DW distinctly weathered / SW – slightly weathered / FR – fresh rock). The idea came about to make this parameter flexible in the regression equations derived by F. MacGregor et al. 1994, to reflect observed weathering characteristics of Brisbane Tuff. Also an idea was in place to simply not 'reinvent the wheel', but manipulate an existing rating method specifically for this rock type, not just in the broad 'igneous' category where other igneous rocks stain and weather differently to Tuff .

So in summary this research will define a new element as the degree of iron / limonite staining, which may be useful in estimating correlations between strength, degree of fracturing and "degree of staining". Degree of staining will be looked at as a modified weathering rating having upper and lower bounds (as a modification to MacGregor's weathering rating) and subsequent input into the regression equations, as the strength variations due to 'weathering alone' can be seen to be less variable for this rock type.

An example of this may be that F. MacGregor et al. 1994 uses a rating from (1) to (10) based on different weathering properties, which show variability in strength between Fresh Rock (FR) and Moderately to / Slightly Weathered (MW-SW) by a numerical factor of (5) between these weathering grades. From observation of drilling and point load results, there are only minor strength variations between these weathering grades, particularly from Fresh Rock (FR) to Slightly Weathered (SW) grades, to justify such numerical variance between the weathering grades.

It is therefore proposed to adjust the weathering ratings or converge the semi-quantitative values numerically, to mirror the observed lesser degree of variation across weathering / strength in the samples. The method proposed is a weathering description based on the percentage (%) of the 'overall' core stained from its original colour, for a particular Tuff 'colour' (i.e. grey, pink, purple, white). Staining and defect interactions will be discussed later and proposed to become dependant upon each other, but for the sake of staining vs. strength within the groundmass, the core will be looked at globally rather than adjacent defects, where the defect will likely influence the strength locally.

Table 4 below is a collated data table showing borehole number, point load test results and proposed 'degree of weathering' description and legend. Core Photographs, Logs and Point Load Test results are shown in **Appendix A.**

Table 4 : Typical Data Collation Showing Point Load Test Results and Proposed '*Degree of Staining and Parameters'*.

NST207			
Depth (m)	**Test Type**	**Is (50) MPa**	***Degree of Staining***
1.85	A	2.31	**XS**
2.76	A	3.49	**SS**
3.07	D	2.03	**TS**
4.00	A	4.69	**XS**
6.92	A	5.09	**TS**
8.72	A	4.99	**SS**
11.75	D	4.35	**SS**
15.00	A	4.69	**TS**
18.00	A	3.48	**TS**
20.93	A	2.54	**TS**
21.40	A	4.64	**TS**
24.94	A	3.49	**TS**
A = Axial Test			

D = Diametral Test
Degree of staining on TOTAL core surface not relating to local defect: **XS (70 -100%)** , **DS DS (40-70%), SS (5-40%), TS (0-5%)**
Where XS (Extreme Staining) / DS (Distinct Staining)
SS (Slight Staining) / TS (Trace to NO Staining)

CHAPTER 4 DATA ANALYSIS

4.1 UCS / Is (50) Correlation Data Analysis

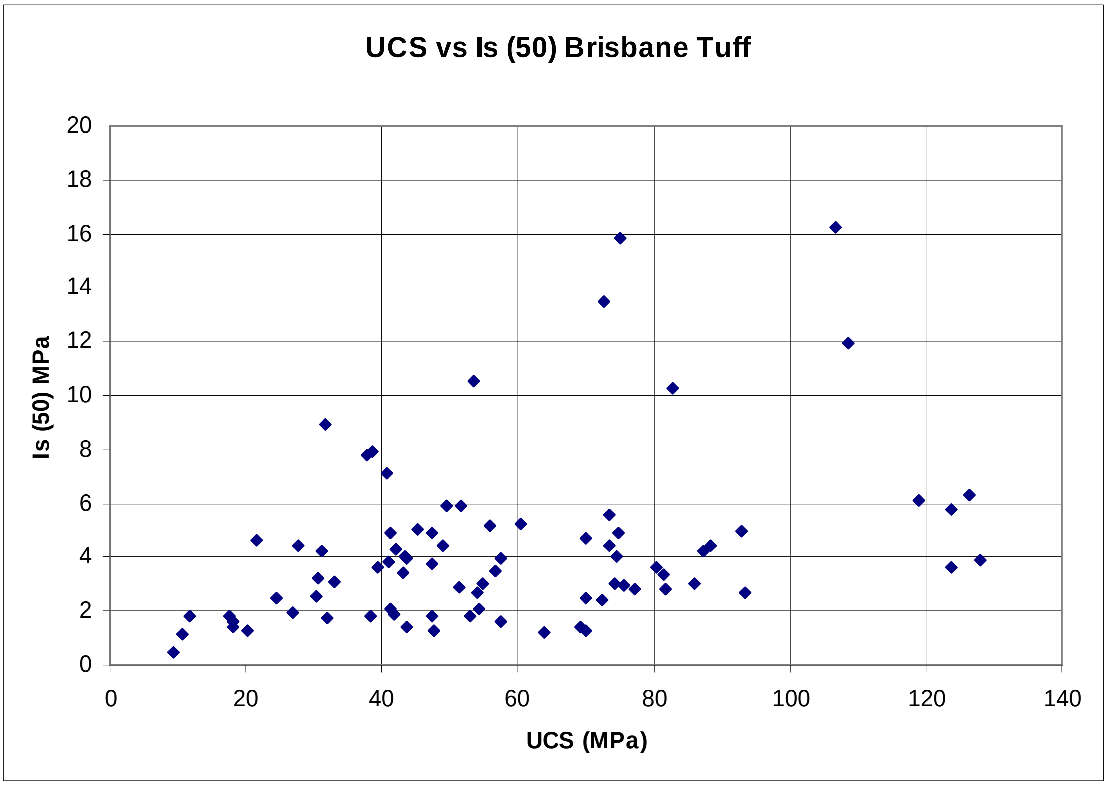
Table 5 : UCS and Is (50) test Results for Tuff core in various Boreholes

Borehole No	Depth	UCS (Failure ok)	Point Load (MPa)
NST1	21-26	123.7	5.75
NST8	23.5	20.3	1.3
NST8	26.8	54.7	3
NST8	35.2	54	2.7
NST8	39.8	70.1	1.3
NST9	23-25	88.24	4.42
NST9	35.3	72.5	2.4
NST13	22.1	69.1	1.4
NST13	30	86.1	3
NST13	31-33	93.5	2.68
NST24	16.1	126.5	6.3
NST24	20.8	31.2	4.2
NST24	21.83	27.7	4.4
NST25	17.1	18.1	1.4
NST26	11.78	57.6	1.6
NST26	16.1-19	77.25	2.85
NST26	17.39	53	1.8
NST26	21	47.7	1.3
NST26	24.37	17.5	1.8
NST28	8.76	38.2	1.8
NST28	17.09	39.3	3.6
NST28	20.27	42	4.3
NST29	24.67	43.7	1.4
NST29	28.17	70	2.5
NST32	41.54	63.9	1.2
NST32	45.07-46.95	10.54	1.15
NST32	47.98	11.8	1.8
NST32	50.53	24.6	2.5
NST34	34.37	73.4	5.6
NST34	37.31	31.7	8.9
NST34	41.6	49.4	5.9
NST34	45.24	38.7	7.9
NST35	13.05	74.2	3

NST35	14.1	41	3.8
NST35	18-20	45.16	5.05
NST35	21.1-21.65	108.54	11.92
NST35	22.69	80.5	3.6
NST35	27	74.4	4
NST35	27.3-27.9	82.76	10.26
NST36	7.55	41.2	4.9
NST36	10.1	37.8	7.8
NST36	13.2	40.8	7.1
NST41	16-18	75.68	2.94
NST41	20.43	47.5	3.77
NST41	24	18.2	1.58
NST45	18.25	56.6	3.51
NST45	20	43.7	3.94
NST45	22.4	30.4	2.55
NST50	24.57	43.1	3.4
NST50	28.75	27	1.96
NST50	29-31	41.73	1.9
NST55	34	21.5	4.61
NST55	38	43.5	4
NST56	19.12	51.7	5.91
NST57	12.02	47.3	4.92
NST58	17.11	30.7	3.21
NST58	20.82	47.3	1.84
NST58	21-23	81.73	2.82
NST58	26.3	41.3	2.08
NST59	3.8	31.9	1.75
NST61	23.51	51.5	2.88
NST62	38-40	70.03	4.71
NST62	42.22	33.1	3.06
NST62	44.75	60.4	5.26
NST62	48.55	57.5	3.99
NST63	59-61	123.87	3.62
NST65	28-30	54.23	2.08
NST67	13-15	9.35	0.5
NST_GA102	6.1-6.4	72.7	13.47
NST_GA102	6.9-7.2	75	15.82
NST_GA102	7.2-7.4	92.97	4.95
NST_GA102	7.4-7.6	118.96	6.11
NST_GA102	7.7-8.2	48.93	4.4
NST_GA102	11.6-11.8	106.8	16.26
NST_GA102	12.1-12.2	74.92	4.91
NST_GA102	12.7-13.1	53.6	10.52
NST_GA102	13.1-13.5	128.11	3.88
NST_GA102	15.7-16.0	87.3	4.22
NST_GA102	16.0-16.3	73.48	4.41
NST_GA102	17.6-17.8	81.5	3.35
NST_GA102	18.2-18.4	55.88	5.18

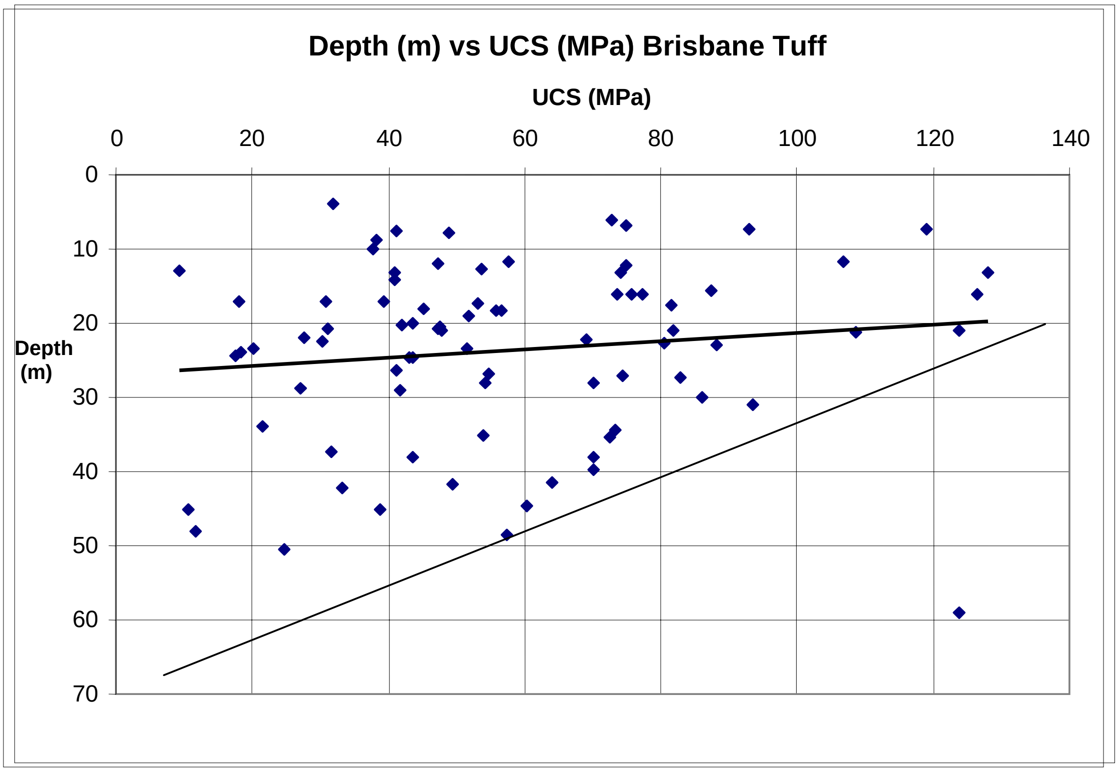
Note : Data Used from B.C.C tests results as published in NSBT Design Lot No.0802 Zone 0 Geotechnical Interpretive Report – Driven Tunnels – 0802-GT-RP-055005[04]

Figure 4 : Plot of Is (50) vs. UCS



It can be seen from **Figure 4** above there is a strong linear correlation between UCS and Is (50) which is expected. It must be said that some variation in Is (50) results will occur due to poor preparation of samples. (I.e. surfaces not perfectly flat as discussed). Taking the averages of the differences between all UCS and Is (50) results, a multiplication factor / correlation factor for UCS and Is (50) of (17.6) was calculated for the samples tested above. This included all data. The scatter appears to increase as the Is (50) value increases above 9MPa, this could possibly be attributed to the testing methodology itself, as the faces of the test samples were not always perfectly parallel, and any slipping between the pointload platens will cause a divergence of results between the ‘better prepared’ UCS samples and crude point load samples. Also, as the point load value is so high, it may not be apparent to the technician that the rock has failed on a micro-defect as the sample tends to shatter.

Figure 5 : Plot of Depth vs. UCS

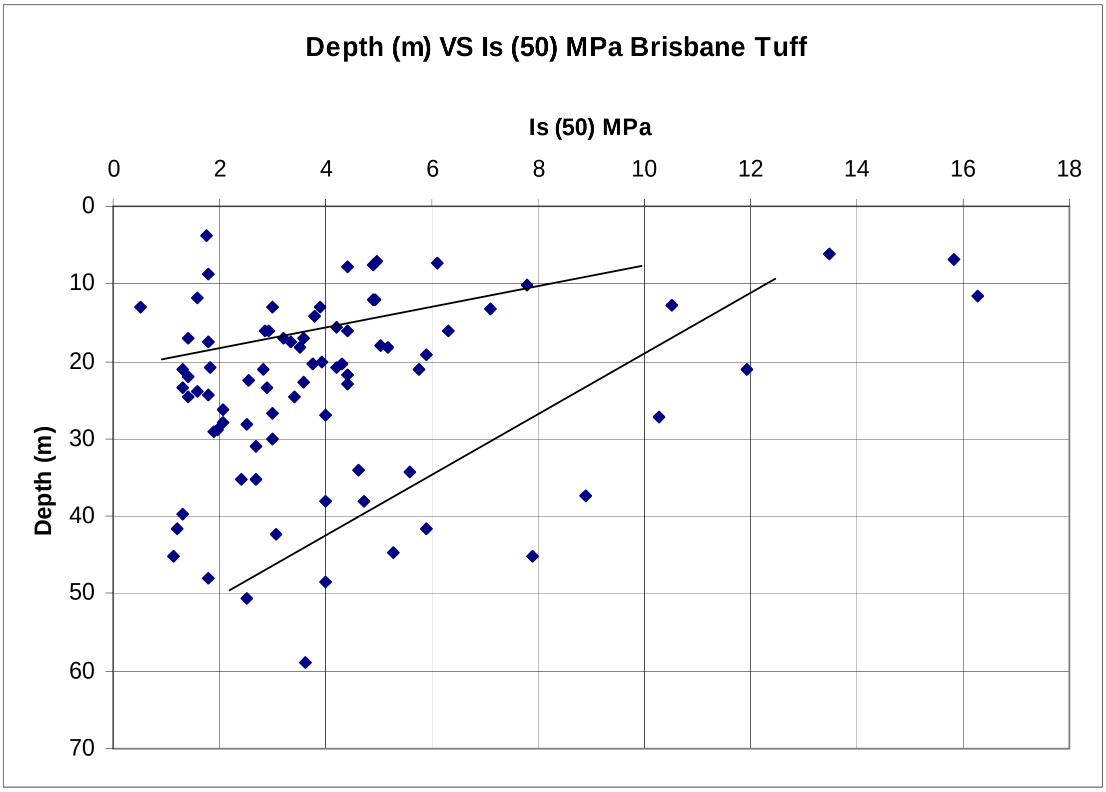


Examining **Figure 5** above, there seems to be some trend showing variation of USC results from 5-22m depth, then a linear decrease below 22-25m. Several possibilities are offered as an explanation for these trends.

Firstly, as stated earlier in the literature by Roach 1996, the trend may be due to the proximity of the contact zone at depth to the conglomerate deposits (Aspley Formation) where, water movement / infiltration or stratification has altered the strength of the Tuff at depth long term, or interfered with the thermal welding at deposition.

Secondly, from the research done by J. R Riehle et al. 2005, it is possible more complex and multilayered cooling flows have caused some variation in welding between lower and upper cooling units due to either separate depositional events, or thermal convection variation within the ash 'sheet'. (Roach 1996, J. R Riehle et al. 2005) The cause in trend will not be researched further in this paper, but may explain the possible (2) data trends. Degree of welding and alterations within a Tuff matrix will simply be measured by their associated Is (50) strength values. The data set however, is somewhat limited to fully appreciate a trend.

Figure 6: Plot of Depth vs. Is (50)



Examining the above **Figure 6,** the Is (50) results seem to be scattered around 1.6 to 8MPa at 10 – 20m depth, then decrease somewhat linearly with depth. As per UCS vs. depth, this may be due to the proximity of the contact zone at depth to the conglomerate deposits where, water movement / infiltration or stratification has altered the strength of the Tuff at depth long term, or interfered with the thermal welding at deposition. Also, it is possible, more complex and multilayered cooling flows caused variation in welding in upper and lower cooling units.

4.1.1 Calculated UCS / Is (50) Correlation for Brisbane Tuff

Is (50) test results were plotted against UCS values and analyzed by initially drawing the resulting trend line. This will give an approximate security or calibration to the results used in design, if both Point Load Index and UCS tests are done. For most rocks, it is estimated that a multiplication factor / ratio of (24) be considered a check for Is (50) and UCS correlation based on the findings of Broch & Franklin as cited in Burt & Look 2001. An Is (50) / UCS correlation of (17.6) was determined by averaging the individual test result differences between UCS and Is (50), then calculating a multiplication factor unique to the data set. This ratio, specific to the data collected for this research, agrees with the findings of B. G Look and S.G Griffiths 2001, who adopted a ratio of (18) for Brisbane Tuff (DW & SW/Fr weather grades) based on a more rigorous testing regime than was carried out for this project. Although it was found that the (24) multiplier is probably acceptable to assign to Tuff for design purposes it was slightly high. Bert and Look also state that the correlation of point load index to UCS in Brisbane Tuff is quite reliable compared to other rocks tested during their research (i.e. Argillites , Phyllites, Arenite, Meta-greywacke) and showed less variation most likely due to its inherent massive structure and lack of bedding and laminations.

This part of the research gave assurance that the Is (50) / UCS calibration for this data set is accurate and reliable

It is noted that samples of Brisbane Tuff tested by Burt & Look were taken from Kelvin Grove, Herston and Woolloongabba in close proximity to where samples were tested for this research paper.

Table 6: UCS / Is (50) Ratio

Rock	UCS/Is (50) Ratio (Bert & Look 2001)	Calculated UCS / Is (50) Ratio based on NSBT Brisbane Tuff samples
Tuff	**18**	**17.6**

4.2 Proposed Weathering Rating for Brisbane Tuff

Plots were produced of raw data sorted by Is (50) MPa, UCS MPa and depth (m), colour coded in different data series for each of the (4) categories of 'degree of staining'. As shown below, a semi-subjective judgement was made for each piece of core tested as to the percentage (%) of staining on the overall core sample not relating to a local defect. This means the rock mass as a whole was looked at globally. A judgement was also made as to whether the length of core tested (usually 100mm min), represented the weathering profile and not a lower or higher strength band. This is usually the case anyway when choosing samples to conduct Is (50) or UCS testing, to choose samples which represent a weathering grade and not just the 'best', or 'worst' section.

Often the worst sections of core may be treated as a defect such as a decomposed zone which will be a separate parameter, or a narrow band of very high strength rock within a medium strength overall groundmass may simply be logged as a band when the strength classification may remain 'medium strength with occasional very high strength bands'. This just ensures that if analyzing a borehole that the sections observed represent the greater rock profile, otherwise the analysis is meaningless. Stratified Tuff, or Tuff altered at the contact zone were not included in the 'degree of staining' assessment due to the limited limonite staining on these samples. The contact zone geology and subsequent 'unwelded Tuff' were treated separately.

Table 7: Symbols Legend and (%) staining for classification of '*degree of staining'*

Degree of staining on TOTAL core surface not relating to local defect
XS (70 -100%) DS (40-70%), SS (5-40%), TS (0-5%)
Where XS (Extreme Staining) / DS (Distinct Staining) SS (Slight Staining) / TS (Trace to NO Staining)

Figure 7: Plot of Is (50) MPa vs. Depth (m) for NST207

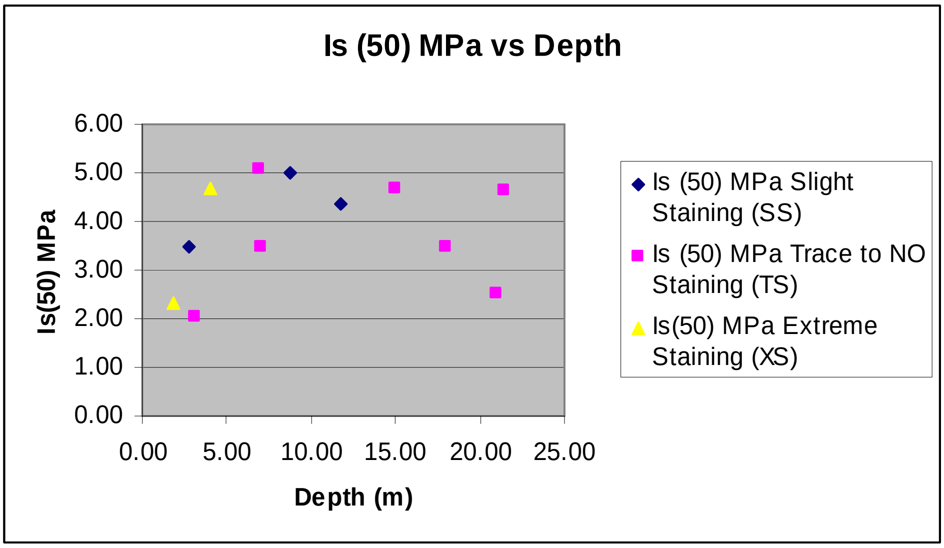


Figure 8: Plot of Is (50) MPa vs. Depth (m) for **(8) Boreholes** (See Appendix A for Data)

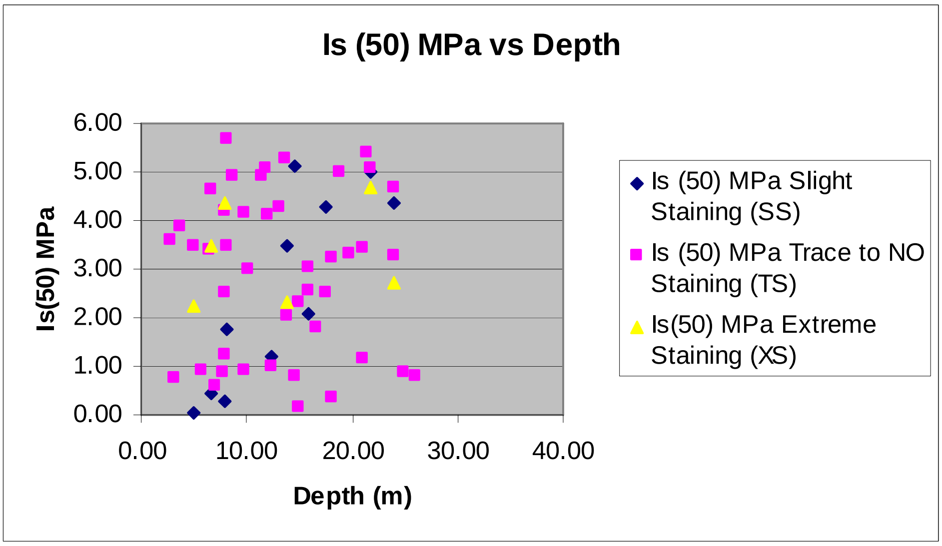


Figure 8 may be somewhat inconclusive as the depth of overburden is slightly variable in each borehole. (i.e. **NST207, 228, 241, 249, 257, 347, 348 & 349**). It is noted however, the samples tested which are classified as possessing ‘extreme staining (XS)’ tend to occupy the middle to higher range of Is (50) Point Load Index, whereas the (SS) ‘slight staining’ and (TS) ‘trace staining’ classifications tend to be more variable, with a large number of (TS) sampled from all sites. It must be noted that this was taken from a data sample of (8) boreholes, which produced only a small sample of the (XS) category, so this analysis is only a guide or a slight justification to the weathering rating to be used.

It is also suggested that a large number of (TS) samples are in the lower range of Is (50) MPa range. In some of these boreholes, the samples tested were in close proximity to a contact zone with the more permeable conglomerates (NST257). The samples tended to be more of a creamy / pale grey colour compared to the grey and pink / purple specimens and were observed to be more stratified in several boreholes. There seems to be little use in a 'Is(50) vs. Depth' correlation across separate boreholes. This correlation is specific to the depth of Tuff at each individual location.

Figure 9: Is (50) MPa vs. 'Degree of Staining Categories" Note 1 = TS , 2 = SS, 3 = DS, 4 = XS.

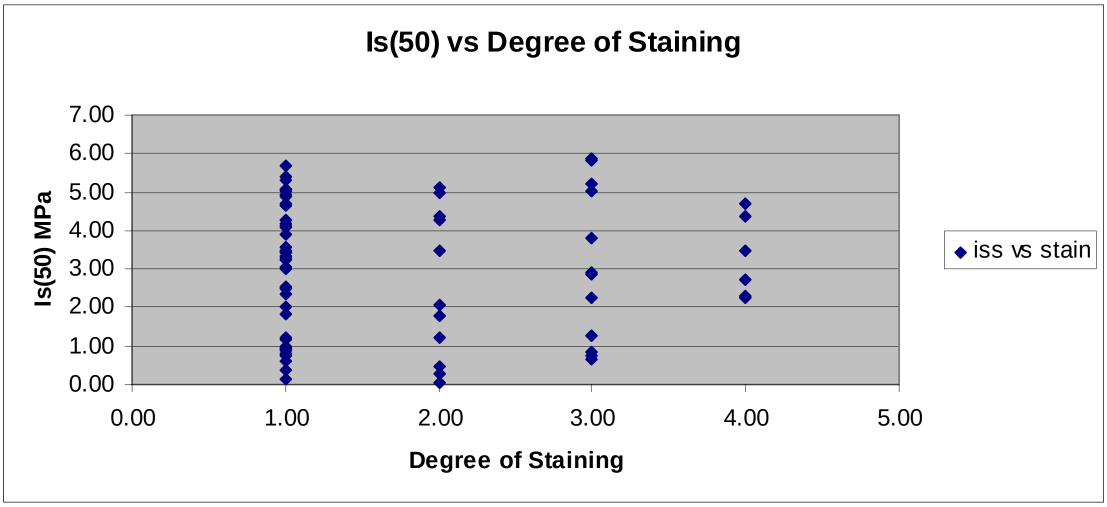


Figure 9 shows Is (50) Point Load results tabulated against their specific 'Degree of Staining' categories for the (8) boreholes mentioned in Figure (8). It can be seen clearly that Category 1 (TS), shows a complete spectrum of variation of strength, where Category 4 (XS) shows a mid to lower high end range only. This may be due to iron leaching strengthening the rock, however localized discontinuities in the rock due to water movement may have decreased the strength on the higher end of the scale. Once again, limitations in the amount of data used must be recognized, as more of the core tested has been of (TS) category.

In summary, it is concluded when developing a 'weathering index' rating based on staining and weathering in Brisbane Tuff the first (3) categories representing 0-70% of total staining on the core (TS SS DS) show only a slight variation in Is (50) values. This is important to note as Australian Standards would categorize these samples from Fresh Rock (Fr) to possibly Highly Weathered (HW), which if semi- quantified to a rating such as developed by F. MacGregor et al. 1994 would 'numerically' be rated from (1 to 8) based on these categories. Using a general average 1m defect spacing and other parameters assumed, the variation of productivity of rippability by a D9R bulldozer (in m^3/sec) from weathering rating of (1) to (8) is shown below for UCS (40MPa) Tuff using F. MacGregor et al. 1994 equation (6).

Table 8: Variation of Productivity over (9) Weathering Ratings

(D9R - Multi Shank 4885kgs)

Productivity (m^3/ hr) vs. Weathering Rating for 40 MPa Brisbane Tuff (F. MacGregor et al. 1994)

Weathering Rating

1	2	3	4	5	6	7	8	9
365	430	499	574	654	739	830	925	1026

As seen in **Table 8** above, numerically there is significant variation in productivity estimates of rippability for a D9R across the (9) quantified F. MacGregor et al. 1994 weathering ratings, as it is a heavily weighted parameter in the MacGregor regressions. This is of some concern if there is actually very little value in a parameter such as ‘weathering rating’ alone if no significant loss of strength is found across the first few weathering ratings.

4.3 Rating Analysis

Using the data collected for (8) boreholes (i.e. NST207, 228, 241, 249, 257, 347, 348 & 349), plotted above (Figure 9) in (4) staining categories, it can be seen clearly Category 1 (TS), shows a complete spectrum of variation of strength, where Category 4 (XS) shows a mid to lower high end range only. The analysis (Is (50) vs. ‘degree of staining’) does show however, that with the (71) individual samples categorized by (%) staining there is only a small variation in Is (50) with increasing (%) limonite staining or colour change from the parent rock. This is not saying that weathered Tuff does not follow the normal trend of decreasing strength with increasing weathering grade, but it shows that it can be justified to adjust or converge weathering ‘rating values’ such as the one devised by F. MacGregor, et al. 1994 shown below. This will mirror the ‘slight’ variation expected across weathering grades

Table 9 : Substance Weathering Rating : F. MacGregor et al. 1994al. 1994

Rating	Description
1	Fresh Rock
2	Fresh Rock with Stained Joints
3	Slightly Weathered to Fresh Rock with Stained Joints
4	Slightly Weathered Rock
5	Moderate to/ and Slightly Weathered Rock
6	Moderately Weathered Rock
7	Highly to Moderately Weathered Rock
8	Highly Weathered Rock
9	Highly to Extremely Weathered Rock
10	Extremely Weathered Rock

Table 10: Weathering of Igneous and Metamorphic: based on Moye (1955) as used in F. MacGregors Weathering Rating

Term	Symbol	Description
Extremely Weathered	XW or EW	Rock which retains most of the original rock texture (fabric) but the bond between its mineral constituents is weakened by chemical weathering to the extent that the rock will disintegrate when immersed and gently shaken in water. In engineering usage this is soil.
Highly Weathered	HW	Rock which is weakened by chemical weathering to the extent that dry pieces about the size of 50mm diameter drill core can be broken by hand across the rock fabric. Highly weathered rock does not readily disintegrate when immersed in water.
Moderately Weathered	MW	Rock which exhibits considerable evidence of chemical weathering, such as discoloration and loss of strength but which has sufficient remaining strength to prevent dry pieces about the size of 50mm diameter drill core (of inherently hard rock) being broken by hand across the rock fabric. Moderately rock does not ring when struck with a hammer.
Slightly Weathered	SW	Rock which exhibits some evidence of chemical weathering, such as discoloration, but which has suffered little reduction in strength. Except for some inherently soft rocks, slightly weathered rock rings when struck with a hammer.
Fresh Rock	Fr	Rock which exhibits no evidence of chemical weathering. Joint faces may be clean or coated with clay, calcite, chlorite or other minerals.

Table 11 : AS1726 – 1993 – Current Classification for Weathering of Rock Mass

Term	Symbol	Description
Residual Soil	RS	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. Described using the Soil Classification System.
Extremely Weathered	XW or EW	Rock is weathered to such an extent that it has soil properties – i.e. it either disintegrates or can be remoulded in water. Remoulded material can be described by the Soil Classification System.
Distinctly Weathered	HW*	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.
	MW*	
Slightly Weathered	SW	Rock is slightly discoloured but shows little or no change of strength relative to fresh rock.
Fresh Rock	Fr	Rock shows no sign of decomposition or staining.

* - The terms Highly Weathered (HW) and Moderately Weathered (MW) are not used in AS1726 – 1993. These terms are often still used where appropriate to further distinguish degree of weathering within the Distinctly Weathered (DW) classification.

Table 12: Golder Associates Technical Procedure 4 (TP4) – Revision Level 3, 2002 based on superceded Australian Standard

Term	Symbol	Description
Highly Weathered	HW	Rock material affected by weathering to the extent that limonite staining or bleaching effects the whole of the rock material and/or other signs of chemical or physical decomposition are evident. Porosity and strength may be increased or decreased compared to the fresh rock usually as a result of iron leaching or deposition. The colour and texture of the original rock material may no longer be recognizable.
Moderately Weathered	MW	Rock material affected by weathering to the extent that staining extends throughout the whole of the rock material and the original colour of the fresh rock may no longer be recognizable.

As can be seen by the Moye weathering descriptions used to quantify a weathering rating in the MacGregor et al. equations, weathering is a subjective classification which can be interpreted quite differently between geologists and engineers of varying experience.

'It is recognized that the degree of weathering is a subjective measure which may be difficult to estimate'. (F. MacGregor et al. 1994)

Also, geologists and field engineers may not be using the outdated Moye weathering classification procedure, but more likely using AS1726 – 1993 as shown below it. To further complicate the matter, some companies may stray from AS1726 – 1993 to further classify rocks as Highly Weathered (HW) and Moderately Weathered (MW) which is shown in the Golder Associates technical procedures. The two descriptions given for HW and MW (Moye and superceded AS), differ significantly enough to create logging inconsistencies, as Moye's is classified mainly by the readiness of rock to be broken by hand, where the superceded AS classification speaks in terms of staining, bleaching, porosity and a decrease / or increase in strength due to iron leaching to justify the classifications. It must be remembered F. MacGregor et al. 1994 regression equations are based on Moye weathering classifications from 1955.

Brisbane Tuff, as seen in the photo in section 4.4.6 'Grainsize and Degree of Welding', can be bleached. This particular sample is observed to exhibit some bleaching as seen in the right hand side of the core, and perhaps if strictly following the guidelines some field geologists may classify the rock as Highly to Moderately Weathered (HW-MW) if using Moye (1955), and some may even classify as Fresh Rock (Fr) if using AS1726. This is pointed out to show the subjective task of classifying weathering, when in the case of 'rippability' it may be more beneficial to classify weathering in relation to decomposition and strength rather than staining and bleaching. This is provided that staining and bleaching does not alter the rock strength which it may in some rock types.

As seen by the Is (50) results in the Tuff samples tested plotted against (%) of total staining on the core tested, there is little evidence that if 0-70% of the core was stained by limonite there is any chemical alteration to the rock mass which causes a loss in strength. Even so, when 70-100% of the rock mass was stained by limonite, data was limited due to limited samples to show that once again there was any more than a slight variation in strength from the 'fresh Tuff', or 'slightly stained' Tuff. The point of this statement is somewhat based on personal experience in that geotechnical engineers and geologists will often heavily base their judgement in classifying a weathering description on limonite staining. This is often done due to inexperience or conservatism, even if there is no evidence to suggest significant loss of a strength compared to the fresh rock, or chemical alteration of the groundmass due to the observed staining.

F. MacGregor et al. 1994 rates numerically the weathering rating from Fresh Rock (FR) to Moderately weathered Rock (MW) a difference of (6). As we have no evidence that there is a 'significant' loss in overall rock mass strength due to staining across several classifications, the F. MacGregor et al. 1994 weathering rating will be modified specifically for Brisbane Tuff to use in the regression equations. This modification can perhaps be seen as an adjustment to the upper and lower bounds of the EW- FR rating, and reclassified as a new weathering characteristic (% staining).

It is noted that different rating methods assign different weighted numerical values to each parameter, and one rating system cannot be compared with another as they usually use different regression equations to which the weighted ratings are uniquely relevant to. Listed below are several weathering rating system by different authors for specific estimation methods.

Table 13: Other Weathering Rating Parameters by Other Authors (cited in F MacGregor et al. 1994)

Weathering Rating	Weaver	Smith	Minty & Kearns	Scoble & Muftu	Kirsten
	9 to 1	**10 to 0**	**12 to -12**	**25 to 0**	**280 to 0**

It can be seen that weighted numerical values assigned to weathering cannot be compared from one rating method to another and are only relevant to the regression equations used specifically for that method.

Table 14 : Proposed Substance Weathering Rating for Brisbane Tuff

Modified Rating	Description
1	No staining to TS
1.5	TS to SS
3.0	SS to DS
5	DS
7.5	DS to XS

9.25	XS

These values reflect the results showing only a small variation in strength due to staining, especially at the TS to DS range (categories 1 to 3 which covers 0-70% staining in rock groundmass). However, to be conservative this research will still follow the norm of ‘the more staining, the more weathered thus decrease in strength’. All that has been done is change the bounds in the first few ratings which will minimize the influence of this weathering parameter to about when 50% of the core is stained. It must be remembered only a small data sample was used for analysis and testing, and it’s a certainty that extremely weathered, extremely low strength Brisbane Tuff is prone to being extremely stained (XS), more so than being completely unstained, so an upper end bound of (9.25) was still applied to maintain conservatism.

4.4 Tuff Rock Mass Properties

4.4.1 Classification of insitu Rock

Strength properties of rock samples cannot be carried out alone when assessing the global ‘condition’ of insitu rock on a given site. A rock mass insitu will possess localized defects

and quality alterations which are unique to either the rock type or geology / features of the site in question. The global condition of the rock mass may vary from the strength and weathering classification (A.S) of the rock core sample due to one dimensional limitation of the borehole. Strength and weathering descriptions for rock, considering Australian standards alone, may be misleading for the purposes of excavation and rippability because of this generality. In considering this, methods used to assess the overall rock quality of the site, and chosen for this research paper were rock logging / testing, measurement of spacing, classification of rock ‘structure’, as well as analysis of seismic velocity from a seismic surveys conducted on an adjacent site in similar geology.

4.4.2 Joints and Defects / & Defect Condition

As shown on the attached logs, for each borehole the joints and defects were logged and noted for each drill run in the ignimbrite. The defect information is used in many rock mass rating schemes, and defect conditions such as roughness, thickness and infilling greatly influence the shear strength of a defect and subsequent influence movement when excavating. (Hoek & Bray, 1974) Defects are normally logged once the NMLC rock core is placed in core boxes carefully to avoid any damage to the rock or defects themselves, to ensure an accurate description of insitu conditions.

Careful note is also taken to determine whether a break in the rock core is either a natural defect, a drilling (mechanical) break or a handling break. If the last two were the case the break is marked as to not be confused with a natural defect. Indicators of a mechanical break or handling break in rock may be sharp edges on the joint faces, lack of staining and veneer or a completely clean joint surface. Using Golder Associates technical rock logging procedures, based on the Australian Standards, all defects were logged as to their type, orientation, infill and thickness. For each defect as shown, a unique symbol was given to it to differentiate between say joints (J), veins (V), crushed seams (CS) and shear seams (SS). For the uniqueness of logging for the NSBT project, careful use of the word 'fault' was required to differentiate between localized shear seams, SS (< 100mm), shear zones SZ (>100mm), and faults which were seen to be more of a global defect which could not be necessarily deduced from the 52mm diamond (NMLC) boreholes. This was not saying faulting did not occur on any of the sites sampled on, but more intense geological mapping was carried out separately as excavations proceeded and from exposed outcrops. A typical defect description on the attached logs may show;

Example 1 : 30.23m - J, 24, St, Ro, In fine angular gravel, clay Vn, 1.5mm

This means at 30.23m depth a joint was noted 24 degrees to the horizontal axis (0), ***stepped*** * joint surface, Rough joint surface, infilled with fine angular gravel, some clay veneer coating the joint surface, and 1.5mm thickness when considering the vertical axis.

Example 2: 21.65m – SS, 60, Un, Sm, fine to medium angular parent fragment, healed black mineral, 62.1mm

This means at 21.65m depth a shear seam was noted 60 degrees to the horizontal axis (0), ***undulating**** joint surface, smooth surface, movement has sheared the parent rock to form fine to medium fragments (not transported there), the shear seam has then healed (cemented) due to some mineral infill, and 62.1mm thickness to the vertical axis.

4.4.3 Defect Roughness (amplitude/length) for Brisbane Tuff)

It is often necessary to further describe the joint surfaces which are logged as undulating, stepped and wavy, amongst other descriptions geologists and geotechnical engineers may use. This is due to the fact that 'defect roughness' tends to influence rippability of rock. Information such as amplitude / length of defect in regards to its undulation is often used as a parameter in rippability estimation regressions. From geotechnical logs which this research is based on, as well as photographs of exposed Tuff outcrops showing more global jointing (i.e. Kangaroo Point Cliffs), it is determined the vast majority of jointing was **amplitude / length ratios of 0.05 > 0.15** classifying generally as medium to very rough defect roughness.

4.4.4 Structural Description of (4) Brisbane Tuff

Brisbane Tuff is described as possessing a 'massive' structure, meaning there is no discernable bedding or laminations within the general groundmass of the rock. In 2006, Golder Associates geologists conducted geological and discontinuity mapping at (2) of the largest Brisbane Tuff outcrop locations to assess the structure of the rock globally. The two locations were Kangaroo Point Cliffs and Howard Street Wharf on the Southern side of the Brisbane River. The final assessment into the structure states;

> *"In the welded Tuff, the most significant structural features include sub-horizontal and sub-vertical joints and occasional narrow shear zones and alteration zones. In outcrop, the welded Tuff usually displays a prominent orthogonal jointing pattern, generally with sub-horizontal joints and two to*

> *three sets of sub-vertical joints."* North South Bypass Tunnel Design Lot No. 0802 Zone 0 Geotechnical Report NSBT – 0802 – GT – RP – 055005[04] / Dec 2006

The welded Tuff mapped was then categorized into (4) structural domains, to be used in (Q) rock mass classification systems.

Table 15: Structural Domains for Mapped Brisbane Tuff Outcrops

Rock Mass Unit	Description
Tuff 1	High to Very High Strength, fresh to slightly weathered. 3 joint sets, dominant sub-horizontal set, generally **600mm to 2m spacing**. **Rough joints**. Narrow sheared zones, widely spaced. ~ **UCS 100MPa**
Tuff 2	High to Very High Strength, some Medium Strength, slightly weathered to fresh. 3 joint sets as above, closer spaced generally 200mm to 600mm with areas of wider and narrow spaced. Rough, mainly open stained joints which extend to ~25m. Narrow shear zones typically typically <100mm thick, widely spaced. ~ **UCS 80MPa**
Tuff 3	Medium to High Strength, some Low Strength, distinctly to slightly weathered. 3 joint sets, closer spaced generally 60mm to 200mm with areas of wider and narrower spaced. Rough, open joints. Narrow sheared zones. **~UCS 30MPa**
Tuff 4	Very Low to Medium Strength, extremely to distinctly weathered or unwelded, 3 joint sets dominant subhorizontal set, joints generally spaced 60mm to 200mm with areas wider and narrower. Rough, open, stained joints, narrow, sheared zones. **~UCS 3MPa**

Data cited in North South Bypass Tunnel Design Lot No. 0802 Zone 0 Geotechnical Report NSBT – 0802 – GT – RP – 055005[04] / Dec 2006

F. MacGregor et al. 1994 quantifies structural units as ratings based on bedding characteristics and number of joint sets as shown below;

Table 16: MacGregor et al. Structural Description /Rating

Rating	**Rocks without Bedding**		
	Joint Set 1	**Joint Set 2**	**Joint Set 3**
1	Very Wide	Very Wide	Very Wide
3	Wide	Very Wide	Very Wide
4	Wide	Wide	Very Wide
6	Wide	Wide	Wide
8	Medium	Wide	Wide
9	Medium	Medium	Wide

MacGregor et al. 1994

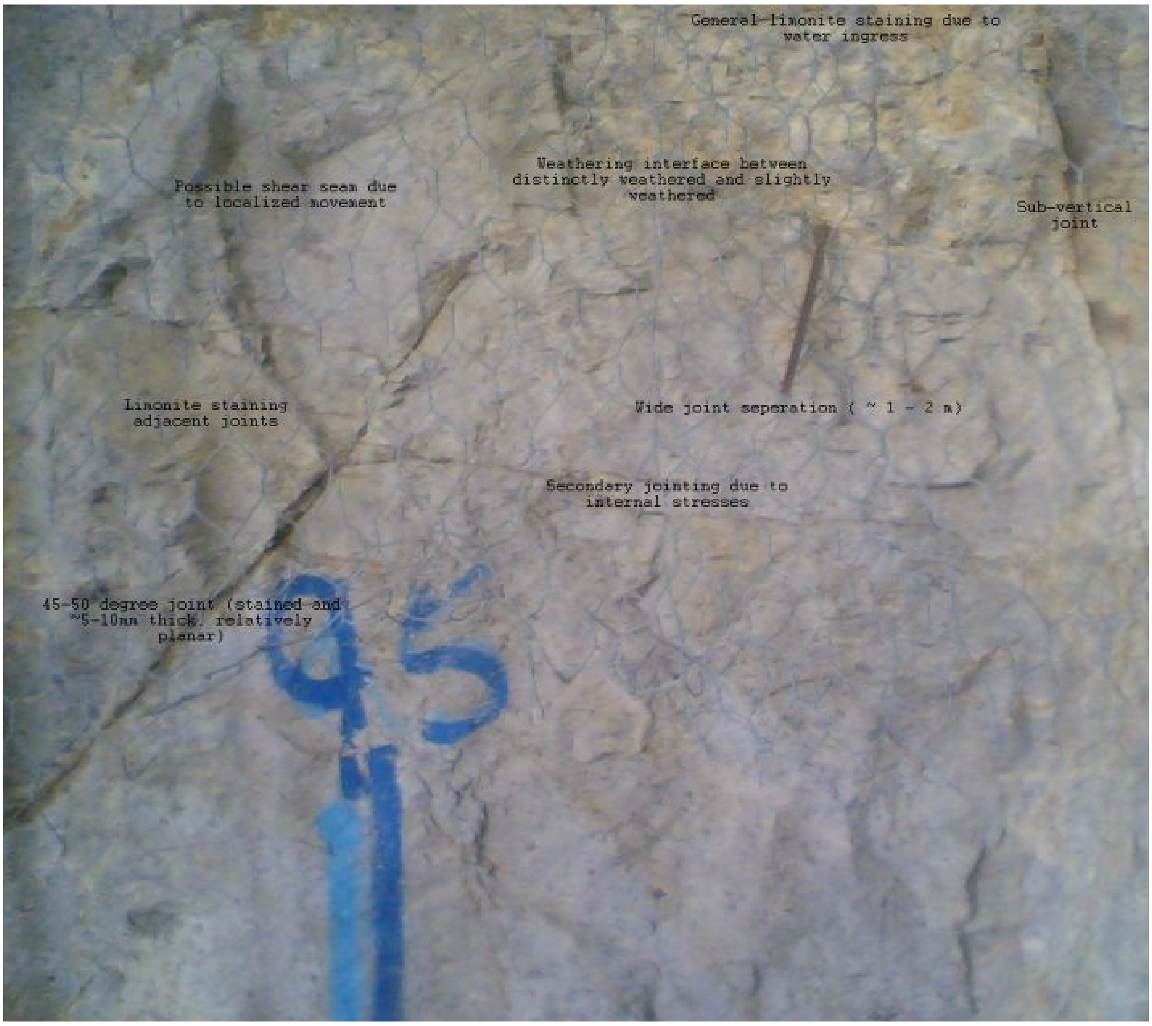
Where;

Very Wide -	>2m Joint separation
Wide -	0.6-2m
Medium-	0.2-0.6m
Close-	0.06-0.2m
Very Close-	0.006- 0.06

MacGregor et al. 1994

Shown below are photographs of a Brisbane Tuff cut face in the northern portal (tunnel entrance) of the North-South Bypass Tunnel directly adjacent to borehole NST241. This area was blasted to enable ripping and removal of rock. This particular cut face was photographed as an example of insitu jointing to fully understand the rock in natural state as opposed to viewing NMLC 52mm core. This face was also chosen as there are no apparent breaks in the rock due to previous blasting. Wide semi-planar jointing can be observed (0.6-2.0m), as well as some limonite staining due to water ingress through fractures. A weathering interface can also be observed between the ‘yellowish’ stained distinctly weathered Tuff (DW) and the ‘pink’ slightly weathered Tuff (SW) on the top and right of the photo. This interface is not horizontal but about 40-45 degrees which shows the limitations of borehole interpretations which are relatively 1-dimensional. (I.e. weathering interface would be quite different over 10-20m)

Figure 10: Brisbane Tuff Cut Face Adjacent NST241



4.4.5 Fracture frequency

Following logging of all defects and joints for a particular borehole, the core was divided into continuous sections of approximately equal defect spacing. An example of this division may be a 10m length of core where over 3m there were 12 defects spaced approximately 200-300mm apart, the following 4m having 8 defects spaced 450 – 500mm, and finally the last 3m having 42 defects spaced approximately 55-80mm. This gives (3) sections of core having fracture frequencies (average no. of defects per metre) of 12/3 = 4 (FF), 8/4 = 2 (FF) and 42/3 = 14 (FF). It is essential to note that it is crucial the sections of similar defect spacings are identified and divided rather than incorrectly saying there were (62) defects over 10m giving 62/10 = 6.2 (FF). The result as can be seen gives a crude average, which is misleading and will affect any further calculations in regard to defect spacing

.

It is therefore imperative to analyse sections of core with similar fracture / defect spacing to produce a similar table as shown below.

Table 17: Example of Average Defect Spacing in Recovered Rock Core

Borehole Depth (m)	**Average Defect Spacing (mm)**
8.75-11.17	50mm
11.17 – 19.72	210mm
19.72 – 28.68	560mm
28.68 – 37.23	860mm
37.23 – 49.5 (EOH)	1230mm

These different sections of average defect spacing would typically be subdivided and analyzed separately in rippability / productivity regression equations as average defect spacing is an influential parameter in many rippability estimation methods.

As discussed earlier, an attempt will be made to correlate an interaction between 'degree of staining' and defect spacing. Staining is generally due to the migration of water through defects within the rock mass such as joints, shear seams, larger shear zones, faults, crushed zones and decomposed veins or dykes / sills. Looking at the core photos of NST207 attached in the Appendix, (2) to (3) different 'degrees of staining' and defect spacing exist globally looking at the total length of core examined. Generally between 1.85m and 7.0m the core may be classified as 'DS' to 'XS' with between 60 to 80% of the core surface stained by limonite due to water ingress through the fractures. When looking at the fracture frequency on the logs it can be seen from the (FF) – fracture frequency from the logs there are about 7-10 fractures per metre which we can say is in the range of spacing between 100 – 150mm spacing.

After this point the degree of staining is minimal at about the 'SS' to 'TS' range which is between 0 and 40% of the total core stained. The fracture spacing also increases to about 400 - 500mm (FF = 2.54 and 1.6 from logs) and even (1) defect occurring between 8.13 to 11.44m. This is mirroring the fact that staining on the rock core is primarily due to the proximity to the nearest water bearing fracture or defect. Due to this relationship between limonite staining and proximity to water bearing joints and defects, the following corresponding lower bound defect spacing values in Table 18 are proposed relating to each 'degree of staining category. Being purely lower bound the values can be flexible and used only as a guide when looking at borehole data and core photos of Brisbane Tuff. This will mean now there is a mathematical dependency on the weathering semi – quantified rating and the quantitative defect spacing value which will influence the productivity of rippability values and shape of the polynomial curves.

Table 18 : Proposed Weathering Rating for Brisbane Tuff vs. Assoc. Defect Spacing

Rating	Description	Proposed associated Min Defect Spacing for Eq (6) (mm) MacGregor et al. 1994
1	No staining to TS	>1000 mm
1.5	TS to SS	1000-1500mm
3.0	SS to DS	600-1000mm
5	DS	400-600mm
7.5	DS to XS	200-400mm
9.25	XS	0-200mm

4.4.6 Grain Size and Degree of Welding

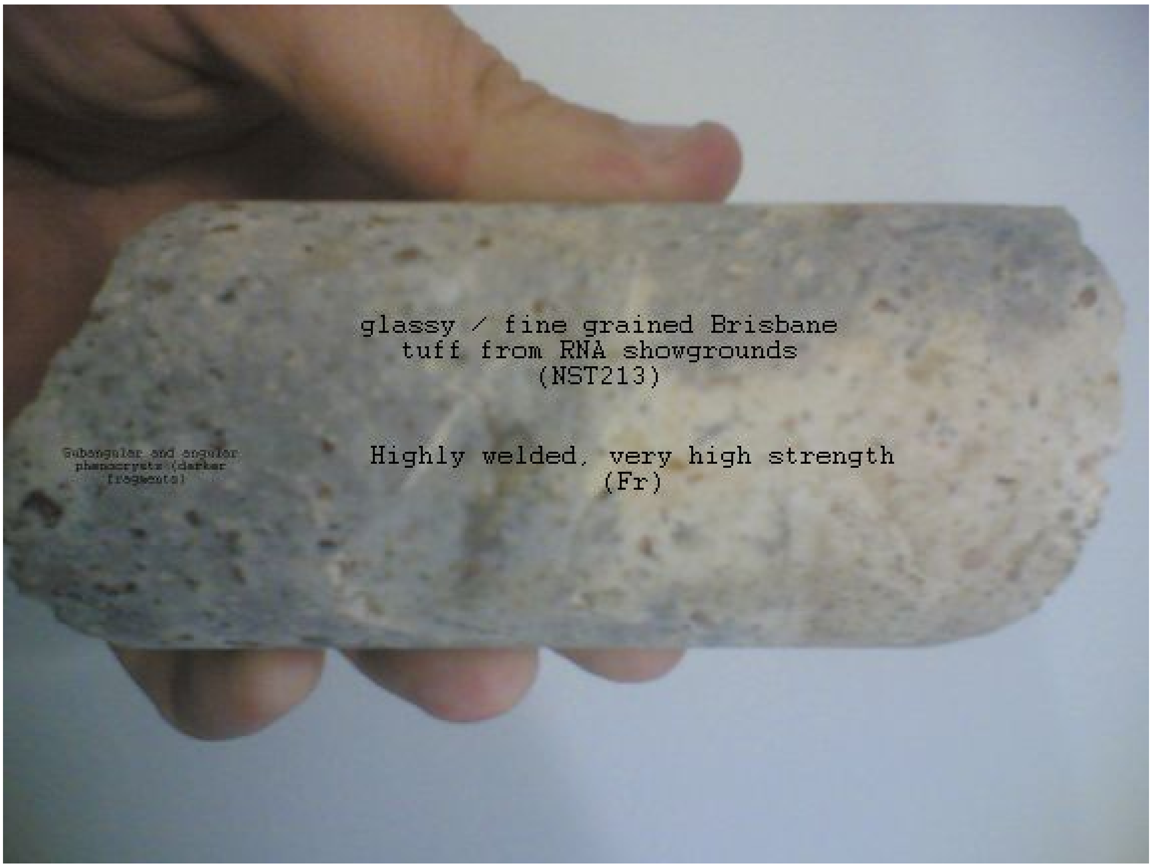
Grain size is described as fine and “powdery” for most of the Tuff sampled, which was predominantly welded and highly welded ignimbrite (see Figure 11 below which is a photo of highly welded Tuff). The welded Tuff appears to be of porphrytic or ‘glassy’ texture.
The unwelded Tuff, however, seemed to possess a larger grain size (up to 1mm at greatest not including phenocrysts.) The ‘greenish grey’ unwelded Tuff was not observed to be porphrytic.

i) Grain Size of Highly Welded Ignimbrite (0 to < 0.5mm)

Grain Size is ‘glassy to fine’ (0 to 1mm), as observed in highly welded test samples and core collected from site. This high degree of welding is due to the glass being heated and causing the groundmass to be in a ‘plastic state’, thus cooling over time to have a glassy texture hence termed porphrytic.

Shown below is a sample of ‘glassy to fine’ grained Brisbane Tuff. Grains have a powdery texture when ground and at times not discernable with the naked eye at the glassy end of the scale. The larger angular fragments (2-6mm) are phenocrysts carried in the ash-flow.

Figure 11: Highly Welded Tuff



All colours of Tuff samples (pale grey, pink, purple, white etc) sampled for this research tended to fall into the medium to very high strength category except the unwelded Tuff which had the greater grainsize of all the samples. Unwelded Tuff tended to fall into the extremely low to medium strength range as shown in Is (50) test results for NST257 shown in Appendix A.

MacGregor et al. semi-quantify grainsize, for fine to 'glassy' grained igneous rocks, for use in the regression equations by rating 'grain diameter' from 1 to 7 as shown below.

Table 19: Igneous Grain Size Rating (MacGregor et al. 1994)

Description	Grain Diameter	Rating
Fine	< 1mm	1
Glassy	0	1

Attempts were made to modify the grainsize ratings specifically for the unwelded ignimbrite as discussed below, to see if changing this parameter slightly could give a better estimate of increased productivity due to the coarser grainsize rock being more rippable.

The resultant values showed quite the opposite effect in that slightly increasing the grainsize rating gave a more conservative estimate on rippability rather than less conservative for equation (6). This may not be representative of the behaviour of this rock type in that the coarser grained material is less welded. The modification of the MacGregor grainsize rating was not considered any further as it would give misleading results as shown below for a trial application on changing this parameter alone.

Table 20 : Productivity Values for D9R Based on Grain Size Rating 1 (MacGregor et al. 1994)

Grainsize Rating	**Defect Spacing**	**(D9R - Multi Shank 4885kgs) Productivity (m^3/hr) vs. UCS (MacGregor)**								
1	**1m**									
Structure Rating										
1					**Weathering Rating**					
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	10	857	954	1056	1164	1277	1395	1518	1646	1780
	20	710	799	892	992	1096	1205	1320	1440	1565
	30	577	657	742	833	929	1030	1136	1247	1364
	40	457	529	606	688	775	868	966	1069	1177
UCS	50	352	415	484	557	636	720	809	904	1003
	60	260	315	375	440	510	586	667	753	844
	70	182	229	280	337	399	466	538	615	698
	80	118	156	199	247	300	359	423	492	566
	90	68	97	132	171	216	266	322	382	448
	100	32	52	78	110	146	188	234	286	344
	120	0	4	13	27	47	71	101	136	176

Table 21: Productivity Values for D9R Based on Adjusted Grain Size Rating 1.5 (MacGregor et al. 1994)

Grainsize Rating	**Defect Spacing**	**(D9R - Multi Shank 4885kgs) Productivity (m^3/hr) vs UCS (MacGregor)**								
1.5	**1m**									
Structure Rating										
1					**Weathering Rating**					
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	10	480	553	631	715	804	898	998	1102	1212
	20	371	436	506	582	662	748	839	935	1036
	30	277	333	395	462	534	611	693	781	874
	40	196	244	297	356	419	488	562	641	725
UCS	50	130	169	214	263	318	379	444	515	591
	60	77	108	144	185	232	283	340	402	470
	70	38	60	88	120	158	202	250	304	363
	80	12	26	45	70	99	134	174	219	270
	90	1	6	17	33	54	80	112	148	190
	100	3	0	2	10	22	40	63	91	125
	120	49	29	14	5	0	1	7	18	35

It can also be seen from the above figures, that adjusting the F. MacGregor et al. grainsize rating slightly gives a more conservative estimate of rippability (by up to 50% in some cases) This is not only opposite to the expected result, but the resultant polynomial shows an anomaly as the values on the upper end of UCS start to increase at the turning point of the polynomial curve.

As grainsize of the Tuff sampled for this research was no greater than 1mm, even for the unwelded samples, the MacGregor grainsize ratings were not altered. The unwelded Tuff however, is discussed more below.

ii) Unwelded Tuff

Roach, 1996, states that ‘greenish – grey’ Late Triassic Tuffs in the Brisbane region are usually fine to medium grained and rarely porphyritic, usually primarily air-fall Tuffs or may be formed by ground surges. He states these ground surges are close to contact zones with the underlying basement rocks. The surge layers can be crystal rich, and contain abundant charcoal, and otherwise essentially deficient in lithic clasts. The contact zones are usually uneven with Brisbane Tuff as it was deposited as predominantly a valley fill ignimbrite.

The green Tuff was located on a site in Windsor whilst drilling large diameter piles. The texture, colour and grainsize of the samples correlate with the Roach’s findings, and the strength ranged from extremely low strength to medium strength (classified by AS rock strength classification using hand and geological pick). The samples recovered showed variation in strength, but not necessarily in weathering classification. What appeared to be the defining difference between this Tuff and other welded ignimbrites sampled was its grain size, apparent lack of welding and non-porphyritic fabric. Also agreeing with Roach, 1996, was that at the Windsor site, these pockets of unwelded Tuff were located very close to highly welded, porphyritic Tuff. This was apparent when drilling bridge piers spaced at about 8 (m), where from one pier to another would change from highly welded to unwelded rock. Previous to these samples it was very difficult to find any rock samples less than low to medium strength, independent of weathering.

The piling works were associated with the NSBT project, for associated bridges in June – July 2007. The areas drilled were in Enoggera Creek approximately 500m from the northern portal of the proposed tunnel. Disturbed samples were collected directly from the Baur BG28 drill bucket for observation, as a 3m socket was required in ‘slightly weathered’ Tuff to satisfy both end bearing dead load of the bridge structure and lateral forces caused by the estimated live loads.

In other areas whilst piling, an ‘obvious’ change was noted in drilling from alluvial and residual soils into a thin (1-2metres) highly weathered Tuff profile before incurring the high to extremely high strength, slightly weathered Tuff. Highly weathered Tuff could be somewhat effortlessly drilled using a drill bucket with tungsten teeth. As these were 1.5m diameter piles, progress could be made at about 0.5m every 5-6 minutes in one dig sequence. Normally the samples would vary from small chips to angular cobbles and boulders depending on strength and orientation of joints and defects, and the material would be of yellow, pink and pale grey colour. It must be noted that although hundreds of geotechnical boreholes have been drilled for NSBT, there are limitations in the geotechnical investigation. This is because the area of investigation is very large, and although specific areas were targeted for design of structures / shafts with specific borehole programs, often it is impossible to drill enough ground to get anything more than a general cross-sectional plot of what the rock profile 'may' be doing. This is especially the case in this area adjacent Enoggera Creek where the nearest geotechnical borehole is some distance away where the geology, deposition and welding of the ignimbrite is quite different to the creek system.

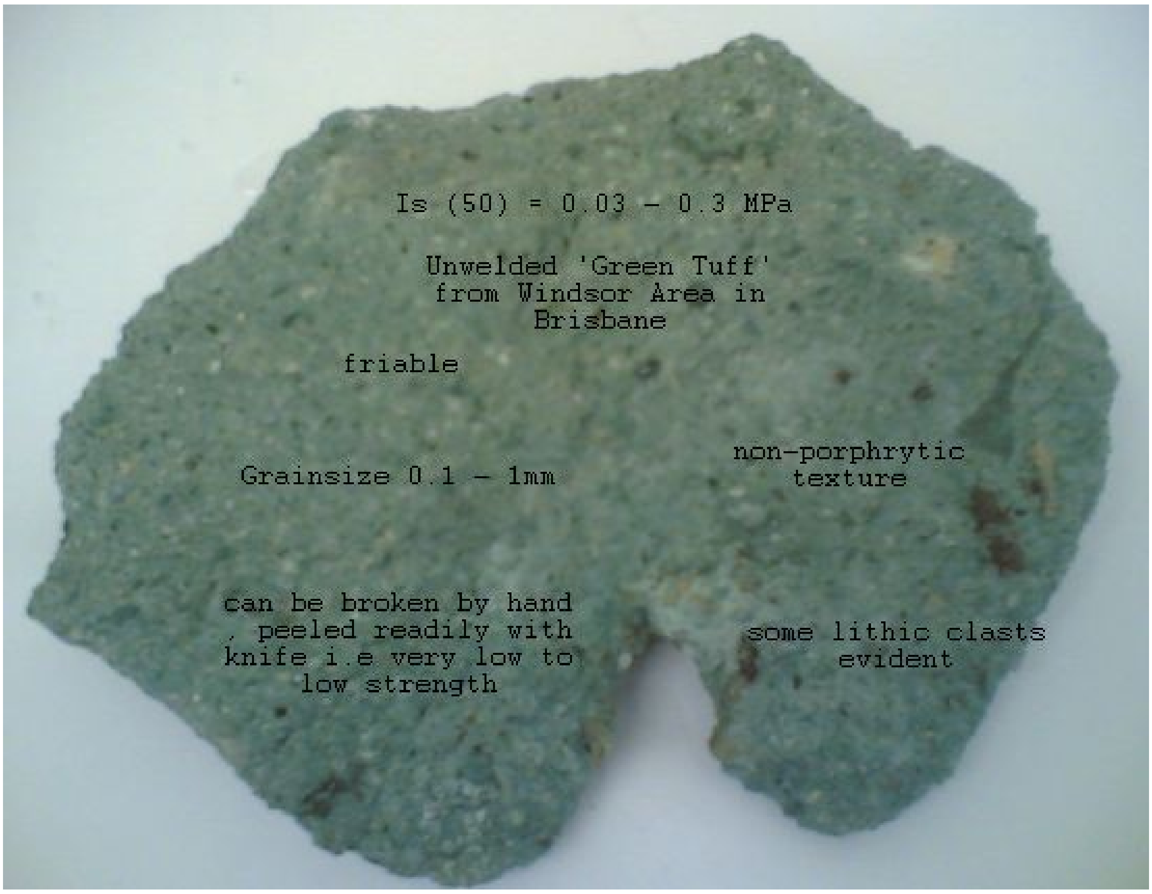
The two bridges which piers were drilled for in Enoggera Creek cross the creek twice as the creek sweeps around from the West under Horace Street at Bowen Hills to then turning near ninety degrees in a northerly direction after Horace Street. These two bridges will traffic vehicles from the Inner City Bypass and Bowen Bridge Road to the northern entrance of the tunnel. It was found whilst drilling piers for bridge MCK2 on the East – West stretch of the creek that the Tuff suddenly dips between 30 to 45 degrees towards the creek, and in some localized areas was completely unwelded. These softened areas were only located during construction and resulted in redesign of all piers on and adjacent the creek.

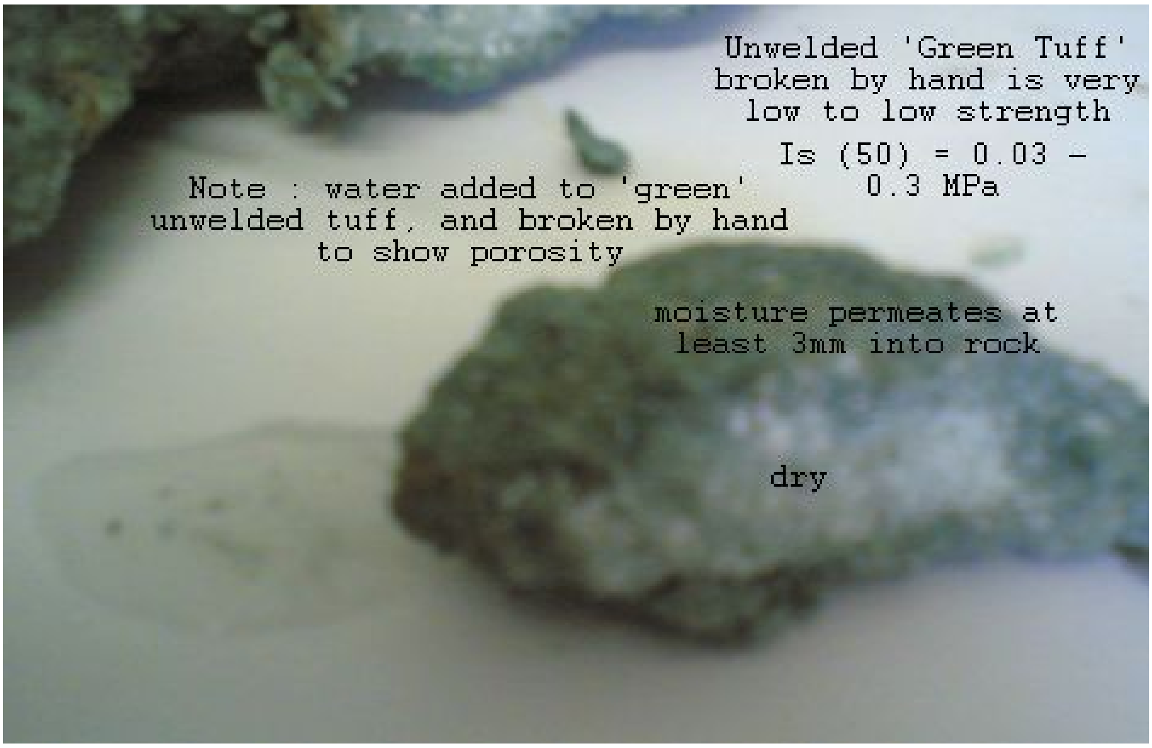
The new design requirement was for a minimum 3m socket opposed to a 1m socket, as one side of the socket would be less than a metre deep if the Tuff was dipping at that angle, and any socket less than 3m metres in length significantly increased the risk of a rock wedge failure between piers due to loading due to the lower strength.

At some locations in Enoggera creek, the Tuff was not only deeper, but was extremely weathered / unwelded with ghost rock structure for 2-3m metres, before becoming low to medium strength (approx 1 – 2 MPa) with some completely weathered, very low strength bands of well less than 1MPa. The Tuff was fine to medium grained, with some chert phenocrysts in the rock fabric. Samples were non-porphrytic and lumps could be broken by hand, or penetrated by a pocket knife (as shown below up to 1cm). Water was added to a sample of 'green' unwelded Tuff to show the porosity characteristics of the unwelded rock. After the water was added the sample was broken by hand and the amount of water penetration was about 3-5mm into the rock fabric. This shows the Brisbane Tuff becomes quite porous when unwelded. (See Figure 12 below)

Figure 12: Very Low to Low Strength Unwelded Tuff

Figure 13: 'Green' Unwelded Tuff and Porosity Characteristics





At times pier socket redesign was required, resulting in an 8m socket in this low strength ‘unwelded’ material to satisfy the load and lateral requirements.

Due to the limited ‘staining’ and possibly alteration of unwelded ignimbrite since deposition, following AS standards of weathering classification it may still be possible to classify as slightly weathered (SW), as was seen on the borelogs for NST257. This was pointed out to designers, and a further geotechnical note was added to some drawings giving a strength requirement as well as weathering requirement. It reinforced the observation that classifying weathering in Ignimbrites can be subjective.

4.4.7 UCS (Unconfined Compressive Strength) MPa

Depending on what information is required in regard to rippability, the UCS values may be presented by upper and lower bounds graphically, by dividing into increments commonly used in Australian Standards, and also used quite often on site. (i.e. EH – extremely high strength, VH – very high strength, H – high strength, M – medium strength, L – low strength, VL – very low strength, EL – extremely low strength). Data can then graphically represented in different series / ranges of UCS values against productivity of ripping.

Table 22 : Weathering and UCS Upper and Lower Bounds

Australian Standard Strength Classification	**UCS (MPa) Lower and Upper bounds**
EH	> 240
VH	70 - 240
H	24 - 70
M	7.0 – 24
L	2.4 – 7.0
VL	0.7 – 2.4
EL	0.7 – 2.4

4.4.8 Seismic Velocity

It was mentioned earlier under section 4.3 'Rating Analysis', that it was recognized through the research done by F. MacGregor et al. that degree of weathering was a subjective parameter when used in several regressions they developed. It was also stated that some of the equations show that weathering is a significant variable in the regression analysis of igneous rocks. (F. MacGregor et al. 1994)

'If it is considered that weathering is a difficult parameter to assess then it provides a reasonable prediction for igneous rocks without this factor. The variables which showed the best correlations with productivity were unconfined compressive strength (UCS) and seismic velocity.' (F. MacGregor et al. 1994)

Field seismic survey data is briefly discussed in this research as F. MacGregor et al. determined seismic velocity gave the best correlation coefficient when using this parameter to estimate productivity in 'igneous rocks'. (i.e. $R^2 = 0.63$). The aim of this research paper was to use borehole information opposed to seismic data. Seismic surveying can become expensive considering time taken to interpret results, and is known to have limitations of use, especially when the rockmass is highly fractured or boulders are present. Although seismic data was not available for this research in the immediate area where borehole drilling was carried out, Golder Associates had previously done the geotechnical investigation for the Brisbane Inner City Bypass Tunnel (ICB) at Herston in the year 2000. The ICB tunnel was a cut and cover tunnel and its entrance is less than 100m from the northern portal for the NSBT tunnel. The ICB tunnel was cut through Brisbane Tuff and was blasted to enable ripping. Large bulldozers including D10 and D11 machines had limited success ripping and a decision was made to blast. Similarly, the northern portal of the NSBT tunnel had been blasted in late 2006 to enable ripping to the invert of the proposed tunnel.

Fieldwork for the ICB tunnel comprised of (8) vertical boreholes (GA48 to 50, 52 to 55 and GA62), (2) angled boreholes (GA61 and GA63). Boreholes were located on the alignment of the outer tunnel walls. Seismic traverses were also conducted to obtain additional information regarding conditions between the walls. High to very high strength Tuff rock was encountered in all boreholes from the depth at which rock was first encountered. The high strength Tuff had a low degree of fracturing. (Golder Associates 00632017 MD – ICB, June 2000)

'Tuff rock encountered across the (ICB) RNA site is either high or very high strength and is considered to be potentially very difficult to excavate. Joints within the rock, which could range from sub-horizontal to sub-vertical, may not be exploitable to assist in excavation, due to their limited extent. The use of line drilling and blasting to advance the excavation will be required in order to facilitate the efficient use of hydraulic rock breakers to further break up and remove the rock'. (Golder Associates 00632017 MD – ICB, June 2000)

Below is the summary of the point load tests conducted on (2) of the ICB boreholes which mirror the results generally found in this research.

Table 23: ICB Is (50) Summary

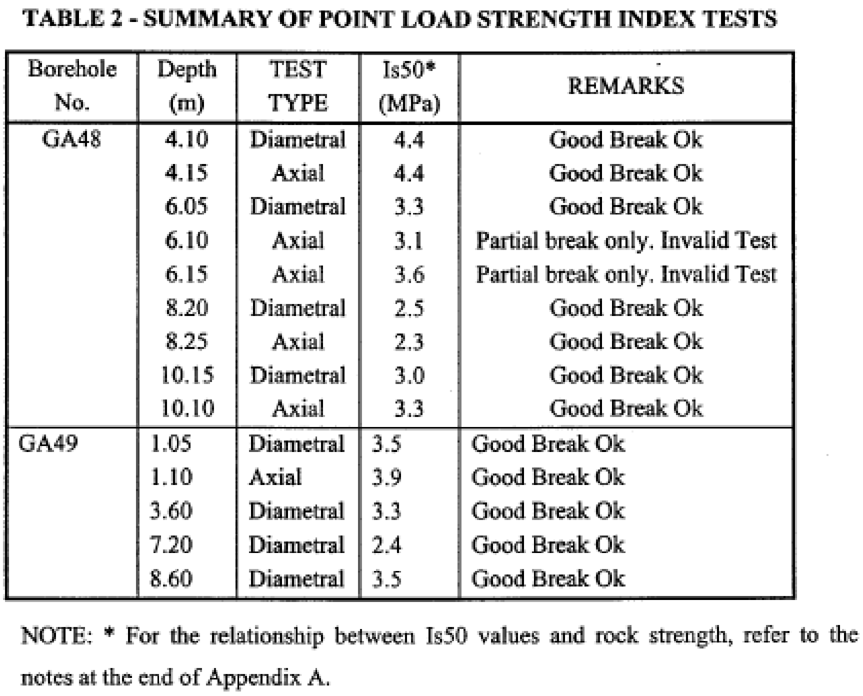


TABLE 2 - SUMMARY OF POINT LOAD STRENGTH INDEX TESTS

Borehole No.	Depth (m)	TEST TYPE	Is50* (MPa)	REMARKS
GA48	4.10	Diametral	4.4	Good Break Ok
	4.15	Axial	4.4	Good Break Ok
	6.05	Diametral	3.3	Good Break Ok
	6.10	Axial	3.1	Partial break only. Invalid Test
	6.15	Axial	3.6	Partial break only. Invalid Test
	8.20	Diametral	2.5	Good Break Ok
	8.25	Axial	2.3	Good Break Ok
	10.15	Diametral	3.0	Good Break Ok
	10.10	Axial	3.3	Good Break Ok
GA49	1.05	Diametral	3.5	Good Break Ok
	1.10	Axial	3.9	Good Break Ok
	3.60	Diametral	3.3	Good Break Ok
	7.20	Diametral	2.4	Good Break Ok
	8.60	Diametral	3.5	Good Break Ok

NOTE: * For the relationship between Is50 values and rock strength, refer to the notes at the end of Appendix A.

(Golder Associates 00632017 MD – ICB, June 2000)

Note: the Is (50) results range from 2.3 – 4.4MPa which is in the high to very high strength range.

*'Seismic traverses ST2, ST3 and ST4 were carried out in the middle of the proposed excavation, rather than along the wall alignments. As can be seen, the depth to high strength rock (**seismic velocities >2000-2300m/s**) do not correlate closely with the results of boreholes carried out along the alignment of the wall. This highlights the variability of the depth to high strength across the site'.* Golder Associates 00632017 MD – ICB, June 2000)

F. MacGregor et al. 1994 states that it could be postulated that a limiting value of efficient ripping for seismic velocity is around 3000m/s, after which the actual ripping data is not accurate.

'Above about 3000m/s, the data indicates that rock is not rippable with bulldozers of D10 size or less'. (F.MacGregor et al. 1994)

As there is no available seismic velocity information below high strength rock, the UCS values will be 24 and 70MPa respectively. This covers rock strength from the lower bound of high strength (UCS = 24MPa), to the high/very high strength interface (UCS = 70MPa) to the upper bound of very high strength (UCS = 240MPa).

In saying this, we will limit the value of seismic velocity to 3500m/s for very high strength rock used in equation (11). Seismic velocity in high strength rock will be 2300m/s as stated in the Golder report.

The ICB seismic velocities have been included in this research to apply the seismic parameters to MacGregor equation (11) for igneous rocks. This regression equation eliminates the subjective weathering rating parameter, structure rating, defect spacing as well as the grainsize parameter and gives a better correlation coefficient of $R^2 = 0.67$. This is opposed to the MacGregor regression equation (6) used for this research (which includes the weathering and grainsize ratings), which gives an R^2 value of 0.53. It must also be mentioned that equation (6) is specific to all rock types, and equation (11) specific to 'igneous rocks'. This comparison was made to compare the estimated productivity results using a different combination of parameters, and also to validate the estimated productivities from the MacGregor regressions for Brisbane Tuff, knowing that large bulldozers were unable to rip this area.

Table 24: MacGregor et al. 1994 Eq (11) – Rippability Productivity of Igneous Rock

Equation No. (11) Factor omitted : Weathering Rating, Grainsize Rating, Defect Spacing &Structure Rating	
√PRODUCTIVITY / MASS Note Mass = mass of Bulldozer inc. Ripper)	
Constant	+0.347
UCS (MPa)	-0.00118
Seismic Velocity (m/s)	-0.00014
Roughness Rating	+0.108
R^2	*0.67*
S (standard error of estimate)	*0.15*

F. MacGregor et al. 1994

4.5 Rippability Rating

Based on F. MacGregor et al. 1994, data was grouped based on the findings and ratings derived in the above headings.

Unconfined Compressive Strength (UCS) values were incremented in values of 10MPa, and weathering ratings from (1) to (9) for F. MacGregor et al., and (1), (1.5), (3), (5), (7.5) and (9.25) for the proposed 'weathering index' for this research. The Modified weathering rating had different bounds set as discussed in the last section in regard to minimum defect spacing, to reflect the typical fracture spacing / vs. degree of staining commonly encountered whilst drilling to significant depths during the investigation.

Defect roughness was given a value of (3), based on the rough nature of the defect surfaces and also the amplitude / length ratio of 0.1 to 0.15 to correspond to the F. MacGregor et al. ratings of defect roughness.

Structural description of the Tuff was categorized from the geological mapping as described earlier, which was (4) Tuff types having typically (3) joint sets for a range of strength values. F. MacGregor et al. structural rating of (1) was used which covered the joint spacing range of 'wide'; 0.6m to ' very wide; > 2m'

F. MacGregor et al. 1994 rates productivity in terms of m^3 / hr with specific reference to an 'ease of ripping'. This is based on observation and efficiency of the machine but it will differentiate between a D11 bulldozer inefficiently ripping $300m^3$/ hr (due to operator) 'without much effort, opposed to a D11 operating efficiently but finding it very difficult to rip more than $300m^3$/ hr. In the first scenario the efficiency of ripping needs to be looked at (i.e. operator experience or methodology of passes and runs), opposed to the second scenario where a larger machine or blasting maybe required. So the descriptor 'ease of ripping' indicates whether the machine is finding it difficult to be productive in ripping while operating as efficiently as possible.

Table 25: Productivity Grouping (F. MacGregor et al. 1994)

Productivity (m^3/hr)	**Ease of Ripping**
0-250	*Very Difficult (Blasting)*
250-750	*Difficult*
750-2000	*Medium*
2000-3500	*Easy*

>3500	*Very easy*

Table 26: Productivity^0.5/MASS vs. UCS for F. Macgregor et al. Weathering Ratings (1) – (9)

Grain Size **Rating glassy - fine** **1**	**Ave defect spacing (mm)** **1000**	**Brisbane Tuff - MASSIVE BEDDING** For 3 Joint Sets Massive : Wide to Very Wide Structural Rating 1 Assume Defect Roughness - Rough amplitude / length = 0.1 to 0.15 **[Rating 3]**								
		Productivity^0.5/ MASS								
		Weathering Rating								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
UCS	10	0.386	0.409	0.433	0.456	0.479	0.502	0.525	0.548	0.571
	20	0.349	0.372	0.395	0.418	0.441	0.464	0.487	0.510	0.534
	30	0.311	0.334	0.357	0.380	0.404	0.427	0.450	0.473	0.496
	40	0.274	0.297	0.320	0.343	0.366	0.389	0.412	0.435	0.458
	50	0.236	0.259	0.282	0.305	0.328	0.351	0.375	0.398	0.421
	60	0.198	0.221	0.245	0.268	0.291	0.314	0.337	0.360	0.383
	70	0.161	0.184	0.207	0.230	0.253	0.276	0.299	0.322	0.346
	80	0.123	0.146	0.169	0.192	0.216	0.239	0.262	0.285	0.308
	90	0.086	0.109	0.132	0.155	0.178	0.201	0.224	0.247	0.270
	100	0.048	0.071	0.094	0.117	0.140	0.163	0.187	0.210	0.233

Table 27: Productivity vs. UCS (D9R) for F. Macgregor et al. Weathering Ratings (1) – (9) & Proposed Modification of Weathering Rating and Defect Spacing / Degree of Staining Interaction

(D9R - Multi Shank 4885kgs)
Productivity vs. UCS (MacGregor)

		Weathering Rating								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
UCS	10	729	819	914	1014	1120	1230	1346	1467	1593
	20	594	675	762	854	951	1053	1160	1273	1390
	30	473	546	624	707	795	889	988	1092	1201
	40	365	430	499	574	654	739	830	925	1026
	50	272	328	389	455	527	603	685	772	865
	60	192	239	292	350	413	481	555	633	717
	70	126	165	209	258	313	373	438	508	583
	80	74	104	140	181	227	278	335	396	463
	90	36	58	85	117	155	197	245	299	357
	100	11	25	43	67	96	130	170	215	265
	120	4	0	2	9	21	38	61	88	121
	150	**Proposed Weathering Rating (Adjusted Brisbane Tuff)**								
		1	**1.5**	**3**	**5**	**7.5**	**9.3**			
UCS	10	612	773	970	1244	1654	1972			
	20	488	634	813	1066	1448	1746			
	30	379	509	670	901	1255	1533			
	40	284	397	541	750	1075	1334			
	50	202	299	425	613	910	1149			
	60	134	215	324	490	758				
	70	80	145	236	381	620				

Likely Defect Spacing (mm)		
Rating		
1.0	**1.5**	**3**
Spacing (mm)		
1500	1000	800

Likely Defect Spacing (mm)
Rating

80	40	89	162	285
90	14	46	102	
100	1	17	56	
120	17	1	5	

5.0	**7.5**	**9.25**
Spacing (mm)		
600	300	100

Note : Alternate Weathering Rating based on "Degree of Staining" truncating higher end values for XS – DS
Note: Upper and Lower Bounds set for defect spacing to use in regression equations
(i.e. weathering / global staining & joint spacing / water ingress interactions)

The first table shows the √Productivity/Mass of Dozer for the (9) F. MacGregor et al. 1994 weathering ratings as applied to regression equation (6). These are plotted against a range of UCS values. Assumed parameters such as defect spacing, defect roughness and grainsize are set to parameters shown in the table.

The first analysis is carried out using a common D9R multi-shank ripper, which weighs 4885kgs total with the multi-shank. This machine possesses a penetration force of 33,249lb (147 958 N), and a pry-out force of 74,639lb (324 680 N). Productivity (m^3/hr) of ripping is calculated across (9) weathering ratings for a range of UCS values as shown. The resulting curves show a general consistency in shape. Equation (6) is for all rock types, whether igneous, metamorphic or sedimentary and does not take into account interactions between weathering and UCS values. An example of this is that it is not likely to achieve a UCS value of 80 MPa for weathering rating (9). Parameters such as defect spacing and staining are also independent variables in this equation.

The lower section of the table shows the introduction of a ‘degree of staining’ rating, instead of ‘degree of weathering’. The idea is to form an interaction between the (5) of staining observed on the rock core, and the likely corresponding defect spacing. This can be justified by observing core photos such as that for NST207 as shown in the appendix. The degree of limonite staining is considered to be dependant on fracture spacing, and distinct changes in (5) of staining on the rock core coincide with increasing or decreasing defect spacing.

The resulting ‘degree of staining’ rating becomes simply a modification of upper and lower bounds for the weathering ratings used by MacGregor, as F. MacGregor state weathering ratings are subjective.

This is further justified by this statement on weathering;

> *‘It is futile to attempt to devise a single scheme of description and/or classification that will be suitable for the treatment of rocks as diverse as, for example, karstic limestones, granites and shales, which have been affected by different weathering processes. A variety of approaches is required for different situations and scales. Classes may be more rigorously defined by following local experience, site-specific studies or through reference to established schemes’.* (BS5930:1999 as cited in TP4 – Rock Description, Revision Level 3 April 2002)

The generic MacGregor weathering ratings of (1) to (9) have been modified to (1), (1.5), (3), (5), (7.5) & (9.25) which produces (6) curves instead of (9) curves.

Variable dependency has been introduced by proposing that average defect spacing values decrease as the 'degree of staining' rating is increased. These productivity values are therefore primarily driven by defect spacing and 'degree of staining' dependency which form a new 'weathering index'. It must be stated that this dependency may only be specific to this rock type, and another rock type would need to be investigated before assuming this particular variable dependency.

It is noted that some of the higher end UCS values have been truncated so that the highly weathered or 'stained rock' at the lower end of perhaps rating (9.25), is unlikely to achieve a UCS value of 80MPa as stated earlier.

The comparison is shown below between the F MacGregor et al. 1994 curves and the proposed modified productivity curves. These curves and subsequent productivity of rippability values are once again specific to a D9R with a multi-shank ripper, but the variance in productivity is discussed.

The proposed modification shows a more conservative spread of values in the first couple of 'degree of staining / defect spacing' categories. For example, MacGregor achieves productivities of 74, 104, 140 and 181m^3/hr for the first (4) weathering categories for UCS 80MPa rock, where the modified approach achieves 40, 89, 162 and 285 m^3/hr productivities respectively for the same UCS value.

This also puts the first (2) 'degree of staining' categories into the 'blast to rip' category at UCS 42 and 58 MPa (High to Very High Strength) respectively, opposed to 46 and 60 MPa (High to Very Strength) when using the unmodified weathering rating. This seems like a small variation, but it is likely a large proportion of samples will be classified in categories (1) , (2) as seen by core photos (i.e. 0 - 40% staining and defect spacing to 1500mm), as well as being in the high to very high strength range. It was already shown by insitu jointing photos that the structural rating for Tuff is based on 'wide to very wide' joint set spacing predominantly. Therefore it is proposed that a larger proportion of Tuff will be unrippable based on this and require blasting if a D9R multishank ripper was the only dozer available.

When observing the values of 'degree of staining' category (3) it is noted that the productivity of rippability value becomes greater than that proposed by MacGregor for the same value of 80 MPa. This is because from category (1) to (3) on the modified approach, the defect spacing has decreased from 1500mm to 800mm. The defect spacing is starting to pull the upper end of the curve steeper, and subsequently from ratings (3) to (6) the calculated productivities are higher than MacGregors. This may be treated with some caution, however, as it must be remembered this is driven by defect spacing and a judgement would be made to categorize a 'degree of staining' as well. The Tuff would need to be highly fractured, or unwelded to achieve these values after about category (3). Once again, this would be a rarity as it is noted both the northern portal of the tunnel as well as the ICB tunnel required blasting. It is proposed that the rippability of Tuff is usually overestimated, and the modified approach would classify more area as unrippable.

Figure 14: Brisbane Tuff Rippability using Equation (6) and MacGregor Weathering Rating for D9R

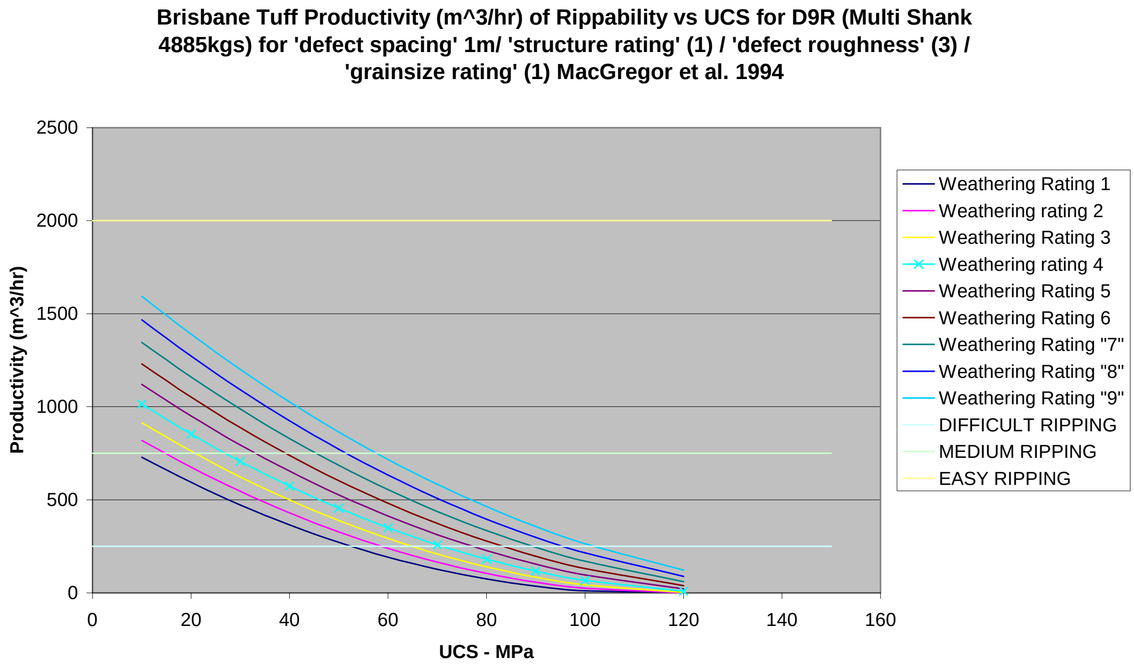
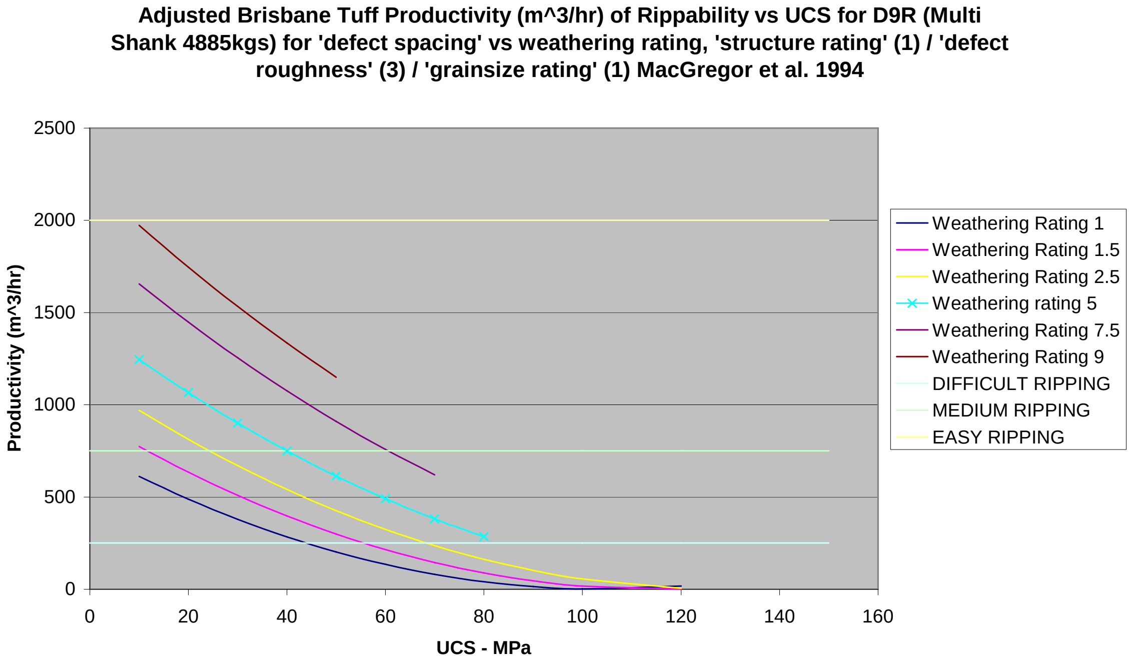


Figure 15 : Brisbane Tuff Rippability using Equation (6) and Modified Weathering Rating for D9R



The D11R CD Dozer with single shank ripper will now be assessed as it is one of the largest rippers as listed in the Caterpillar Performance Handbook Edition 33 October 2002. The installed weight of the machine with the standard shank is 13,584kgs, with ripper forces of about 71,560lb (318 440 N) penetration force vertically and 139,160lb (619260N) pry-out force. This large machine can rip to 1612mm maximum digging depth.

Once again, Productivity (m³/hr) of ripping is calculated across (9) weathering ratings for a range of UCS values as shown, as well as calculated across the proposed 'modified' weathering ratings.

Table 28: Productivity vs. UCS (D11R CD) for F. Macgregor et al. Weathering Ratings (1) – (9) & Proposed Modification of Weathering Rating and Defect Spacing / Degree of Staining Interaction

(D11R CD - Single Shank 13584kgs)
Productivity vs UCS (MacGregor)

Weathering Rating

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	0									
	10	2027	2277	2541	2820	3113	3421	3743	4080	4431
	20	1652	1878	2119	2374	2643	2927	3226	3539	3867
	30	1315	1517	1734	1966	2212	2472	2747	3037	3341
	40	1016	1195	1389	1596	1819	2056	2307	2573	2853
	50	756	911	1081	1265	1464	1678	1905	2148	2404
UCS	60	534	666	812	973	1148	1338	1542	1761	1994
	70	351	459	582	719	870	1036	1217	1412	1622
	80	206	290	389	503	631	773	930	1102	1288
	90	99	160	236	326	430	549	682	830	993
	100	31	69	120	187	267	363	473	597	736
	120	10	0	5	24	58	106	168	245	337
	150									

Proposed Weathering Rating (Adjusted Brisbane Tuff)

		1	**1.5**	**3**	**5**	**7.5**	**9.25**
	10	1701	2150	2696	3460	4601	5484
	20	1358	1763	2260	2964	4025	4854
	30	1055	1414	1863	2506	3489	4263
	40	789	1104	1504	2087	2990	3710
	50	562	832	1183	1705	2530	3195
UCS	60	374	598	901	1363	2108	
	70	223	403	657	1058	1725	
	80	112	246	452	792		
	90	38	128	285			
	100	3	48	156			
	120	49	3	14			

Likely Defect Spacing (mm)
Rating

1.0	**1.5**	**3**
Spacing (mm)		
1500	1000	800

Likely Defect Spacing (mm)
Rating

5.0	**7.5**	**9.25**
Spacing (mm)		
600	300	100

It can be seen from above looking at the UCS = 80MPa (lower bound of very high strength) range that the F. Macgregor et al. weathering ratings estimate a productivity of rippability at 206 & 290 m³/hr (for a D11R CD 13584kg single shank) opposed to 74 & 104 m³/hr for the D9R (4885 kg multi-shank) for the first (2) weathering categories. This means a D11R CD may not be able to rip Brisbane Tuff of UCS = 80 MPa in the first and second 'degree of weathering' ratings, or do so with great 'difficulty' at 206 & 290 m³/hr. Note: Productivity grouping mentioned earlier limits 'difficult' ripping to between 250 – 750 m³/hr, so it is likely the rock may need blasting in 'degree of weathering' rating (1).

Using the modified 'degree of staining' approach, these estimated productivity of rippability values reduce to 112m³/hr & 246 m³/hr respectively in the first (2) 'degree of weathering' categories. This shows that the modified approach used in this research is more conservative, and even the larger D11R CD will be unable to rip the rock until either the 80MPa rock has between 800mm and 1000mm defect spacing and possibly 70% staining over rock mass, or unless the Tuff is UCS 70MPa and 'degree of staining' category (2). These UCS values are still lower bound very high strength (i.e. Is 50 = 3 to 10 MPa using multiplier of 17.6 to determine UCS).

It was stated earlier that it is observed the majority of the Brisbane Tuff formation falls into this Is (50) 3-10 range as shown in test results. It was also proposed under the limitations of the Is (50) test that some samples may have Is (50) values much greater than 3MPa if the samples were prepared with care and an automatic loader was used rather than a hand lever.

Shown below are the respective regression curves for the D11R CD single shank for both the F. MacGregor et al. 1994 weathering rating and the modified approach.

Figure 16: Brisbane Tuff Rippability using Equation (6) & MacGregor Weathering Rating for D11R CD

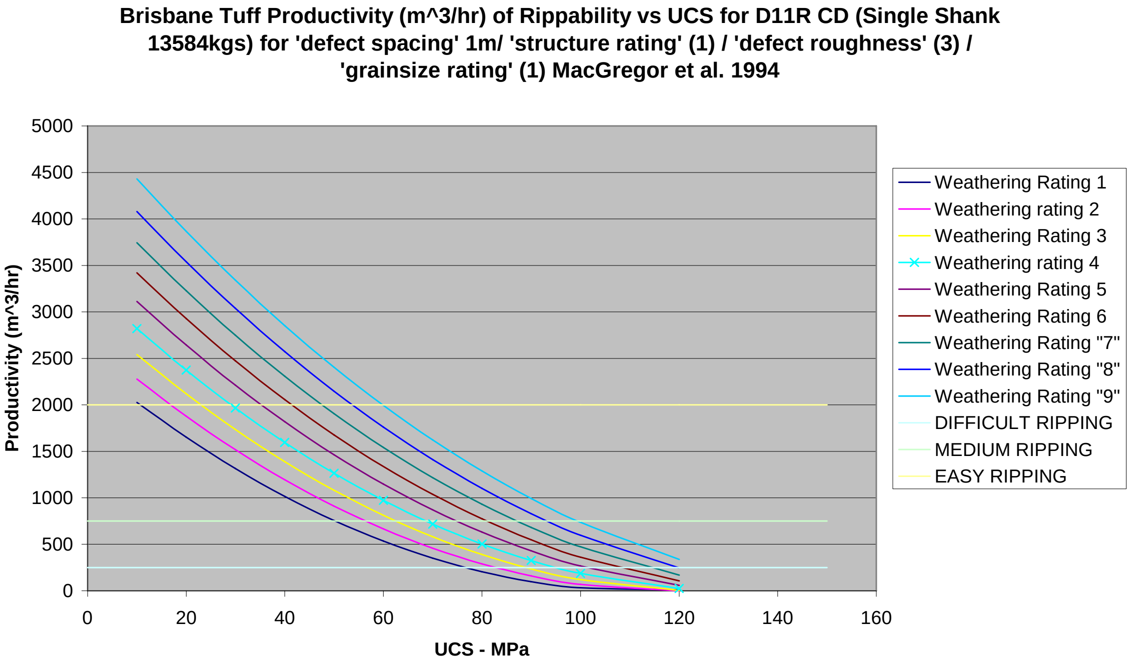
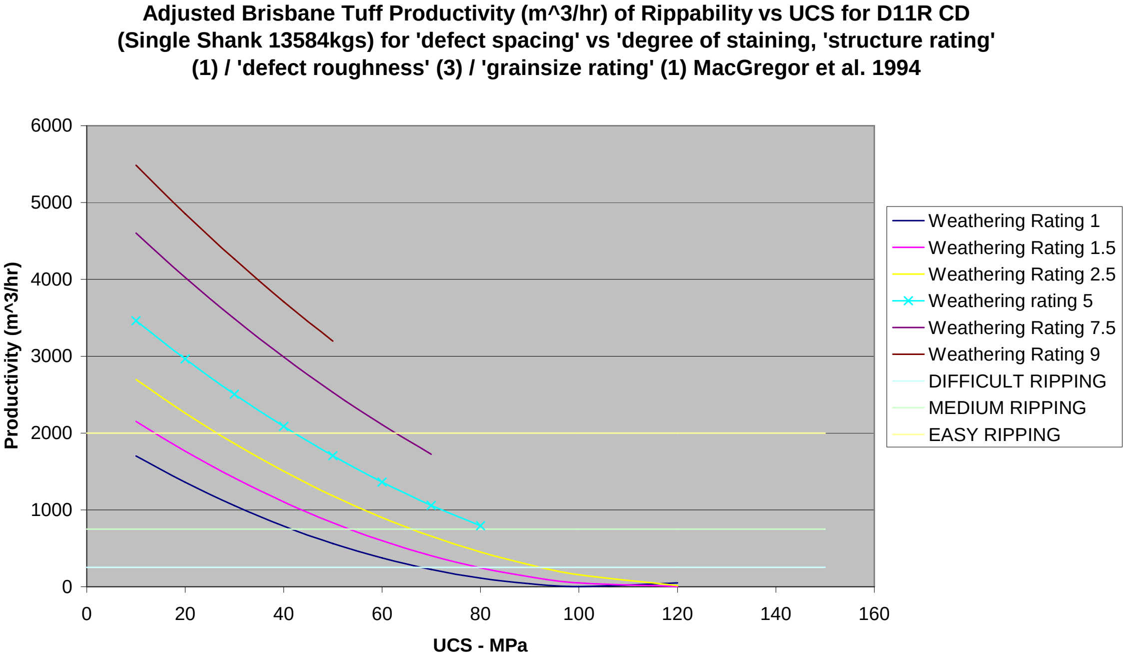


Figure 17: Brisbane Tuff Rippability using Equation (6) and Modified Weathering Rating for D9R



Note: from the curves above, using the modified approach places 'degree of staining' category (1) as unrippable by a D11R CD above UCS 65MPa (~ Is 50 = 3.6MPa). This is the lower bound of very high strength. It is estimated the Tuff is unrippable at ~ UCS 80MPa or thereabouts for 'degree of staining' category (1.5). This may mean any rock classified as 'high to very high' strength could be assessed to be ripped using the modified approach, provided it falls into 'degree of staining' category (1.5) with 1m average defect spacing. A similar result of UCS 90MPa for 'slightly weathered Tuff' (SW) could be expected in comparison to the F. MacGregor et al. rating which is well and truly in the very high strength range. (i.e. Is 50 > 5 MPa). Therefore the comparison is made to show that it may be tempting to rip using a dozer when using the MacGregor approach, and blast using the modified approach.

The ICB seismic velocities will now be applied directly to F. MacGregor et al. equation No. 11 which eliminates subjective parameters such as the weathering and structure rating as mentioned under 'seismic velocities'. This area was previously assessed by Golder Associates to be unrippable before construction of the cut and cover tunnel. Contrary to that advice however, large machines such as D10 and D11 dozers initially attempted to rip and failed, and the area was line blasted to loosen the rock. Applying the data to equation (11) will at least give a data comparison to a failed ripping attempt in similar geology 50-100m away from some of the boreholes that were drilled for this research. The D11R CD 13,584kg single shank dozer will be used in the analysis.

Note: Seismic velocities of 2300m/s will be used in high strength rock (Is 50 > 1MPa), and a limiting velocity of 3500m/s will be used for high and very high strength rock (Is 50 > 3 MPa) as per Golder Associates report 00632017 MD – ICB, June 2000.

Figure 18: Application of ICB Seismic Velocities to MacGregor et al. 1994 Equation (11)

Brisbane Tuff - Equation (11) using ICB seismic data

Seismic velocity H - **2300m/s (UCS = 17.6 Mpa)** & VH - **3500m/s (USC = 53MPa)**

Assume Defect Roughness - Rough amplitude / length = 0.1 to 0.15 **[Rating 3]**

	Mpa	**Productivity^0.5/ MASS**
UCS	**17.6**	**0.328**
	53	**0.118**

		Various Machines **Productivity vs UCS (MacGregor) for 2300 & 3500m/s**		
	Mpa	**D11R - single**	**D10R - multi**	**D9R- multi**
UCS	**17.6**	***1463***	***745***	***526***
	53	***191***	***97***	***69***

Note: H - 2300m/s / VH - 3500m/s

Figure 19: Modified Approach D11R CD ‘Productivities at UCS 17.6 & 53 MPa (H & VH Strength)

UCS	**Degree of Staining Rating (1) ~ (Fr – SW)**	**Degree of Staining Rating (1.5)**
17.6	1437m^3/h	1853 m^3/h
53	**501 m^3/h**	**758 m^3/h**

Figure 20: F. MacGregor et al. D11R CD ‘Productivities at UCS 17.6 & 53MPa (H & VH Strength)

	Weathering Rating								
UCS	**1**	**2**	**3**	**4 (SW)**	**5**	**6**	**7**	**8**	**9**
17.6	1738	1970	2217	2477	2753	3042	3347	3665	3999
53	**685**	**834**	**996**	**1174**	1365	1572	1792	2028	2277

The comparison above shows that the estimation of productivity of ripping is reduced further by using MacGregor equation (11), applied to the ICB seismic data. Productivities of 1463 & 191m^3/hr were calculated for a D11R CD at the lower limit of high strength Tuff (UCS 17.6MPa) and the lower limit of very high strength Tuff (UCS 53MPa). The productivities indicate that the D11R will not be productive in ripping very high strength Tuff, and also the upper values of high strength (i.e. Is 50 = 2-3 MPa). The modified approach using equation (6) shows a similar productivity of ripping value at UCS 17.6 MPa Tuff, but a less conservative value of 501m^3/hr at the lower UCS bound for very high strength rock (i.e. UCS = 53MPa). The MacGregor values are significantly higher for the first (4) weathering ratings with productivity values in excess of 1100m^3/hr for even weathering rating (4), which is ‘slightly weathered’ (SW). When considering this, an observation of the borelogs and core photos show the extensive use of the weathering classification (SW) corresponding to high to very high strength rock, which may give a misleading indication that ‘slightly weathered Tuff’ can be ripped at excessive rates per hour (> 1100m^3/hr). In the modified approach, a term such as ‘slightly weathered’ is taken into account ‘subjectively’ somewhere within the degree of staining rating (1) and (1.5), so productivity estimates could be 50 to 60% less towards the ‘blasting’ rating.

This shows the (3) regression curves are of different shape and gradient, and equation (11) will give more conservative values for ripping productivity at the higher UCS values. It must be pointed out that equation (11) has a higher correlation coefficient of $R^2 = 0.67$, however the seismic data used was limited and from an adjacent site.

Seismic data can easily be misinterpreted if the rock is highly fractured or boulders are present, as the seismic arrival times to geophones will be reduced if the waves intercept voids within the rock groundmass. In this case however, the result is validated as the ICB cut and cover tunnel was blasted to enable ripping of the Tuff, which was high to very high strength as indicated earlier in Table 2 of Golder Associates report 00632017 MD – ICB, June 2000.

CHAPTER 5 CONCLUSIONS

Brisbane Tuff is generally a very difficult rock to rip, or even classified as unrippable using large bulldozers such as the D11R. It is proposed that if using rating methods such as the one devised by F. MacGregor et al. (1994) to estimate rippability of Brisbane Tuff, a characteristic weathering index must be derived specific to the site to avoid an over or under-estimation rippability. As seen in several weathering ratings derived by authors such as F.MacGregor et al. (1994), Franklin (1970), Franklin et al (1971), Weaver (1975), Chevassu (1978), Kirsten (1982), Minty & Kearns (1983), Scoble & Muftuoglu (1984), Pells (1985), Smith (1986), Singh, Denby & Egretli (1987) and Hadji-georgiou & Scoble (1990), weathering is often semi-quantified as a spectrum of numerical values independent of other variables which are associated or contributors to weathering. Some of these dependant variables which are contributors to weathering in many rocks including ignimbrite, may include defect type and spacing, geochemistry, water ingress and associated limonite staining, alteration, depositional factors or degrees of cementation and welding.

This research paper intended to firstly dispel the common idea that there is a significant strength variation in Brisbane Tuff across typically used weathering grades (Fr-HW), to justify the variation in rippability estimates (m^3/hr) using F. MacGregor et al. regression equations. MacGregor and other authors listed above use the same assumption that weathering and strength are married.

In conclusion, the results showed less than expected strength variation between weathering grades, as well as a more apparent dependency between limonite staining and defect spacing in Brisbane Tuff. These (2) factors were used to develop a ‘weathering index’ specific to the Tuff which gave more conservative estimates of rippability when applied to F. MacGregor et al. 1994 equations. These more conservative estimates showed Brisbane Tuff generally falls into the ‘blast to rip’ category when point load index or Is (50) is greater than 3 MPa. Most of the attached boreholes show Tuff as Is (50) > 3MPa even at shallow depths, with limited weathering profiles. It has been found some sites such as the Brisbane ICB cut and cover tunnel could not be ripped using large machines, and rippability was in fact overestimated for a Brisbane Tuff site (Royal Brisbane Hospital -

RBH) resulting in litigation proceedings, so the more conservative rippability results obtained have some validation.

Quantitative and qualitative information was gathered from boreholes and tests to apply to MacGregors regressions to justify all numerical results.

Seismic data (from similar Brisbane Tuff geology) mirrored these more conservative values when applied to MacGregor regression number (11). The equation used gave a more accurate coefficient of regression than equation (6) which weighted heavily on UCS and weathering characteristics. It is suggested that if a site specific weathering is derived to modify the MacGregor numerical weathering rating, it may improve the accuracy of the rippability assessment.

Also, it was shown the correlation of pointload index (Is 50) to unconfined compressive strength (UCS) is much lower for Brisbane Tuff at (17.6), than the generally used correlation of (20-24) for most rock types. These results were justified by relevant literature based on extensive testing in the same area by another author.

Another conclusion is that although Brisbane Tuff may be classified as a homogeneous rock, varying degrees of welding and alteration exist within the deposit possibly due to depositional cooling units and proximity of the ash-fall to the underlying conglomerates. This may have implications when excavating or tunneling on designs based on limited borehole information. It is proposed that sections of highly welded porphrytic Tuff and unwelded Tuff can co exist within metres as found whilst drilling large diameter piles at Windsor, possibly ranging in strength from UCS 0.1MPa to UCS 150+ MPa. At the time of submission of this paper the 12m diameter TBM (tunnel boring machines) are to shortly commence boring (December 2007) in areas directly investigated for this research. The clients expectations are the TBM's will advance at 20m per day, so it will be seen if tunnel boring progress is hampered by zones of highly welded 'porphrytic' rock.

Future work may include an application of the methodologies used in this research to estimate rippability in other rock types including other igneous, metamorphic and sedimentary rocks. This may mean further analysis of specific rock characteristics and developing a 'weathering index' relevant for other rocks. Geochemistry and rockmass alterations may be included to develop an alternative index, or new regression equations developed using different parameters with greater accuracy.

CHAPTER 6 REFERENCES

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APPENDIX A – PROJECT SPECIFICATION

University of Southern Queensland
Faculty of Engineering and Surveying

ENG 4111/2 Research Project
PROJECT SPECIFICATION

FOR:	Stephen Schuh
STUDENT NO:	0019920352
SUPERVISOR:	John Worden
TECHNICAL ADVISOR:	David Starr

PROJECT AIM: This project aims to measure / correlate rock density, point load index, unconfined compressive strength (UCS), average defect spacing and weathering index for Brisbane Tuff's of similar weathering profiles, then devise a rippability index which could be used to determine costing and excavation properties.

PROGRAMME: Issue A, 04 April 2007

1. Determine suitable Brisbane Tuff site / sites which have similar weathering profiles and 'formation / geological properties' (i.e. welding properties, no folding but vertical weathering profiles)

2. Examine existing core logs / defect logs and test result data. Choose samples / boreholes for analysis and view existing test data and conduct UCS testing, point load testing Is (50), and other tests where required.

3. Start thinking about what could be done with rock strength / weathering / fracture spacing data for the Tuff in regard to correlations.

4. Demonstrate a correlation between properties, such as strength, fracture spacing and weathering to formulate a useful 'rippability index' for this rock type.

Agreed;

John Worden: Stephen Schuh:

(Supervisor) Dated: 4 /4 /2007 (Student)

APPENDIX B – CORE PHOTOS

Golder Associates

PRELIMINARY REPORT OF PHOTOGRAPHS: NST207

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: RNA Showgrounds
JOB NO: 06632062

COORDS: 53213.0 m E 161022.0 m N BCSG02
SURFACE RL: 9.10 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 25.00 m

DEPTH RANGE: 1.85 – 19.00 m
DRILL RIG: FD500
DRILLER: Foundril
LOGGED: SS DATE: 3/10/06
CHECKED: LBM DATE: 2/01/07

PRELIMINARY REPORT OF PHOTOGRAPHS: NST207

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: RNA Showgrounds
JOB NO: 06632062

COORDS: 53213.0 m E 161022.0 m N
BCSG02
SURFACE RL: 9.10 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 25.00 m

DEPTH RANGE: 19.00 – 25.00 m
DRILL RIG: FD500
DRILLER: Foundril
LOGGED: SS DATE: 3/10/06
CHECKED: LBM DATE: 2/01/07

Golder Associates

PRELIMINARY REPORT OF PHOTOGRAPHS: NST206

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: RNA Showgrounds
JOB NO: 06632062

COORDS: 53234.0 m E 161049.0 m N BCSG02
SURFACE RL: 11.80 m DATUM: AHD
INCLINATION: -64° DIRECTION: 011°
HOLE DEPTH: 29.08 m

DEPTH RANGE: 1.60 – 18.70 m
DRILL RIG: FD500
DRILLER: Foundril
LOGGED: VAL DATE: 14/9/06
CHECKED: LBM DATE: 2/01/07

PRELIMINARY REPORT OF PHOTOGRAPHS: NST206

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: RNA Showgrounds
JOB NO: 06632062

COORDS: 53234.0 m E 161049.0 m N BCSG02
SURFACE RL: 11.80 m DATUM: AHD
INCLINATION: -64° DIRECTION: 011°
HOLE DEPTH: 29.08 m

DEPTH RANGE: 18.70 – 29.08 m
DRILL RIG: FD500
DRILLER: Foundril
LOGGED: VAL DATE: 14/9/06
CHECKED: LBM DATE: 2/01/07

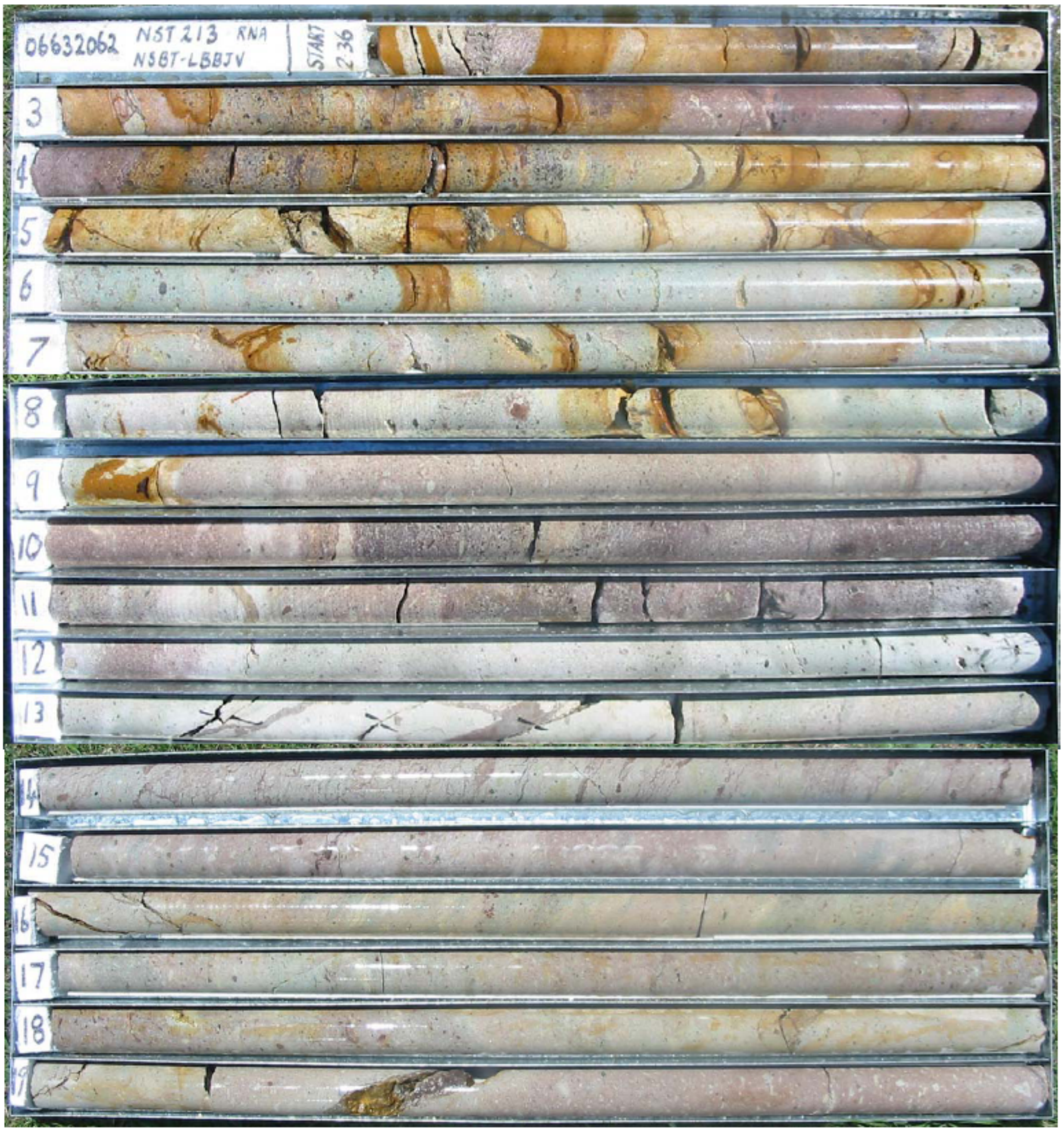
Golder Associates

PRELIMINARY REPORT OF PHOTOGRAPHS: NST213

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: RNA (Adj Douglas Wodley Dog Pav)
JOB NO: 06632062

COORDS: 53332.1 m E 160625.2 m N BSCG02
SURFACE RL: 6.63m DATUM: AHD
INCLINATION: -60° DIRECTION: 045°
HOLE DEPTH: 43.16m

DEPTH RANGE: 2.36 – 20.00m
DRILL RIG: FD500
DRILLER: Foundril
LOGGED: SS DATE: 5/10/06
CHECKED: LBM DATE: 8/01/07



Golder Associates

PRELIMINARY REPORT OF PHOTOGRAPHS: NST213

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: RNA (Adj Douglas Wodley Dog Pav)
JOB NO: 06632062

COORDS: 53332.1 m E 160625.2 m N BSCG02
SURFACE RL: 6.63m DATUM: AHD
INCLINATION: -60° DIRECTION: 045°
HOLE DEPTH: 43.16m

DEPTH RANGE: 20.00 – 38.00m
DRILL RIG: FD500
DRILLER: Foundril
LOGGED: SS DATE: 5/10/06
CHECKED: LBM DATE: 8/01/07

Golder Associates

PRELIMINARY REPORT OF PHOTOGRAPHS: NST213

	COORDS: 53332.1 m E 160625.2 m N BSCG02	DEPTH RANGE: 38.0 – 43.16m
CLIENT: LBBJV	SURFACE RL: 6.63m DATUM: AHD	DRILL RIG: FD500
PROJECT: NSBT	INCLINATION: -60° DIRECTION: 045°	DRILLER: Foundril
LOCATION: RNA (Adj Douglas Wodley Dog Pav)	HOLE DEPTH: 43.16m	LOGGED: SS DATE: 5/10/06
JOB NO: 06632062		CHECKED: LBM DATE: 8/01/07

PRELIMINARY REPORT OF PHOTOGRAPHS: NST228

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: Shaftston Avenue
JOB NO: 06632062

COORDS: 53690.8 m E 158075.3 m N BCGS02
SURFACE RL: 19.40 m DATUM: AHD
INCLINATION: -60° DIRECTION 000°
HOLE DEPTH: 25.00 m

DEPTH RANGE: 5.29 – 25.0 m
DRILL RIG: FD500
DRILLER: Foundril
LOGGED: SRT/SS DATE: 23/6/06
CHECKED: LBM DATE: 30/09/06

Golder Associates

PRELIMINARY REPORT OF PHOTOGRAPHS: NST241

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: Sneyd St
JOB NO: 06632062

COORDS: 53158.0 m E 161215.4 m N BCSG02
SURFACE RL: 9.55 m DATUM: AHD
INCLINATION: -60° DIRECTION 188°
HOLE DEPTH: 26.00 m

DEPTH RANGE: 0.10 – 18.00 m
DRILL RIG: Fox B40
DRILLER: Schneider Drilling
LOGGED: SS DATE: 7/11/06
CHECKED: LBM DATE: 5/02/07

PRELIMINARY REPORT OF PHOTOGRAPHS: NST241

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: Sneyd St
JOB NO: 06632062

COORDS: 53158.0 m E 161215.4 m N BCSG02
SURFACE RL: 9.55 m DATUM: AHD
INCLINATION: -60° DIRECTION 188°
HOLE DEPTH: 26.00 m

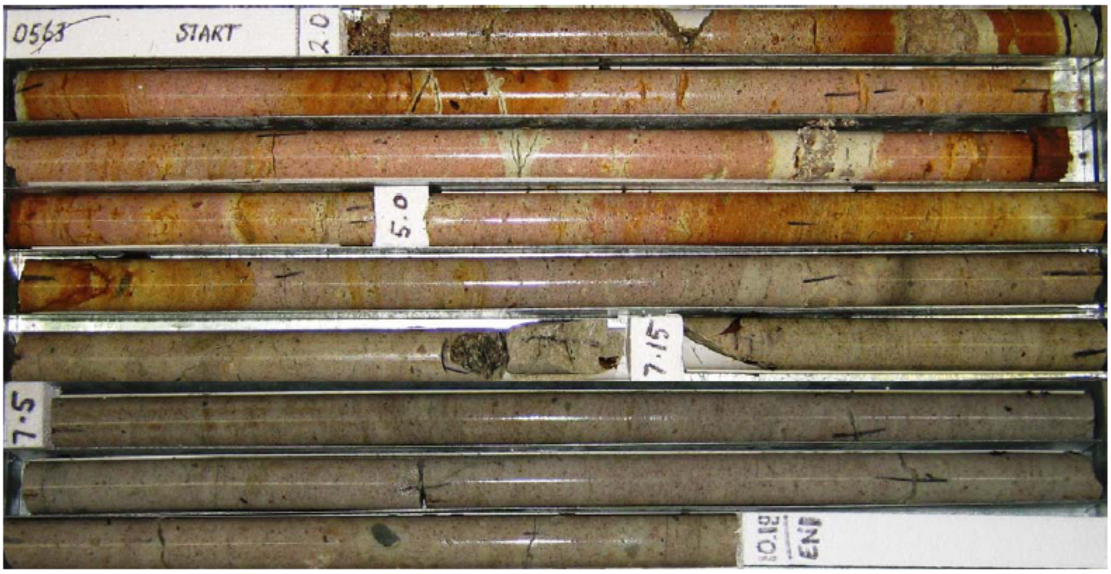
DEPTH RANGE: 18.00 – 26.00 m
DRILL RIG: Fox B40
DRILLER: Schneider Drilling
LOGGED: SS DATE: 7/11/06
CHECKED: LBM DATE: 5/02/07

PRELIMINARY REPORT OF PHOTOGRAPHS: NST249

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: Shafston Avenue
JOB NO: 06632062

COORDS: 53690.9 m E 158050.8 m N BCSG02
SURFACE RL: 17.5 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 10.18 m

DEPTH RANGE: 2.0 – 10.18 m
DRILL RIG: FD500
DRILLER: Foundril
LOGGED: SS DATE: 29/6/06
CHECKED: LBM DATE: 30/09/06



Golder Associates

REPORT OF PHOTOGRAPHS: NST257

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: Deakin St
JOB NO: 06632062

COORDS: 53574.4 m E 158406.8 m N BSCG02
SURFACE RL: 10.11 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 36.00m

DEPTH RANGE: 3.00 – 20.00m
DRILL RIG: FD500
DRILLER: Foundril
LOGGED: SS DATE 27/11/06:
CHECKED:MSC DATE: 18/4/07

Golder Associates

REPORT OF PHOTOGRAPHS: NST257

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: Deakin St, Kangaroo Point
JOB NO: 06632062

COORDS: 53574.4 m E 158406.8m N BSCG02
SURFACE RL: 10.11m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 36.00m

DEPTH RANGE: 20.00 – 32.00m
DRILL RIG: FD500
DRILLER: Foundril
LOGGED: SS DATE 27/11/06:
CHECKED:MSC DATE: 18/4/07

Golder Associates

PRELIMINARY REPORT OF PHOTOGRAPHS: NST347

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: Horace St
JOB NO: 06632062

COORDS: 53238 m E 161392.1 m N BCSG02
SURFACE RL: 5.07 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 15.90 m

DEPTH RANGE: 10.7 m to 15.9 m
DRILL RIG: Fox B40
DRILLER: Schneider Drilling
LOGGED: SS DATE: 20/11/06
CHECKED: MSC DATE: 2/04/07

PRELIMINARY REPORT OF PHOTOGRAPHS: NST348

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: Horace St
JOB NO: 06632062

COORDS: 53220.1 m E 161377.2 m N BCSG02
SURFACE RL: 5.00 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 21.50 m

DEPTH RANGE: 16.30 m to 21.50 m
DRILL RIG: Fox B40
DRILLER: Schneider Drilling
LOGGED: SS/AGS DATE: 21/11/06
CHECKED: MSC DATE: 2/04/07

Golder Associates

PRELIMINARY REPORT OF PHOTOGRAPHS: NST349

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: Horace St
JOB NO: 06632062

COORDS: 53107.4 m E 161415.8 m N BCSG02
SURFACE RL: 2.89 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 25.92 m

DEPTH RANGE: 20.70 m to 25.92 m
DRILL RIG: Fox B40
DRILLER: Schneider Drilling
LOGGED: SS DATE: 9/11/06
CHECKED: MSC DATE: 2/04/07

APPENDIX C – BOREHOLE LOGS

Golder Associates

FIELD DRILLING REPORT

(SOIL OR
SOIL & ROCK)

REPORT OF BOREHOLE: NST 207

PROJECT No.: 06632062 SHEET 1 of
CLIENT: LBBJV.
PROJECT: NSBT.
LOCATION: RN4.
BOREHOLE LOCATION: E. N
SURFACE RL: m DATUM: CO-ORD. SYSTEM
INCLINATION: -90. ° AZIMUTH: ° ZONE:
START: 3/10/6 at 0700 hrs FINISH: 4/10/6 at 1500 hrs
DRILL RIG: J.McDonald LOGGED: 88

DRILLING METHOD

CONTRACTOR: Foundril.
DIATUBE CORE/DTHH: m to. m
AUGER (V, [✓ T-C], HAND): 0 mm dia. to. 1.6 m
ROTARY (BLADE/TRI[✓ CONE]): 1.6 m to. 1.8 m
ROTARY (AIR/WATER): m to. m
MUD P, N: 1.8 m to. 25.0 m
[✓ NMLC]/ /CORE: 1.8 m to 25.0 m
CASING HW to m NW to m
OTHER:

GROUNDWATER

☐ Groundwater Observed at ....m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at ....m depth .... hrs
☐ Groundwater Level at ......m on completion of drilling at .....hrs
☐ Groundwater Level at ......m at ......hrs date ../../..
☐ Groundwater Level at ......m at ......hrs date ../../..
☐ ....
☐ Groundwater Not Encountered while ....* to ....m depth
☑ Groundwater Not Observed due to introduction of Drilling Water Below 1.6 m depth
☐ Total/Partial Drilling Water Loss at/Below ..m...
☐ Borehole baled to ....m depth on completion of drilling
☐ ....mm Standpipe Installed to ....m depth on Completion of Drilling
*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING					FIELD SAMPLING AND TESTING									FIELD MATERIAL DESCRIPTION					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DRILLING OBSERVATIONS DESCRIPTION OF CUTTINGS, DETAILS OF STRATA CHANGES MINOR PROPERTIES, DRILL METHOD, DRILL REFUSAL ETC.	TYPE	DEPTH FROM	DEPTH TO	RESULTS 0–150mm or Run Length	RESULTS 150–300 or Rec. Length	RESULTS 300–450 or R.Q.D. Length	RESULTS N VALUE % Rec. % RQD	P.P. kPa	SAMPLE DESCRIPTION FIELD ASSESMENT OF RECOVERED SAMPLE e.g. SOIL OR ROCK TYPE, PLASTICITY, COLOUR, INCLUSIONS, MOISTURE, STRENGTH	DEPTH (metres)	UC Symbol	SOIL / ROCK MATERIAL DESCRIPTION (SOIL OR ROCK NAME, PLASTICITY OR PARTICLE SIZE, COLOUR, SECONDARY COMPONENTS, MOISTURE, STRENGTH)	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
A	L	–	0	Concrete – Pavement.										0		Concrete Pavement.			
H			0.15	FILL – clayey GRAVEL (GC) fine – med gravel, dk brown, MD, moist	SPT	1.0		2	2	45	76		Sandy CLAY (CL), low pl, grey, fine – med sand, moist, stiff (RS).	0.15	GC	FILL – clayey GRAVEL (GC) fine-medium gravel, dark brown, moist, medium dense.	m	MD	
D			0.5	sandy CLAY (CL), l.p.l., dk grey, fine sand, stiff, moist.										0.5	CL	sandy CLAY (CL), low plasticity, dark grey, fine sand, moist, stiff.	m	St.	
R D	M-H		1.6	– rock – ~~[illegible]~~ higher drilling resist										1.6		TUFF, fine grained, pale grey, slightly weathered, high strength			
				START CORING 1.85m												See Rock log			

O:\GAIMS\Brisbane Forms\GA_BO-108 FIELD DRILLING REPORT SOIL & ROCK.dwg Sep 08, 2006 – 1:53pm

11.62 FR ??

Golder Associates
611 Coronation Drive
Toowong, QLD 4066
&
Unit1/51 Secam Street
Mansfield, QLD 4122

FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? Y/N

REPORT OF BOREHOLE: NST 207

PROJECT No.: 06632062 SHEET 1 of ~~2~~ 3
CLIENT: LBBJV
PROJECT: NSBT
LOCATION: RN4
BOREHOLE LOCATION: ………… E ………… N
SURFACE RL: ………… m DATUM: ………… CO-ORD. SYSTEM …………
INCLINATION: -90 ° AZIMUTH: ………… ° ZONE: …………
START: 3 / 10 / 6 at 0 hrs FINISH: 4 / 10 / 6 at 1500 hrs
DRILL RIG: J. McDonald (FD500) LOGGED:

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD
1.85	25.0	76	NMLC

Note: Water loss 22.6 m

OTHER: …………

GROUNDWATER

☐ Groundwater Observed at ……… m depth during drilling 0.05
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW 0.09
☐ Sample Wet at ……… m depth ……… hrs 0.04
☐ Groundwater Level at ……… m on completion of drilling at ……… hrs 0.18
☒ Groundwater Level at 12.3 m at 0700 hrs date 4 / 10 / 6
☒ Groundwater Level at 11.9 m at 1400 hrs date 4 / 10 / 6
☐ …………
Water loss 22.6. 0.06
☐ Groundwater Not Encountered while ……… * to ……… m depth
☒ Groundwater Not Observed due to introduction of Drilling Water Below 1.8 m depth
☐ Total/Partial Drilling Water Loss at/Below 22.6 m
☐ Borehole baled to ……… m depth on completion of drilling
☐ ……… mm Standpipe Installed to ……… m depth on Completion of Drilling
*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING							FIELD MATERIAL DESCRIPTION										DEFECT INFORMATION						COMMENTS
DEPTH (m)		RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS		DEPTH (m)		MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING			STRENGTH			DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	ADS ☐ FF ☒ DEFECT FREQUENCY				SAMPLES, IN-SITU TESTS, DRILLING NOTES
FROM	TO				FROM	TO	FROM	TO		FROM	TO	CODE	FROM	TO	CODE			FROM	TO	No./(m)	FREQUENCY	
1.85	2.7	0.85	0.85/100	0.68/80	-	-	1.85	2.84	TUFF, fine grained to medium	1.85	2.84	SW	1.85	3.1	H-VH	2.06	J, 0°, Un, Ro - Sn	1.85	4.15	17/2.3	7.4	
									grained, pale grey, sub-angular							2.06	J, 70°, Un, Ro, healed.					
2.7	5.7	3.0	3.0/100	2.82/94	-	-			clasts to 10mm, staining around	3.1	11.62	SW-FR	2.84	11.62	VH	2.2	J, 80°, Un, Sm, clay veneer					
									fractures							2.25	J, 80°, Un, Sm, clay veneer					
							2.84	4.6	- becoming purple & pale grey	11.62	25.0	FR	11.62	25.0	VH	2.31	J, 10°, Un, Ro, Sn black mineral	6.17	6.87	5/0.7	7.14	
5.7	8.7	3.0	3.0/100	2.9/97	-	-	4.6	6.31	- becoming pale grey							2.5	J, 0°, Un, Ro					
							6.31	17.96	- becoming purple / pale grey							2.54	J, 0-5°, Un, Ro, Sn yellow br.	6.87	8.13	3/1.18	2.54	
8.7	11.78	3.08	3.08/100	3.08/100	-	-	17.96	19.1	- becoming pale grey							2.57	J, 5°, Un, Ro, Vn clay					
							19.1	23.86	- becoming pale grey & purple							2.84	J, 10-15°, Un, Ro, Vn clay & fine sand, Sn yellow br	8.13	11.44	1/3.31	0.3	
11.78	14.5	2.7	2.7/100	2.7/100	-	-										2.98	J, 10°, St, Ro, Vn clay + black mineral, Sn yellow br					
							23.86	25.0	- becoming purple & pale grey							3.07	J, 15-20°, Un, Ro, Sn yellow-brown	17.75	23.35	9/5.6	1.6	
14.5	17.54	3.04	3.04/100	2.8/92	-	-										3.26	J, 5°, Un, Ro, Vn fine sand					
																3.3	J, 10°, Un, Ro, Sn yellow br & black					
17.54	20.46	3.08	3.08/100	1.28/41.6	-	-			End of Borehole 25.0m							3.56	J, 10-15°, Un, Ro, Sn black					
																3.77	J, 15°, Un, Ro, Sn yellow br					
20.46	23.56	3.1	3.1/100	2.9/93.5	-	-										4.07	CZ, 20°, Un, Ro, fine angular gravel, Sn black, 10mm					
																4.15	J, 5°, Un, Ro, Sn yellow b.					
23.56	25.00	1.44	1.94/100	1.44/100	-	-										5.05	CZ, 10-15°, Un, Ro, fine angular gravel Sn black, 5mm					
																5.09	J, 25°, Un, Ro, Sn yellow br.					
																6.17	J, 10°, Un, Ro, Sn yellow brown					
																6.31	J, 10°, Un, Ro, Sn yellow brown,					
																6.35	CZ, 10-13°, Un, Ro, med angular gravel & fine sand, 20mm					
																6.66	J, ~~30°~~ 25°, Un, Ro, Sn yellow brown					
																6.87	J, 30°, Un, Ro, Sn yellow-brown.					
																7.41	J, 35°, Pl, Sm, Sn yellow brown & black					
																8.13	SZ, 30-35°, Pl, Sn, fine gravel, Vn clay, 40mm					
																9.94	J, 0-5°, Un, Ro, Sn yellow br & black.					
																11.44	SZ, 20°, Pl, Ro, med gravel, Sn yellow br & black, 7mm					
																11.6	SZ, 20°, Un, Ro, med gravel, Sn yellow brown & black, 10-15mm					
																12.48	J, 20°, Un, Ro, Sn yellow brown & black.					

1.85

23.6

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GOLDER FORM GA_BQ-106 VERSION No. 7 REVISED 09/12/04

Golder Associates

611 Coronation Drive
Toowong, QLD 4066
&
Unit1/51 Secam Street
Mansfield, QLD 4122

FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? [✓ Y]/N

REPORT OF BOREHOLE: NST207

PROJECT No.: 06632062 SHEET 2 of 3
CLIENT: LBBJV
PROJECT: NSBT
LOCATION: RN4
BOREHOLE LOCATION: .... E........ N
SURFACE RL: ....m DATUM: .... CO-ORD. SYSTEM ....
INCLINATION: -90 ° AZIMUTH: ....° ZONE: ....
START: 3/10/6 at .... hrs FINISH: 4/10/6 at 1500 hrs
DRILL RIG: J. McDonald (KD500.) LOGGED: S.Sch.

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD

OTHER: ....

GROUNDWATER

☐ Groundwater Observed at ....m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at ....m depth .... hrs
☐ Groundwater Level at ......m on completion of drilling at ....hrs
☐ Groundwater Level at ....m at ....hrs date ..../..../....
☐ Groundwater Level at ....m at ....hrs date ..../..../....
☐ ....
☐ Groundwater Not Encountered while ....* to ....m. depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below .....m depth
☐ Total/Partial Drilling Water Loss at/Below ....m...
☐ Borehole baled to ....m depth on completion of drilling
☐ ....mm Standpipe Installed to ....m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING							FIELD MATERIAL DESCRIPTION										DEFECT INFORMATION						COMMENTS
DEPTH (m)		RUN LENGTH	TCR	RQD	CORE LOSS		DEPTH (m)		MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING			STRENGTH			DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	ADS ☐ FF ☐ DEFECT FREQUENCY				SAMPLES, IN-SITU TESTS, DRILLING NOTES
FROM	TO	(m)	(m)/(%)	(m)/(%)	FROM	TO	FROM	TO		FROM	TO	CODE	FROM	TO	CODE			FROM	TO	No./(m)	FREQUENCY	
																15.78	CZ, 0-5°, Un, Ro, fine to medium subangular gravel, Sn yellow brown, 6-10mm					
																15.9	J, 75°, Un, Ro, clay Vn, Sn yellow brown					
																17.75	J, 75°, Un, Ro, clay Vn, Sn yellow brown, healed.					
																18.28	J, 20°, Un, Ro, Infill fine to med. Sand					
																18.45	J, 75°, Un, Ro, Infill fine to med Sand					
																18.46	CZ, 10°, Un, Ro, fine to medium angular gravel, 5mm.					
																18.58.	J, 70°, Un, Ro, clay Vn.					
																18.78	J, 70-80°, St, Ro, clay Vn, Sn yellow brown					
																19.31	J, 30-50°, St, Ro, Sn yellow brown					
																18.65-20.1	J, 90°, Un, Ro, fine angular gravel, Sn yellow brown, 1-2mm					
																23.35	J, 75°, Un, Ro, fine angular gravel, 1-2mm					

EOH @ 25.0

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GOLDER FORM GA_BQ-106 VERSION No. 7 REVISED 09/12/04

Golder Associates

FIELD DRILLING REPORT

[✓ SOIL] OR SOIL & ROCK)

NST

REPORT OF BOREHOLE: 206

PROJECT No.: 06632262 SHEET 1 of 5
CLIENT: LBBJV
PROJECT: N&BT
LOCATION: RNA
BOREHOLE LOCATION: SURVEY SUBCONTRACTOR PROVIDE [illegible]
SURFACE RL: ....m DATUM: .... CO-ORD. SYSTEM ....
INCLINATION: -64° AZIMUTH: 0° ZONE: ....
START: 14/09/06 at 10 hrs FINISH: 18/09/06 at 14 hrs
DRILL RIG: JOHN MC DONALD LOGGED: UAL

DRILLING METHOD

CONTRACTOR: Foundrill
DIATUBE CORE/DTHH: ....m to. ......m
AUGER (V, T-C, HAND): 120 mm dia. to. 1.60 m
ROTARY (BLADE/TRICONE): ....m to. ......m
ROTARY (AIR/WATER): ....m to ......m
MUD P, N: ....m to. ....m
NMLC/ /CORE: 1.6 m to 29.08 m
CASING HW to 1.60 m NW to 1.60 m
OTHER: ....

GROUNDWATER

☐ Groundwater Observed at ....m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at ....m depth ....hrs
☐ Groundwater Level at ......m on completion of drilling at .....hrs
☑ Groundwater Level at 1.8 m at 7 hrs date 15/09/06
☑ Groundwater Level at 3.9 m at 7 hrs date 18/09/06
☐ ....
☐ Groundwater Not Encountered while ....* to ...m. depth
☐ Groundwater Not Observed due to Introduction of Drilling Water Below .....m depth
☐ Total/Partial Drilling Water Loss at/Below ..m...
☐ Borehole baled to ....m depth on completion of drilling
☐ ....mm Standpipe Installed to ....m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING

	METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DRILLING OBSERVATIONS DESCRIPTION OF CUTTINGS, DETAILS OF STRATA CHANGES MINOR PROPERTIES, DRILL METHOD, DRILL REFUSAL, ETC.
CONCRETE CUTTER		/	/	0	
AUGER DRILLING	AD	M		0.12	
	AD	H		1.25	some fine to medium rock fragments
	NMLC			1.6	

FIELD SAMPLING AND TESTING

TYPE	DEPTH FROM	DEPTH TO	RESULTS 0–150mm or Run Length	150–300 or Rec. Length	300–450 or R.Q.D. Length	N VALUE or % Rec. % RQD	P.P. kPa	SAMPLE DESCRIPTION FIELD ASSESMENT OF RECOVERED SAMPLE e.g. SOIL OR ROCK TYPE, PLASTICITY, COLOUR, INCLUSIONS, MOISTURE, STRENGTH

FIELD MATERIAL DESCRIPTION

DEPTH (metres)	UC Symbol	SOIL / ROCK MATERIAL DESCRIPTION (SOIL OR ROCK NAME, PLASTICITY OR PARTICLE SIZE, COLOUR, SECONDARY COMPONENTS, MOISTURE, STRENGTH)	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
0	/	Base: CONCRETE	/	/	NOTE BOREHOLE INCLINATION IS 64°
0.12	/	Fill: clayey GRAVEL, small to medium size, brown with some sand, few silts	M	/	
0.6	SC	Sandy CLAY / clayey SAND, fine to medium sand, pale grey and pale brown, low plastic clay, with some ~~[illegible]~~ fine gravel	M	F	Residual Soil
1.25	SC	getting harder - with some fine to medium gravel - orange brown (rock fragments)	M	H	Extremely weathered rock
1.6		rock - TUFF			

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GOLDER FORM GA_BQ-108 VERSION No. 10 REVISED 30/05/06

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FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? [✓ Y]/N

REPORT OF BOREHOLE: NS5 206
PROJECT No.: 06632062 SHEET 2 of 5
CLIENT: LBBJV
PROJECT: NBT
LOCATION: RNA
BOREHOLE LOCATION: See Survey E .... N
SURFACE RL: ---- m DATUM: .... CO-ORD. SYSTEM ....
INCLINATION: -64° ° AZIMUTH: .... ° ZONE: ....
START: ../../.. at .... hrs FINISH: ../../.. at .... hrs
DRILL RIG: .... LOGGED: ....

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD
1.6	29.08	52/76	NMLC

OTHER: ....

GROUNDWATER

☐ Groundwater Observed at .... m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at .... m depth .... hrs
☐ Groundwater Level at .... m on completion of drilling at .... hrs
☑ Groundwater Level at 1.8 m at 7 hrs date 15/09/06
☑ Groundwater Level at 3.9 m at 7 hrs date 18/09/06
☐ ....
☐ Groundwater Not Encountered while ....* to ....m. depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below .... m depth
☐ Total/Partial Drilling Water Loss at/Below .... m...
☐ Borehole baled to ....m depth on completion of drilling
☐ .... mm Standpipe Installed to .... m depth on Completion of Drilling
*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING

DEPTH (m) FROM	DEPTH (m) TO	RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS FROM	CORE LOSS TO
1.6	2.5	0.9	0.9/100	0.56/62	/	/
2.5	5.42	2.92	2.92/100	2.44/83		
5.42	8.42	3.0	3.0/100	2.85/95		
8.42	11.45	3.03	3.03/100	3.02/99		
11.45	14.45	3.00	3.00/100	2.91/97		
14.45	17.45	3.0	3.0/100	3.0/100		
17.45	20.45	3.0	3.0/100	2.93/97		
20.45	22.45	3.00	2.0/100	1.90/95		
22.45	25.45	3.00	3.00/100	3.00/100		
25.45	28.50	3.05	3.05/100	3.05/100		
28.50	29.08	0.58	0.58/100	0.58/100		

FIELD MATERIAL DESCRIPTION

Brisbane

DEPTH (m) FROM	DEPTH (m) TO	MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)
1.6	6.67	TUFF, fine, pale grey, with many sub-angular inclusions from 1 to 12mm approx. Pale orange to orange staining on core and in and around fractures.
6.67	19.7	pale grey, pale pink and pale purple
19.7	23.7	Pale purple core with pale grey and orange fractures. Joints are stained and often veneer (black material)
23.7	26.3	pale purple and pale grey ⊛
26.3	27.0	same cavities with pale grey cemented sand
27	29.08	same as above ⊛
		End of hole

WEATHERING FROM	WEATHERING TO	WEATHERING CODE	STRENGTH FROM	STRENGTH TO	STRENGTH CODE
1.9	5	MW	1.9	29.08	H
5	20.5	SW			
20.5	29.08	F			

DEFECT INFORMATION

DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)
2.01	J, 70-90°, St, Ro, St (on and around fracture)
2.04	J, 60°, Un, Ro, sandy clay 2mm
2.12	DS, 70°, fine gravel, sand & clay 30-40 mm
2.30	J, 80°, Un, Ro, gravel & clay 10 mm
2.38	J, 90°, Un, Ro, St
2.75	J, 80°, Un, Ro, St, sand 1mm
2.76	J, 80°, Un, Ro, " " "
2.86	J, 80°, Un, Ro, Cn
3.24	J, 80-90°, St, Ro, Cn
3.32	J, 80°, St, Ro, fragmented rock 5mm
3.40	J, 40°, Un, Ro, Cn
3.47	J, 30°, Un, Ro, St
3.73	J, 20-30°, Un, Ro, clay (infill ?), 3mm
3.95	J, 30°, Un, Ro, clay (infill ?), 1mm
4.0	J, 40°, Un, Ro, clay (infill ?) 2mm
4.17	J, 50°, Pl, Ro, St
4.36	J, 50°, Pl, Ro, "
4.37	" " " " "
4.53	" " " " "
4.94	J, 70°, Pl, Ro, St
4.97	J, 70°, Un, Ro, St, sand 1mm
4.98	J, 70°, Un, Ro, " "
5.20	J, 50°, Pl, Ro, sandy clay 1mm
5.25	J, 30°, Un, Ro, Cn
5.57	J, 80°, Un, Ro, St
5.58	" " " " "
5.83	J, 40-80°, St, Ro, Cn
6.08	J, 80°, St, Ro, veneer
6.30	J, 50°, Un, Ro, St
6.37	" " " " "

ADS ☐ FF ☐

DEFECT FREQUENCY FROM	TO	No./(m)	FREQUENCY	COMMENTS: SAMPLES, IN-SITU TESTS, DRILLING NOTES
1.6	3.7	12/2.1	5.7	
3.7	4.17	4/0.47	8.5	SHEARED ZONE?
4.17	22.10	90/17.93	5	
22.10	29.08	6/6.98	0.86	FRESH TUFF:

Golder Associates

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FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? [✓ Y]/N

REPORT OF BOREHOLE: NR 206

PROJECT No.: 08632061 SHEET 3 of 5

CLIENT: Same

PROJECT:

LOCATION:

BOREHOLE LOCATION: .... E........ N

SURFACE RL: ....m DATUM: .... CO-ORD. SYSTEM ....

INCLINATION: ....° AZIMUTH: ....° ZONE: ....

START: .../.../... at ... hrs FINISH: .../.../... at ... hrs

DRILL RIG: .... LOGGED: ....

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD

OTHER: ....

GROUNDWATER

☐ Groundwater Observed at ....m depth during drilling

☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW

☐ Sample Wet at ....m depth .... hrs

☐ Groundwater Level at ....m on completion of drilling at ....hrs

☐ Groundwater Level at ....m at ....hrs date .../.../...

☐ Groundwater Level at ....m at ....hrs date .../.../...

☐ ....

☐ Groundwater Not Encountered while ....* to ....m. depth

☐ Groundwater Not Observed due to introduction of Drilling Water Below ......m depth

☐ Total/Partial Drilling Water Loss at/Below ..m...

☐ Borehole bailed to ....m depth on completion of drilling

☐ ....mm Standpipe Installed to ....m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING							FIELD MATERIAL DESCRIPTION										DEFECT INFORMATION						COMMENTS
DEPTH (m)		RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS		DEPTH (m)		MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING			STRENGTH			DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	ADS ☐ FF ☐ DEFECT FREQUENCY				SAMPLES, IN-SITU TESTS, DRILLING NOTES
FROM	TO				FROM	TO	FROM	TO		FROM	TO	CODE	FROM	TO	CODE			FROM	TO	No./(m)	FREQU-ENCY	
																6.96	J, 70°, Un, Ro, limonite staining					
																7.22	J, 40°, Un, Sm, " "					
																7.30	J, 80°, Un, Ro, " "					
																7.34	J, 60°, Un, Ro, " "					
																7.58	J, 30°, Un, Ro, sandy clay 1 mm					
																7.78	J, 80°, Un, Ro, limonite staining + black coating					
																8.0	J, 70°, Un, Ro, limonite staining, sand + clay 1mm					
																8.65	J, 70°, Un, Ro, limonite staining					
																8.71	J, 20°, Pl, Ro?, limonite staining, healed					
																8.99	J, 60°, Un, Ro, limonite staining					
																9.50	J, 70°, Un, Ro, " "					
																9.98	SZ 50°, Un, Ro, fragmented rock 12mm					
																10.34	J, 60°, Un, Ro, limonite staining					
																10.43	" " " "					
																10.58	J, 20°, Un, Ro, limonite staining, clay 1mm					
																10.76	" " Pl " " , sandy clay 1mm					
																10.95	J, 20°, Pl, Ro, limonite staining, healed					
																11.16	J, 20°, Un, Ro, limonite staining, healed					
																11.33	J, 30°, Pl, Ro, " "					
																11.37	J, 30°, Pl, Sm, patchy veneer					
																10.91	J, 50°, St, Ro, Cn					
																11.09	" " " " "					
																11.81	J, 75°, Un, Ro, black / limonite coating					
																12.1	J, 60°, Un, Ro, patchy veneer					
																12.35	J, 30°, Un, Ro, limonite staining, Cemented, 10-15mm					
																12.56	J, 30°, Un, Ro, limonite 1mm					
																12.64	J, 60°, Un, Ro, patchy veneer					
																12.80	J, 80°, Un, Ro, Cn					
																13.01	J, 80-90°, St, Ro, patchy veneer					
																13.17	J, 70°, Un, Ro, patchy veneer					

Golder Associates

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FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? [✓ Y]/N

REPORT OF BOREHOLE: NBT 206

PROJECT No.: 06632062 SHEET 4 of 5

CLIENT:

PROJECT: Same

LOCATION:

BOREHOLE LOCATION: .... E .... N

SURFACE RL: .... m DATUM: .... CO-ORD. SYSTEM ....

INCLINATION: ....° AZIMUTH: ....° ZONE: ....

START: .../.../... at ... hrs FINISH: .../.../... at ... hrs

DRILL RIG: .... LOGGED: ....

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD

OTHER:

GROUNDWATER

☐ Groundwater Observed at ....m depth during drilling

☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW

☐ Sample Wet at ....m depth .... hrs

☐ Groundwater Level at ......m on completion of drilling at ......hrs

☐ Groundwater Level at ......m at ......hrs date .../.../...

☐ Groundwater Level at ......m at ......hrs date .../.../...

☐ ....

☐ Groundwater Not Encountered while ....* to ....m. depth

☐ Groundwater Not Observed due to introduction of Drilling Water Below .....m depth

☐ Total/Partial Drilling Water Loss at/Below ....m...

☐ Borehole baled to ....m depth on completion of drilling

☐ ....mm Standpipe Installed to ....m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING							FIELD MATERIAL DESCRIPTION										DEFECT INFORMATION						COMMENTS
DEPTH (m)		RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS		DEPTH (m)		MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING			STRENGTH			DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	ADS ☐ FF ☐ DEFECT FREQUENCY				SAMPLES, IN-SITU TESTS, DRILLING NOTES
FROM	TO				FROM	TO	FROM	TO		FROM	TO	CODE	FROM	TO	CODE			FROM	TO	No./(m)	FREQU-ENCY	
																13.5	J, 60°, Pl, Ro, patchy veneer					
																13.74	J, 40°, St, Ro, limonite staining, black veneer, sandy clay 1mm					
																13.87	J, 40°, Un, Ro, limonite staining, healed					
																13.88	J, " " " " "					
																14.06	J, 40°, Un, Ro, St, limonite healed 4mm					
																14.13	J, 65°, Pl, Ro, Cn					
																14.18	J, 60°, Pl, Ro, St					
																14.3	J, 30°, Un, Ro, St, limonite healed 4mm					
																14.47	J, 70°, Pl, Ro, St					
																14.9	J, 40°, Pl, Ro, St, black veneer					
																15	J, 75°, Un Ro, patchy veneer					
																15.44	J, 70°, Un, Ro, St, black veneer					
																15.46	J, 60°, " " " " "					
																15.78	J, 80°, Un, Ro, patchy veneer					
																16.03	J, 40°, Pl, Ro, St, clay 1mm					
																16.11	J, 30°, ~~Pl~~ ~~St~~ Pl-St, Ro, patchy veneer					
																16.15	J, 70°, St, Ro, St					
																16.23	J, 60°, Un, Ro, patchy veneer					
																16.40	J, 50°, Un, Ro, " "					
																16.52	J, 80°, " " " "					
																15.99	J, 80°, Un, Ro, St					
																16.16	J, 70°, Pl, Ro, "					
																16.32	J, 30°, Pl, Ro, St, healed					
																	see following page					

Golder Associates

FIELD DRILLING REPORT

[✓ SOIL] OR SOIL & ROCK)

REPORT OF BOREHOLE: VW 206

PROJECT No.: 06632062 SHEET 5 of 5
CLIENT:
PROJECT:
LOCATION: same
BOREHOLE LOCATION: E N
SURFACE RL: m DATUM: CO-ORD. SYSTEM
INCLINATION: ° AZIMUTH: ° ZONE:
START: / / at hrs FINISH: 18/09/06 at 14h00
DRILL RIG: LOGGED:

DRILLING METHOD

CONTRACTOR:
DIATUBE CORE/DTHH: m to. m
AUGER (V, T-C, HAND): mm dia. to. m
ROTARY (BLADE/TRICONE): m to. m
ROTARY (AIR/WATER): m to. m
MUD P, N: m to. m
NMLC/ /CORE: m to. m
CASING HW to m NW to. m
OTHER:

GROUNDWATER

☐ Groundwater Observed at m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at m depth hrs
☐ Groundwater Level at m on completion of drilling at hrs
☐ Groundwater Level at m at hrs date / /
☐ Groundwater Level at m at hrs date / /
☐
☐ Groundwater Not Encountered while * to m. depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below m depth
☐ Total/Partial Drilling Water Loss at/Below m
☐ Borehole baled to m depth on completion of drilling
☐ mm Standpipe installed to m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING

METHOD | PENETRATION RESISTANCE | WATER | DEPTH (metres) | DRILLING OBSERVATIONS DESCRIPTION OF CUTTINGS, DETAILS OF STRATA CHANGES MINOR PROPERTIES, DRILL METHOD, DRILL REFUSAL ETC.

FIELD SAMPLING AND TESTING

TYPE | DEPTH FROM | TO | RESULTS 0–150mm or Run Length | 150–300 or Rec. Length | 300–450 or R.Q.D. Length | N VALUE % Rec. % RQD | P.P. kPa | SAMPLE DESCRIPTION FIELD ASSESMENT OF RECOVERED SAMPLE e.g. SOIL OR ROCK TYPE, PLASTICITY, COLOUR, INCLUSIONS, MOISTURE, STRENGTH

FIELD MATERIAL DESCRIPTION

DEPTH (metres)	UC Symbol	SOIL / ROCK MATERIAL DESCRIPTION (SOIL OR ROCK NAME, PLASTICITY OR PARTICLE SIZE, COLOUR, SECONDARY COMPONENTS, MOISTURE/STRENGTH) DEFECTS.	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
16,99		J, 80°, Un, Ro, St			
17,14		J, 70°, Pl, Ro, veneer			
17,35		J, 30°, Pl, Ro, veneer, healed			
17,92		J, 40°, Pl, Ro, veneer			
17,97		J, 30°, Pl, Ro, sand and clay 9 mm			
18,09		J, 20°, Pl, Ro, veneer (black), stained			
18,62		J, 70°, Un, Ro, Cn			
18,66		J, 40°, Pl, Ro, St, healed			
18,84		J, 30°, Pl, Ro, clay 1mm (infill?)			
18,98		J, 70°, Pl, Ro, veneer			
19,1		J, 30°, Pl, Ro, St, healed			
19,5		J, 50°, " " " "			
19,6		J, 30°, " " " "			
19,66		J, 40°, " " " "			
19,87		J, 40°, Un, Ro, St, healed			
19,98		J, 80°, St, Ro, veneer			
20,06		J, 20°, Un, Ro, St, veneer, (black) 1mm			
20,14		J, 60°, Un, Ro, Cn			
21		J, 60°, Un, Ro, patchy veneer			
21,20		J, 40°, Un, Ro, St, veneer (black)			
21,71		J, 40°, " " " "			
21,80		J, 40°, Un, Ro, patchy veneer			
21,98		J, 50°, St, Ro, veneer			
22,08		J, 40°, Un, Ro, patchy veneer			
23,80		J, 10°, Un, Ro, veneer			along "purple" vein
24,83		J, 30°, Un, Ro, veneer (black)			
25,11		J, 30°, St, Ro, Cn			
26,33		J, 80°, Un, Ro, cemented sand 4-6mm			
26,91		J, 20°, Un, Ro, Cn			
28,41		J, 20°, Pl, Ro, coated w/ clay			

$H_s - [d_w(10) x [H_s + H_T]$ height stick up

Golder Associates

FIELD DRILLING REPORT (SOIL OR SOIL & ROCK)

REPORT OF BOREHOLE: NST 213

PROJECT No.: 06632062 SHEET 1 of 4
CLIENT: LBBJV
PROJECT: NSBT
LOCATION: RNA (adj Douglas Wadley Dog Pavilion)
BOREHOLE LOCATION: .... E........ N
SURFACE RL: .... m DATUM: .... CO-ORD. SYSTEM ....
INCLINATION: -60° AZIMUTH: ....° ZONE: ....
START: 5/10/6 at .... hrs FINISH: ../../.. at ... hrs
DRILL RIG: F050a LOGGED: SSchul

DRILLING METHOD

CONTRACTOR: Foundrill
DIATUBE CORE/DTHH: .... m to 1.8 m
AUGER (V, [✓ T-C], HAND): 0 ...mm dia. to ~~[illegible]~~ m
ROTARY (BLADE/[✓ TRICONE]): ~~2.4~~ 1.8 m to 2.35 m
ROTARY (AIR/WATER): .... m to .... m
MUD P, N: .... m to .... m
[✓ NMLC] /CORE: 2.35 m to 43.16 m
CASING HW to .... m NW to .... m
OTHER: ....

GROUNDWATER

☐ Groundwater Observed at .... m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at .... m depth .... hrs
☐ Groundwater Level at .... m on completion of drilling at .... hrs
☐ Groundwater Level at .... m at .... hrs date ../../..
☐ Groundwater Level at .... m at .... hrs date ../../..
☐ ....
☐ Groundwater Not Encountered while ....* to .... m depth
☑ Groundwater Not Observed due to introduction of Drilling Water Below 1.8 m depth
☐ Total/Partial Drilling Water Loss at/Below .... m...
☐ Borehole baled to .... m depth on completion of drilling
☐ .... mm Standpipe Installed to .... m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DRILLING OBSERVATIONS DESCRIPTION OF CUTTINGS, DETAILS OF STRATA CHANGES MINOR PROPERTIES, DRILL METHOD, DRILL REFUSAL ETC.
A	M		0	Bitumen.
A			0.15	Fill - clayey GRAVEL (GC),
D	L			f-m angular gravel, dk br,
				MD, moist.
			0.25	becoming yellow brown
			0.6	Silty CLAY (CI), m pl,
				grey & brown, firm, moist
			1.0	becoming brown, firm, (CI-CH)
			1.3	gravelly CLAY (CH), h pl,
				brown, fine to med angular gravel
				moist, stiff.
			1.8	RS (silty CLAY) CH, pale grey
	M		2.4	~~cased to 2.4m~~ cased to 1.8
R			2.2	Note: NL cuttings.
D			2.35	TUFF (SW) - H ??, pale grey,
	H			fine grained
				change to NMLC &
				Rock log

FIELD SAMPLING AND TESTING

TYPE	DEPTH FROM	DEPTH TO	RESULTS 0–150mm or Run Length	150–300 or Rec. Length	300–450 or R.Q.D. Length	N VALUE % Rec. % RQD	P.P. kPa	SAMPLE DESCRIPTION FIELD ASSESMENT OF RECOVERED SAMPLE e.g. SOIL OR ROCK TYPE, PLASTICITY, COLOUR, INCLUSIONS, MOISTURE, STRENGTH

FIELD MATERIAL DESCRIPTION

DEPTH (metres)	UC Symbol	SOIL / ROCK MATERIAL DESCRIPTION (SOIL OR ROCK NAME, PLASTICITY OR PARTICLE SIZE, COLOUR, SECONDARY COMPONENTS, MOISTURE, STRENGTH)	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
0		Bitumen Pavement			
0.15	GC	Fill - clayey GRAVEL (GC), fine to			
		medium angular gravel, dark brown,			
		moist, medium dense	m	MD	
0.25		-becoming yellow brown.			
0.6	CI	silty CLAY (CI), medium plasticity,			
		grey & brown, moist, firm	m	Firm	
1.0	CI-CH	-becoming medium to high plasticity,			
		brown.			
1.3	CH	gravelly CLAY (CH), high plasticity,			
		brown, fine to medium angular			
		gravel, moist, stiff	m	stiff.	
1.8	CI	silty CLAY (CI), medium plasticity,			
		pale grey & yellow brown, moist,			
		very stiff. (NATURAL - RS)			
2.25		TUFF, fine to medium grained.			
		See sheet 2			
		SEE ROCK LOG - SHEET 2.			

M.

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&
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Mansfield, QLD 4122

13.55
2.64
16.15

FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? Y/N

REPORT OF BOREHOLE: NST 213

PROJECT No.: 06632062 SHEET 2 of 4
CLIENT: LBBJV
PROJECT: NSBT
LOCATION: RNA (adj Douglas Wadley Dog Pavilion)
BOREHOLE LOCATION: .... E .... N
SURFACE RL: .... m DATUM: .... CO-ORD. SYSTEM ....
INCLINATION: -60° AZIMUTH: ....° ZONE: ....
START: 5/10/16 at 0730 hrs FINISH: 10/10/16 at 1100 hrs
DRILL RIG: FD500 LOGGED: S.Schuh

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD
2.35	43.16	80	NMLC

OTHER: ....

GROUNDWATER

☐ Groundwater Observed at .... m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at .... m depth .... hrs
☐ Groundwater Level at 14.?? m on completion of drilling at .... hrs
☒ Groundwater Level at 14.3 m at 725 hrs date 6/10/16
☐ Groundwater Level at 14.4 m at 0700 hrs date 9/10/16
☐ ....
☐ Groundwater Not Encountered while ....* to .... m. depth
☒ Groundwater Not Observed due to introduction of Drilling Water Below .... m depth
☐ Total/Partial Drilling Water Loss at/Below .... m
☐ Borehole baled to .... m depth on completion of drilling
☐ .... mm Standpipe Installed to .... m depth on Completion of Drilling
*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING

DEPTH (m) FROM	DEPTH (m) TO	RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS FROM	CORE LOSS TO
2.36	5.36	3.0	3.0/100	2.62	–	–
5.36	8.36	3.0	3.0/100	2.82	–	–
8.36	11.55	3.19	3.19/100	2.69	–	–
11.55	13.55	2.0	2.0/100	1.77	–	–
13.55	16.2	2.6	2.6/100	2.45	–	–
16.2	19.2	3.0	3.0	3.0/100	–	–
19.2	22.26	3.06	3.06/103	2.85	–	–
22.2	25.2	3.0	3.0/100	3.0/100	–	–
25.2	27.8	2.6	2.6/100	2.6/100	–	–
27.8	30.82	3.02	3.02/100	3.0/100	–	–
30.8	33.87	3.07	3.07/100	3.07/100	–	–
33.87	36.83	2.96	2.96/100	2.81/95	–	–
36.83	38.7	1.87	1.87/100	1.87/100	–	–
38.7	41.7	3.0	3.0/100	3.0/100	–	–
41.7	43.16	1.46	1.46/100	1.46/100		

FIELD MATERIAL DESCRIPTION

DEPTH (m) FROM	DEPTH (m) TO	MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)
2.36	3.5	TUFF, fine to medium grained, massive, pale grey/purple, subangular clasts to 15mm, staining adj to joints.
3.5	4.6	- becoming purple and pale grey - brown
4.6	8.63	- becoming pale grey
8.63	9.3	- becoming pale greenish grey
9.3	10.27	- becoming pinkish grey
10.27	11.1	- becoming dark purple/grey angular clasts 1-20mm increasing within rock matrix.
11.1	11.55	- becoming grey/purple
11.55	13.15	- becoming dark purple/grey, angular clasts 1-8mm increasing
13.15	13.62	- becoming pale grey, some subangular clasts to 10mm
13.62	~~15.0~~ 16.0	becoming pale grey, trace subangular clasts 14.0-15.0 flow banding (14-15)
16.0	19.2	becoming pale greenish grey, subangular clasts to 8mm
19.2	25.95	becoming pinkish grey, subangular clasts to 10-12mm increasing
25.95	27.0	becoming pinkish grey & red-brown
27.0	32.2	becoming pinkish grey, subangular clasts to 10mm
32.2	37.0	- becoming purple/pink and grey
37.0	43.16	- becoming pink ~~purple~~

End of Borehole 43.16 m

WEATHERING FROM	WEATHERING TO	CODE	STRENGTH FROM	STRENGTH TO	CODE
2.36	5.93	SW	2.36	5.93	VH
5.93	7.65	SW/FR	5.93	7.65	VH
7.65	43.16	FR	7.65		VH

breccia ??

DEFECT INFORMATION

DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)
2.44	J, 25-30°, Un, Ro, Clay Vn
2.46	CZ, 20-30°, Pl, Ro, fine to med gravel and clay, 5-30mm
2.78	J, 30°, Un, Ro, Sn yellow brown
3.5	J, 30-40°, Un, Ro
3.85	J, 20°, Un, Ro, Sn yellow br & black
4.33	J, 20° Un, Ro, clay Vn, Sn yellow brown
4.4	J, 20-25°, Un, Ro, clay and fine sand Vn
4.42	J, 20-25°, Un, Ro, Sn yellow brown
4.71	J, 30°, Un, Ro, Sn yellow br
5.04	J, 30-35°, Un, Ro, Sn yellow brown & black
5.24	CZ, 0-40°, St, Ro, gravel to 10mm and fine to coarse sand, Sn yellow brown, ~50mm
5.44	J, 40-45°, Un, Ro, sand & clay Vn, Sn yellow br & black
5.6	J, 10°, Un, Ro, clay Vn, Sn yellow br
5.73	J, 25°, Un, Ro, Sn yellow brown
6.36	J, 20-25°, Un, Ro, Sn yellow brown
7.5	J, 30°, St, Ro, fine angular gravel, Sn yellow brown
7.59	SZ, 30°, Un, Ro, fine angular gravel, Sn yellow brown, 2-3mm
8.57	J, 45°, Un, Ro, Clay & sand Vn
8.6	J, 40°, Un, Sn, Sn yellow brown & black
11.21	V, 35°, Un, fine grained rock, ~11mm
11.72	J, 0°, Un, Ro
11.78	J, 0-10°, Un, Ro
14.2	V, 70°, Un, fine grained rock, 7-8mm
14.46	V, 70°, Un, fine grained rock, ~85mm
[illegible]	[illegible] fine grained rock & clasts, 27mm
19.20 / 19.[illegible]	[illegible] healed J, 70°, Un, healed
19.35	[illegible] fine gravel cemented in black mineral, [illegible] 50% decomposed, clay Vn, 40mm

V, 65°, Un

DEFECT FREQUENCY (FF ☒ ADS ☐) FROM	TO	No./(m)	FREQUENCY
2.44	2.78	3/0.34	8.8
3.5	5.73	11/2.25	4.9
5.73	8.6	6/2.87	2.1
11.21	11.78	3/0.57	5.2
14.2	14.46	2/0.26	7.69

COMMENTS: SAMPLES, IN-SITU TESTS, DRILLING NOTES

13.5

45
41.7

Q:\QA\Brisbane Forms\GA_BQ-106 FIELD DRILLING REPORT - ROCK.dwg Dec 09, 2004 - 10:02am

GOLDER FORM GA_BQ-106 VERSION No. 7 REVISED 09/12/04

Golder Associates

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FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? Y/N

REPORT OF BOREHOLE: NST213

PROJECT No.: 06632062 SHEET 3 of 4
CLIENT: LBBJV
PROJECT: NSBT
LOCATION: RNA (adj. Douglas Wadley Dog Pavilion)
BOREHOLE LOCATION: .... E .... N
SURFACE RL: ~~A~~ 60 m DATUM: .... CO-ORD. SYSTEM ....
INCLINATION: -60 ° AZIMUTH: .... ° ZONE: ....
START: 5 / 10 / 6 at 0730 hrs FINISH: .. / .. / .. at .. hrs
DRILL RIG: FD500 LOGGED: S.Schul

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD

OTHER: ....

GROUNDWATER

- ☐ Groundwater Observed at ....m depth during drilling
- ☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
- ☐ Sample Wet at ....m depth .... hrs
- ☐ Groundwater Level at ......m on completion of drilling at .....hrs
- ☐ Groundwater Level at ....m at ....hrs date .../.../...
- ☐ Groundwater Level at ....m at ....hrs date .../.../...
- ☐ ....
- ☐ Groundwater Not Encountered while ....* to ....m. depth
- ☐ Groundwater Not Observed due to introduction of Drilling Water Below .....m depth
- ☐ Total/Partial Drilling Water Loss at/Below ....m...
- ☐ Borehole baled to ....m depth on completion of drilling
- ☐ ....mm Standpipe Installed to ....m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING / **FIELD MATERIAL DESCRIPTION**

DEPTH (m) FROM	DEPTH (m) TO	RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS FROM	CORE LOSS TO	DEPTH (m) FROM	DEPTH (m) TO	MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING FROM	WEATHERING TO	WEATHERING CODE	STRENGTH FROM	STRENGTH TO	STRENGTH CODE

DEFECT INFORMATION

ADS ☐ FF ☑

DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	DEFECT FREQUENCY FROM	DEFECT FREQUENCY TO	No./(m)	FREQUENCY	COMMENTS SAMPLES, IN-SITU TESTS, DRILLING NOTES
20.6	CZ, 65-70°, Un, Ro, fine & medium angular gravel and	20.6	25.65	12/5.05	2.37	
	~~the~~ associated seam cemented in ~~dark~~ black mineral,					
20.85	clay Vn, 80mm.	27.53	27.87	3/0.34	8.8	
20.85 -21.15	V, 60-80°, st, fine grained sand and black					
	mineral ~~f~~, 4-5mm.	28.63	30.47	4/1.84	2.2	
21.98	SZ, 45°, Pl, Ro, ~~angular~~ lamina & angular gravel ~~15~~ 15-30mm length,					
	,5mm.					
22.55	J, 25°, Pl, Ro.					
22.62	V, 45°, very fine angular gravel & coarse sand cemented					
	with black mineral, 10mm.					
22.62 -23.16	V, 85°, Un, fine angular gravel & coarse sand					
	cemented with black mineral, ~~8mm~~, partly					
	decomposed ~ 40%, 8mm					
23.55 -23.9	V, 65-80°, Un, fine angular gravel & coarse sand					
	cemented with black mineral, 2-8mm					
23.97 -24.1	V, 45°, Pl, fine angular gravel & coarse sand					
	cemented with black mineral, 5-6mm					
24.22	J, 60°, Un, Ro, cemented fine angular gravel					
	& coarse sand.					
24.48 to 24.50	SZ, 45°, Pl, Ro, 5-6mm.					
25.19	J, 45°, Un, Ro, medium to coase sand, 2mm.					
25.65	V, 45°, Un, Ro, grey mineral cemented,					
	partly healed, 8-9mm.					
27.53	J, 60°, Un, Ro.					
27.87	J, 60°, Un, Ro, fine sand Vn.					
28.63	J, 30°, Un, Ro.					
29.07	V, 35°, Pl, Ro, fine angula gravel cemented					
	with dark brown mineral, 15mm					
29.97	J, 0-5°, Un, Ro, clay Vn.					
30.47	V, 40°, Pl, ~~Ro~~ partly decomposed, 20mm					

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FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? Y/N

REPORT OF BOREHOLE: NST 213

PROJECT No.: 06632062 SHEET 4 of 4

CLIENT: LBBJV

PROJECT: NSBT

LOCATION: RNA (Adj Douglas Wadley Pavilion)

BOREHOLE LOCATION: .... E .... N

SURFACE RL: .... m DATUM: .... CO-ORD. SYSTEM ....

INCLINATION: -60. ° AZIMUTH: .... ° ZONE: ....

START: 9/10/6 at .... hrs FINISH: ../../.. at .. hrs

DRILL RIG: FD500 LOGGED: S Schul

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD

OTHER: ....

GROUNDWATER

☐ Groundwater Observed at ....m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at ....m depth ....hrs
☐ Groundwater Level at ......m on completion of drilling at ......hrs
☐ Groundwater Level at ......m at ......hrs date ../../..
☐ Groundwater Level at ......m at ......hrs date ../../..
☐ ....
☐ Groundwater Not Encountered while ....* to ....m depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below ......m depth
☐ Total/Partial Drilling Water Loss at/Below ....m...
☐ Borehole baled to ....m depth on completion of drilling
☐ ....mm Standpipe installed to ......m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING DEPTH (m) FROM	DRILLING DEPTH (m) TO	RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS FROM	CORE LOSS TO	FIELD MATERIAL DESCRIPTION DEPTH (m) FROM	DEPTH (m) TO	MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING FROM	WEATHERING TO	WEATHERING CODE	STRENGTH FROM	STRENGTH TO	STRENGTH CODE	DEFECT INFORMATION DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	ADS ☐ FF ☑ DEFECT FREQUENCY FROM	TO	No./(m)	FREQUENCY	COMMENTS SAMPLES, IN-SITU TESTS, DRILLING NOTES
																34.09	J, 15°, Un, Ro, fine sand Vn	34.09	36.57	12/2.48	4.8	
																34.16	J, 45°, Pl, Ro, fine-coarse Sand Vn.					
																34.46	V, 75°, 3 Veins, 40mm spacing, Pl,					
																34.54	Ro, partly decomposed dark brown cemented mineral, 4mm					
																34.56	V, 55°, Un, Ro, partly decomposed, dark brown mineral, 4mm.					
																35.0	V, 35°, Un, Ro, dark brown cemented mineral, 10mm.					
																35.47	J, 35° Pl, Ro, Some fine angular gravel.					
																35.94	J, 55°, Pl, Sm, clay Vn.					
																35.96	J, 55° Pl, Sm, clay Vn.					
																36.08	J, 55°, Un, Sm, clay Vn.					
																36.47	J, 55°, Pl, Sm, clay Vn.					
																36.57	J, 65-70°, Un, Ro, associated vein 5mm thickness, dk brown cemented mineral, clay Vn.					
																38.2	V, 35°, Pl, brown cemented mineral, 4-5m.					
																38.3						
																42.29	J, 35°, Pl, Ro, clay Vn.					

5 18.5 22.25.5 ...

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FIELD DRILLING REPORT (SOIL OR SOIL & ROCK)

REPORT OF BOREHOLE: NST 228

PROJECT No.: 05632108 SHEET 1 of ....
CLIENT: PB - Maunsell - Aecom
PROJECT: NSBT
LOCATION: Shaftston Ave.
note o/s due to tree cover
BOREHOLE LOCATION: 563 050.3685 E 6960853 N
SURFACE RL: ....m DATUM: .... CO-ORD. SYSTEM ....
INCLINATION: -60 ° AZIMUTH: .... ° ZONE: ....
START: 22/6/6 at 0700 hrs FINISH: ../../.. at ... hrs
DRILL RIG: FD500 LOGGED: SSchul

DRILLING METHOD

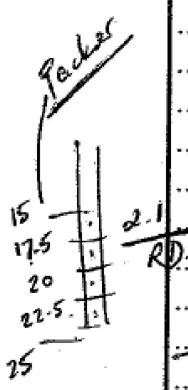
CONTRACTOR: Foundit.
DIATUBE CORE/DTHH: ....m to. ....m
AUGER (V, [✓ T-C], HAND): 0 mm dia. to. 2.1 m
ROTARY (BLADE/TRICONE): ....m to. ....m
ROTARY (AIR/[✓ WATER]): 2.1 m to. ....m
MUD P, N: ....m to. ....m
NMLC/ /CORE: ....m to. ....m
CASING HW to 2.1 m NW to ....m
OTHER: ....

GROUNDWATER

☐ Groundwater Observed at ....m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at ....m depth ....hrs
☐ Groundwater Level at ....m on completion of drilling at ....hrs
☐ Groundwater Level at ....m at ....hrs date ../../..
☐ Groundwater Level at ....m at ....hrs date ../../..
☐ ....
☐ Groundwater Not Encountered while ....* to ....m. depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below ....m depth
☐ Total/Partial Drilling Water Loss at/Below ....m...
☐ Borehole baled to ....m depth on completion of drilling
☐ .... mm Standpipe Installed to ....m depth
at Completion of Drilling
*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DRILLING OBSERVATIONS DESCRIPTION OF CUTTINGS, DETAILS OF STRATA CHANGES MINOR PROPERTIES, DRILL METHOD, DRILL REFUSAL, ETC.
AHD	L			Fill - Sandy, clayey GRAVEL (GP-GC), f-c grained, dk br, some hpl fines, MD, m.
			0.5	- pale grey, dry
			1.0	Sandy CLAY (CI), m pl, orange-br, fine sand, some f-c gravel and demolition rubble, very stiff, moist.
2.1 RD.			2.5	orange-brown and pale brown, RS, tending XW @ 4.0m.
	M		4.9	Tuff, XW, EL, pale grey & orange br cuttings



FIELD SAMPLING AND TESTING

TYPE	DEPTH FROM	DEPTH TO	RESULTS 0-150mm or Run Length	150-300 or Rec. Length	300-450 or R.Q.D. Length	N VALUE % Rec. % RQD	P.P. kPa	SAMPLE DESCRIPTION FIELD ASSESMENT OF RECOVERED SAMPLE e.g. SOIL OR ROCK TYPE, PLASTICITY, COLOUR, INCLUSIONS, MOISTURE, STRENGTH

FIELD MATERIAL DESCRIPTION

DEPTH (metres)	UC Symbol	SOIL / ROCK MATERIAL DESCRIPTION (SOIL OR ROCK NAME, PLASTICITY OR PARTICLE SIZE, COLOUR, SECONDARY COMPONENTS, MOISTURE, STRENGTH)	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
0.	GP-GC	FILL - sandy clayey GRAVEL, fine to coarse gravel, dark brown, some high plasticity fines, medium dense, moist	m	MD	
0.5		- becoming pale grey, dry	d.	MD	
1.0	CI	Sandy CLAY, medium plasticity, orange-brown, fine sand, some fine to coarse grained gravel and demolition rubble (to 1.5m), very stiff, moist	m	VSt	
2.5		- becoming orange-brown & pale brown, ~~tending XW rock at [illegible]~~.			
4.01		- tending XW-DW rock, pale grey & yellow br., EL - VL.			
4.9		TUFF (DW-SW) M strength, pale grey & yellow br., fine grained.			
5.29		change to rock log at 5.29m			

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GOLDER FORM GA_BQ-108 VERSION No. 10 REVISED 30/05/06

Leighton Baulderstone Bilfinger Joint Venture

Golder Associates
611 Coronation Drive
Toowong, QLD 4066
&
Unit1/51 Secam Street
Mansfield, QLD 4122

FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? Y/N

REPORT OF BOREHOLE: NST 228
PROJECT No.: 05632108 SHEET 2 of
CLIENT: ~~[illegible]~~ LSBB JV
PROJECT: NSBT
LOCATION: Shafston Ave.
BOREHOLE LOCATION: 563 050.3685 E 6960853 N
SURFACE RL: ...m DATUM: ... CO-ORD. SYSTEM WGS84
INCLINATION: -60 ° AZIMUTH: ...° ZONE: ...
START: 22/6/16 at 0700 hrs FINISH: ../../.. at ...hrs
DRILL RIG: FD500 LOGGED: SSchul

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD
5.29	20.7	80	1 NMLC

OTHER:

GROUNDWATER

☐ Groundwater Observed at ......m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at ......m depth ......hrs
☐ Groundwater Level at ......m on completion of drilling at ......hrs
☐ Groundwater Level at ......m at ......hrs date ../../..
☐ Groundwater Level at ......m at ......hrs date ../../..
☐ ......
☐ Groundwater Not Encountered while ......* to ....m depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below .....m depth
☐ Total/Partial Drilling Water Loss at/Below ....m...
☐ Borehole baled to ....m depth on completion of drilling
☐ ......mm Standpipe Installed to ......m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING							FIELD MATERIAL DESCRIPTION										DEFECT INFORMATION						COMMENTS
DEPTH (m)		RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS		DEPTH (m)		MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING			STRENGTH			DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	ADS ☐ FF ☐ DEFECT FREQUENCY				SAMPLES, IN-SITU TESTS, DRILLING NOTES
FROM	TO				FROM	TO	FROM	TO		FROM	TO	CODE	FROM	TO	CODE			FROM	TO	No./(m)	FREQU-ENCY	
5.29	7.05	1.76	1.76/100	0.8/45.5	–	–	5.29	5.34	TUFF, pale grey & yellow br.	5.29	5.34	DW-SW	5.29	5.34	L-M							
									fine grained, L-M, DW-SW													
							5.34	7.00	DW-SW M-H, pale grey.	5.34	7.0	DW-SW	5.34	7.0.	M-H							
							7.0	7.1	EW, yellow br seam. ~~[illegible]~~ EL-VL.	7.0	7.1	XW	7.0	7.1	EL-VL							
7.05	9.15	2.1	2.1/100	0.74/35	–	–	7.1	9.15	~~M~~ M/H, ~~M~~ SW, pale grey,	7.1	9.15	SW	7.0	9.15	~~M-H~~ M-H							
									high fractured, tending VL adj													
									jointing, pale grey & yellow br.													
9.15	11.77	2.62	2.62/100	2.42/92.3	–	–			fine grained.													
							9.15	12.5	(H), SW-~~FR~~ pale grey, slightly	9.15	11.27	SW-FR	9.15	11.77	H							
									fractured, some oxidization colour													
									@ 9.45m – 9.55 & 11.27 – 11.77													
11.77	14.77	3.0	3.0/100	1.95/65.0	–	↴			@ 12.77 - Some fine angular	11.27	11.77	DW	11.27	11.77	H							
									clasts within rock matrix /	11.77	12.1	DW	11.77	12.1	H							
									pale grey > pink grey	12.5	12.85	SW	12.5	12.85	H							
14.77	16.82	2.05	2.05/100	1.73/84	–	–	12.5	14.77	- Some seams & jointing / 12.5-14.77	12.5	14.77	DW-SW	12.5	14.77	H							
									vertical jointing & oxidization,													
									pale grey & or br.													
							14.77	16.82	TUFF SW-FR (H)VH, pale grey, fine	14.77	16.82	SW-FR	14.77	16.82	H							
									grained, & slightly fractured,													
									some oxidization adj joints													
16.82	17.77	0.95	0.95/100	0.95	–	–	16.82	17.77	(H-~~VH~~), SW-FR (note: 17.2-17.9 broken from drilling)	16.82	17.77	SW-FR	16.82	17.77	H							
17.77	17.87	0.1	0.1/100	–/100	–	–	17.77	17.87	(H), SW, bl/or br.	17.77	17.87	SW	17.77	17.87	H							
17.87	20.0	2.13	2.13/100	1.56/73.2	–	–	17.87	20.0	(H-VH) SW-FR grey & or br,	17.87	20.	SW-FR	17.87	20	H-VH.							
									some oxidation @ joints and													
									slightly fractured.													
20.	20.7	0.7	0.7/100	0.4/57%	–	–	20	20.7	(H-VH), grey & yellow	20	20.7	SW-FR	20	20.7	H-VH							

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GOLDER FORM GA_BQ-106 VERSION No. 7 REVISED 09/12/04

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611 Coronation Drive
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Mansfield, QLD 4122

FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? [✓ Y]/N

REPORT OF BOREHOLE: NST 228

PROJECT No.: 05632608 SHEET 2 of

CLIENT: LBBJV

PROJECT: NSBT

LOCATION: SHAFTSTON AVE

BOREHOLE LOCATION: 0503685 E 6960853 N

SURFACE RL: ....m DATUM: .... CO-ORD. SYSTEM WGS84

INCLINATION: -60 ° AZIMUTH: ....° ZONE: 56

START: 22/6/06 at 0700 hrs FINISH: .../.../... at ... hrs

DRILL RIG: FD500 LOGGED: SRT

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD
5.29		76	NMLC

OTHER:

GROUNDWATER

☐ Groundwater Observed at ....m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at ....m depth .... hrs
☐ Groundwater Level at ......m on completion of drilling at ....hrs
☐ Groundwater Level at ....m at ....hrs date .../.../......
☐ Groundwater Level at ....m at ....hrs date .../.../......
☐ ....
☐ Groundwater Not Encountered while ....* to ....m. depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below .....m depth
☐ Total/Partial Drilling Water Loss at/Below ..m...
☐ Borehole baled to ....m depth on completion of drilling
☐ .... mm Standpipe Installed to .... m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING

DEPTH (m) FROM	DEPTH (m) TO	RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS FROM	CORE LOSS TO
5.29	7.05	1.76	1.76/100	1.52/86	–	–
7.05	9.15	2.10	2.10/100	1.45/69	–	–
9.15	11.77	2.62	2.62/100	2.59/99	–	–
11.77	14.77	3.0	3.0/100	2.87/96	–	–
14.77	16.82	2.05	2.05/100	1.93/94	–	–
16.82	17.77	0.95	0.95/100	0.82/86	–	–
17.77	17.87	0.10	0.10/100	0.10/100	–	–
17.87	20.0	2.13	2.13/100	2.13/100	–	–
20.0	20.70	0.70	0.70/100	0.70/100	–	–

FIELD MATERIAL DESCRIPTION

DEPTH (m) FROM	DEPTH (m) TO	MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING FROM	WEATHERING TO	WEATHERING CODE	STRENGTH FROM	STRENGTH TO	STRENGTH CODE
5.29		TUFF	5.29	7.10	SW-DW	5.29	7.10	H-VH
		Fine to coarse grained, cream,						
		brown & yellow brown, slightly to	7.10	11.13	SW	7.10	25.0	VH
		distinctly weathered, high to very						
		high strength						
7.10		very high strength						
11.13		slightly weathered with distinct	11.13	21.90	SW-DW			
		weathering around joints						
12.70		cream brown, yellow brown & some						
		purple mottling						

DEFECT INFORMATION

DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	DEFECT FREQUENCY FROM	DEFECT FREQUENCY TO	No./(m)	FREQU-ENCY
5.32	J, 60°, Un, Ro, Sn, brown	5.29	6.57	6/1.28	5
5.45	J, 75-80°, Un, Sm-Ro, Sn, brown				
5.78	J, 70°, Un, Sm-Ro, Sn, brown healed				
5.96	J, 50°, Un, Sm, Sn, brown				
6.19	IS, 55°, Un, Ro, In, clayey gravel, 30mm	6.57	7.97	3/1.40	2
6.39	J, 50°, Un-St, Ro, Sn, brown				
6.57	IS, 35-40°, Pl-Un, Sm-Ro, In, fine clayey gravel, 4mm				
6.96	IS, 30°, Pl-Un, Sm-Ro, In, clay & fine gravel 4-10mm				
7.44	J, 25-30°, Un, Ro, Cn				
7.51	J, 65°, Un, Ro, Sn, dark brown				
7.97	J, 70°, Un, Ro, Cn	7.97	8.22	4/0.25	16
8.07	J, 75°, Un, Ro, Sn, brown				
8.14	J, 20°, Un, Ro, Sn, yellow brown				
8.22	J, 60-65°, Un-St, Ro, Sn, yellow brown	8.22	8.83	5/0.61	8
7.73-	8.30 Numerous drilling breaks				
8.45	J, 45°, Un, Ro, Sn, brown				
8.63	J, 50-55°, Un, Ro, Sn, brown				
8.78	SS, 30°, Pl-Un, St, In, clay, 8-10mm				
8.83	J, 30°, Un, Sm-Ro, Cn	8.83	11.13	1/2.30	1
10.07	J, 40-50°, Un, Sn, brown, closed				
11.13	J, 30-25°, Un, Ro, Sn, yellow brown, closed				
11.46	J, 5-35°, Un, Ro, Vr, dark brown black oxidisation, healed				
11.70	J, 20-30°, Un, Ro, In, dark brown black oxidisation healed, 5mm				
11.79	J, 35°, Un, Ro, Sn-In, dark to black oxidisation healed				
12.06	J, 30°, Un, Ro, In, dark brown oxidisation, healed, 1mm	11.13	12.06	3/0.93	3.5
12.65	J, 30-35°, Pl, Ro, Vr, clay fines				
12.69	J, 60°, Un, Ro, Sn, yellow brown				
13.00	J, 40-70°, St, Ro, Vr, weathering with no stain				
13.04	DS, 50-65°, Un, Ro, weathering 4-8mm				
13.15	J, 45-50° Un, Ro, Vr, weathering				

ADS ☐ FF ☐

COMMENTS
SAMPLES, IN-SITU TESTS, DRILLING NOTES

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&
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Mansfield, QLD 4122

FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? Y/N

REPORT OF BOREHOLE: NST228

PROJECT No.: 05632108 SHEET 3 of
CLIENT: LBBJV
PROJECT: NSBT
LOCATION: SHAFTSTON AVE
BOREHOLE LOCATION: 503685 E 6960853 N
SURFACE RL: ……m DATUM: …… CO-ORD. SYSTEM WGS84
INCLINATION: -60 ° AZIMUTH: …… ° ZONE: 56
START: …/…/… at … hrs FINISH: …/…/… at … hrs
DRILL RIG: FD500 LOGGED: SRT

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD

OTHER: ……

GROUNDWATER

☐ Groundwater Observed at ……m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at ……m depth ……hrs
☐ Groundwater Level at ……m on completion of drilling at ……hrs
☐ Groundwater Level at ……m at ……hrs date …/…/……
☐ Groundwater Level at ……m at ……hrs date …/…/……
☐ ……
☐ Groundwater Not Encountered while ……* to ……m depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below ……m depth
☐ Total/Partial Drilling Water Loss at/Below ……m
☐ Borehole baled to ……m depth on completion of drilling
☐ ……mm Standpipe Installed to ……m depth on Completion of Drilling
*Insert Drilling Method e.g. Augering, Hammering etc.

23/6/06

DRILLING							FIELD MATERIAL DESCRIPTION									
DEPTH (m)		RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS		DEPTH (m)		MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING			STRENGTH			
FROM	TO				FROM	TO	FROM	TO		FROM	TO	CODE	FROM	TO	CODE	
20.70	23.70	3.0	3.0/100	3.0/100	–	–	13.80		purple, green grey, brown & yellow brown							
23.70	25.0	1.30	1.30/100	1.30/100	–	–										
							20.70		green grey, brown & yellow brown							
							21.90		grey green, slightly weathered to fresh	21.90	25.0	SW-FR				
							23.10		purple & grey green							
								25.0								
							25.0		END OF BOREHOLE @ 25.0m							

DEFECT INFORMATION

ADS ☐ FF ☐

DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	DEFECT FREQUENCY FROM	TO	No./(m)	FREQUENCY
13.56	J, 45°, Pl, Ro, In, brown oxidisation healed 3mm				
13.65	-14.15: J, 0-35°, Un, Ro, In, dark	12.06	13.56	5/1.50	4
	brown black oxidisation, 5mm, healed,				
	amplitude >52mm	13.56	14.58		6
14.58	J, 60°, PL, Sm, Sn, dark brown				
15.33	J, 45°, PL, Sm, Sn, dark brown black	14.58	15.90	4/1.32	3
15.49	J, 70°, Un, Ro, Sn, yellow brown				
15.90	J, 25-30°, Pl, Ro, Sn, dark brown				
16.11	J, 60°, Un, Ro, Sn, dark brown black	15.90	16.80	4/0.80	5
16.18	J, 25-30°, Un, Ro, In, dark brown black oxidisation, 3-8mm				
16.56	J, 40°, Un, Ro, Sn, dark brown black oxidisation				
16.65	-16.92: J, 0-30°, Un, Ro, Sn, dark brown	16.80	19.08		2
	black oxidisation, 10-15mm, amplitude >25mm				
17.25	-17.49: J, 0-30°, Un, Ro, Sn, dark				
	brown oxidisation	19.08	20.52	2/1.42	1.5
17.70	J, 35-60°, Un, Sm, Cn				
18.37	J, 55-60°, PL, Sm, Sn, yellow brown, closed	20.52	24.30		1
18.90	J, 40°, Un, Ro, Sn, yellow brown				
19.08	J, 60°, PL, Sm, Sn, brown				
19.55	J, 70°, PL, Sm, Sn, yellow brown				
20.12	-20.30: J, 25°, PL-Un, Ro, Sn, dark				
	brown black oxidisation				
20.52	J, 45°, Un, Ro, Sn, dark brown black oxidisation	24.30	25.0		5
21.76	J, 30-35°, PL-Un, Ro, Sn, dark br bl oxid.				
21.86	J, 45°, PL, Sm-Ro, Sn, dark br bl oxidisation				
22.58	J, 20-25°, PL, Sm, Sn, dark brown, closed				
23.42	J, 45°, Un, Ro, Cn, low strength around joint				
23.70	J, 20-25°, Un-St, Ro, Cn				
23.75	J, 30°, Un, Ro, Cn				
23.80	J, 20°, PL-St, Ro, Cn				
24.30	J, 50°, PL, Sm-Ro, Cn				
24.53	J, 55°, PL-St, Ro, Cn				
24.73	J, 60°, PL, Ro, Cn				

COMMENTS
SAMPLES, IN-SITU TESTS, DRILLING NOTES

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FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? Y/N

REPORT OF BOREHOLE: NS1 24.1

PROJECT No.: 06632062 SHEET 1 of 3
CLIENT: LBBJV
PROJECT: NSBT
LOCATION: Shaw St, Hendra
BOREHOLE LOCATION: .... E .... N
SURFACE RL: .... m DATUM: .... CO-ORD. SYSTEM ....
INCLINATION: -60 ° AZIMUTH: .... ° ZONE: ....
START: 7/11/6 at 0700 hrs FINISH: ..../..../.... at .... hrs
DRILL RIG: F08 LOGGED: S Schuh

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD
0.1	26.0	80	NMLC

OTHER: ....

GROUNDWATER

☐ Groundwater Observed at .... m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at .... m depth .... hrs
☐ Groundwater Level at ...... m on completion of drilling at ..... hrs
☐ Groundwater Level at .... m at .... hrs date .../.../...
☐ Groundwater Level at .... m at .... hrs date .../.../...
☐ ....
☐ Groundwater Not Encountered while ....* to ... m. depth
☒ Groundwater Not Observed due to introduction of Drilling Water Below 0.1 m depth
☐ Total/Partial Drilling Water Loss at/Below .. m...
☐ Borehole baled to .... m depth on completion of drilling
☐ .... mm Standpipe Installed to .... m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING

DEPTH (m) FROM	DEPTH (m) TO	RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS FROM	CORE LOSS TO
0.1	1.9	1.2	1.8/	1.0/	–	–
1.9	4.9	3.0	3.0/100	3.0/100	–	–
4.9	8.0	3.1	3.1/100	2.65/	–	–
8.0	11.0	3.0	3.0/100	2.57/	–	–
11.0	14.0	3.0	3.0/	2.85/	–	–
14.0	17.0	3.0	3.0/100	3.0/100	–	–
17.0	20.0	3.0	3.0/100	3.0/100	–	–
20.0	23.0	3.0	3.0/100	3.0/100	–	–
23.0	26.0	3.0	3.0/100	2.93/	–	–

FIELD MATERIAL DESCRIPTION

DEPTH (m) FROM	DEPTH (m) TO	MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING FROM	WEATHERING TO	WEATHERING CODE	STRENGTH FROM	STRENGTH TO	STRENGTH CODE
0.1	2.83	Tuff, fine grained, pale grey, clasts to 15mm	0.1	16.44	SW	0.1	26.0	H-VH
2.83	10.67	pinkish/pale grey	16.44	26.0	SW-FR			
10.67	16.43	purple & pale pinkish grey, clasts to 20mm						
16.43	20.0	purple & red brown						
20.0	26.0	pale grey & purple						
		24.7 - water loss						
		16.5 1.3 End of Hole 26.0m						

DEFECT INFORMATION

DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	DEFECT FREQUENCY (ADS ☐ FF ☒) FROM	TO	No./(m)	FREQUENCY	COMMENTS (SAMPLES, IN-SITU TESTS, DRILLING NOTES)
0.25	J, 15°, Un, Ro, Sn					
0.35	CZ, 30°, St, Ro, red gravel, 30mm					
0.5	CZ, 35°, Un, Ro, red gravel, 20mm					
0.71	J, 0°, Un, Ro					
0.83	J, 5°, Un, Ro					
1.22	CZ, 10°, St, Ro, fine hard gravel, 25mm					
1.34	CZ, 5°, Pl, Sm, fine gravel, Sn, 10mm					
1.51	CZ, 6.5°, Pl, Sn, fine hard gravel, Sn, 10mm					
1.64	CZ, 7°, Un, Ro, fine gravel, 5mm					
1.76	J, 30°, Un, Ro, Sn, 1mm	0.25	1.76	10/1.51	6.6	
2.08	J, 35°, Un, Ro, clay Vn, 1mm					
2.3	J, 30°, St, Ro, Sn					
2.55	J, 10°, Un, Ro, Sn					
2.8	SZ, 40°, Un, Ro, fine-medium brown gravel, Sn, 30mm					
3.14	J, 20°, Pl, Ro, Sn, 2mm					
3.54	SZ, 20°, Un, Ro, fine brown gravel, Sn, 5mm	2.08	3.54	6/1.46	4.1	
4.34	J, 35°, Un, Ro, fine gravel, Sn, 4mm					
4.67	J, 75°, Un, Ro, healed, 1mm					
4.8	J, 25°, Un, Ro, clay, Vn					
5.41	J, 30°, Un, Ro, 2mm					
5.48	J, 25°, Pl, Ro, clay Vn, Sn, 2mm					
5.51	J, 65°, Un, Ro, fine gravel, clay Vn					
5.58	J, 0°, St, Ro, healed, Sn					
5.73	J, 70°, Un, Ro, clay Vn					
5.94	SZ, 65°, Pl, Sn, clay Vn, 73mm					
6.06	J, 10°, Un, Ro, Sn					
6.35	J, 65°, Un, Ro, fine gravel, clay Vn, 3mm					
6.40	J, 15°, Un, Ro, Sn					
6.46	J, 15°, Un, Ro, Sn					
6.97	J, 20°, Un, Ro, Sn					

Golder Associates

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Unit1/51 Secam Street
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FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? Y/N

REPORT OF BOREHOLE: NST241

PROJECT No.: 06622062 SHEET 2 of 3

CLIENT: LBBJV

PROJECT: NSBT

LOCATION: SNEYD ST

BOREHOLE LOCATION: .... E .... N

SURFACE RL: .... m DATUM: .... CO-ORD. SYSTEM ....

INCLINATION: 60 ° AZIMUTH: .... ° ZONE: ....

START: 7/11/06 at 0700 hrs FINISH: ../../.. at .... hrs

DRILL RIG: Fox LOGGED: ....

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD
		[illegible]	NMLC

OTHER: ....

GROUNDWATER

☐ Groundwater Observed at .... m depth during drilling

☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW

☐ Sample Wet at .... m depth .... hrs

☐ Groundwater Level at ...... m on completion of drilling at .... hrs

☐ Groundwater Level at .... m at ...... hrs date ../../..

☐ Groundwater Level at .... m at ...... hrs date ../../..

☐ ....

☐ Groundwater Not Encountered while ....* to .... m. depth

☑ Groundwater Not Observed due to introduction of Drilling Water Below ..... m depth

☐ Total/Partial Drilling Water Loss at/Below .. m...

☐ Borehole baled to .... m depth on completion of drilling

☐ .... mm Standpipe Installed to .... m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING							FIELD MATERIAL DESCRIPTION									DEFECT INFORMATION						COMMENTS
DEPTH (m)		RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS		DEPTH (m)		MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING			STRENGTH			DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	DEFECT FREQUENCY ADS ☐ FF ☑				SAMPLES, IN-SITU TESTS, DRILLING NOTES
FROM	TO				FROM	TO	FROM	TO		FROM	TO	CODE	FROM	TO	CODE			FROM	TO	No./(m)	FREQU-ENCY	
																7.06	J, 25°, Pl, Sn, healed	4.34	7.06	15/2.72	5.5	
																7.66	SZ, 25°, Un, Ro, fine gravel, Sn, 10mm					
																7.95	J, 25°, Un, Ro, Sn					
																8.54	J, 5°, Un, Ro, clay Vn, 1mm					
																8.58	J, 5°, Un, Ro, Sn					
																8.63	J, 20°, Un, Ro, Sn, 3mm					
																8.67	J, 5-10°, Un, Ro, Sn					
																8.70	J, 65°, Un, Ro, Sn					
																8.85	J, 15°, St, Ro, Sn					
																9.31	SZ, 20°, Un, Ro, fine gravel, Sn, 5mm					
																9.45	J, 15°, Pl, Ro, Sn					
																9.59	J, 25°, Pl, Ro, fine sand, Sn	7.66	9.59	11/1.93	5.7	
																10.57	SZ, 15°, Un, Ro, [illegible] gravel, Sn, 3mm					
																11.34	J, 30°, Un, Ro					
																11.67	J, 20°, Un, Ro, Sn	10.57	11.67	3/1.1	2.7	
																12.36	CS, 40°, Un, Ro, 3mm					
																12.43	J, 40°, Un, Ro					
																12.83	J, 40°, St, Ro, clay Vn, 2mm					
																12.94	J, 40°, Un, Ro					
																13.07	J, 60°, Un, Ro, Sn					
																13.24	J, 60°, Un, Ro, Sn	12.36	13.24	6/0.88	6.8	
																13.80	J, 40°, Un, Ro, Sn					
																14.0	J, 60°, Un, Ro, Sn	13.8	15.78	3/1.98	1.52	
																15.78	J, 20°, Un, Ro, Sn					
																16.04	J, 60°, Un, Ro, Sn					
																16.22	SZ, 65°, Un, Ro, fine gravel, Sn, 10mm					
																16.43	J, 20°, St, Ro, fine gravel, clay Vn, 2mm	15.78	17.1	5/1.32	3.8	
																17.1	J, 10°, Un, Ro					
																20.47	J, 25°, Un, Ro, Sn					
																21.43	J, 50°, Un, Ro, Sn					

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FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? Y/N

REPORT OF BOREHOLE: NST241

PROJECT No.: 46632062 SHEET 3 of 3

CLIENT: LBBTJ

PROJECT: NSBT

LOCATION: SNEYD ST

BOREHOLE LOCATION: .... E .... N

SURFACE RL: .... m DATUM: .... CO-ORD. SYSTEM ....

INCLINATION: -60 ° AZIMUTH: .... ° ZONE: ....

START: 7/11/6 at ..... hrs FINISH: 7/11/6 at ..... hrs

DRILL RIG: Fox LOGGED: SS[illegible]

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD

OTHER: ....

GROUNDWATER

☐ Groundwater Observed at .... m depth during drilling

☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW

☐ Sample Wet at .... m depth .... hrs

☐ Groundwater Level at ..... m on completion of drilling at ..... hrs

☐ Groundwater Level at ..... m at ..... hrs date ..../..../....

☐ Groundwater Level at ..... m at ..... hrs date ..../..../....

☐ ....

☐ Groundwater Not Encountered while ....* to ..... m depth

☐ Groundwater Not Observed due to introduction of Drilling Water Below ..... m depth

☐ Total/Partial Drilling Water Loss at/Below ..... m...

☐ Borehole baled to ..... m depth on completion of drilling

☐ .... mm Standpipe Installed to ..... m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING							FIELD MATERIAL DESCRIPTION										DEFECT INFORMATION						COMMENTS
DEPTH (m)		RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS		DEPTH (m)		MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING			STRENGTH			DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	ADS ☐ FF ☐ DEFECT FREQUENCY				SAMPLES, IN-SITU TESTS, DRILLING NOTES
FROM	TO				FROM	TO	FROM	TO		FROM	TO	CODE	FROM	TO	CODE			FROM	TO	No./(m)	FREQUENCY	
																21.75	J, 50°, Un, Ro, clay Vn, 2mm	20.42	21.75	3/1.33	2.2	
																22.66	J, 45°, Un, Ro, Sn					
																23.0	J, 0°, Un, Ro, clay sand Vn					
																23.74	J, 45°, Un, Ro, clay Vn					
																23.65	J, 40°, Un, Ro, Sn	22.66	23.65	4/0.99	4.0	
																24.45	J, 75°, U, Ro, fine sand, Sn, 2mm					
														[illegible]		24.83	CZ, 45°, Un, Ro, fine to coarse gravel, Sn, 50mm					
																25.24	DS, 40°, Un, Ro, Sn, 25mm					
																25.36	DS, 30° Un, Ro, 20mm					
														check [illegible] AS.		25.45	CZ, 40°, Un, Ro, fine gravel & sand, 20mm	24.45	25.45	5/1	5.0	

EOH

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FIELD DRILLING REPORT (SOIL OR SOIL & ROCK)

REPORT OF BOREHOLE: NST 257
PROJECT No.: 06632062 SHEET 1 of
CLIENT: LBBJV
PROJECT: NSBT.
LOCATION:
BOREHOLE LOCATION: E N
SURFACE RL: m DATUM: CO-ORD. SYSTEM
INCLINATION: ° AZIMUTH: ° ZONE:
START: / / at hrs FINISH: / / at hrs
DRILL RIG: FD500. LOGGED:

DRILLING METHOD

CONTRACTOR: FoundM.
DIATUBE CORE/DTHH: m to. m
AUGER (V, [✓ T-C], HAND): 0 mm dia. to. 2.5 m
ROTARY ([✓ BLADE]/[✓ TRICONE]): 2.5 m to. 3.0 m
ROTARY (AIR/WATER): m to. m
MUD P, N: m to. m
NMLC/ /CORE: m to. m
CASING HW to m NW to m
OTHER:

GROUNDWATER

☐ Groundwater Observed at 1.0 m depth during drilling
☐ SURFACE SEEPAGE ☑ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at 1.0 m depth 0815 hrs
☐ Groundwater Level at m on completion of drilling at hrs
☐ Groundwater Level at m at hrs date / /
☐ Groundwater Level at m at hrs date / /
☐
☐ Groundwater Not Encountered while * to m. depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below m depth
☐ Total/Partial Drilling Water Loss at/Below m
☐ Borehole baled to m depth on completion of drilling
☐ mm Standpipe Installed to m depth on Completion of Drilling
*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING					FIELD SAMPLING AND TESTING									FIELD MATERIAL DESCRIPTION					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DRILLING OBSERVATIONS DESCRIPTION OF CUTTINGS, DETAILS OF STRATA CHANGES MINOR PROPERTIES, DRILL METHOD, DRILL REFUSAL ETC.	TYPE	DEPTH FROM	DEPTH TO	RESULTS 0-150mm or Run Length	150-300 or Rec. Length	300-450 or R.Q.D. Length	N VALUE % Rec. % RQD	P.P. kPa	SAMPLE DESCRIPTION FIELD ASSESMENT OF RECOVERED SAMPLE e.g. SOIL OR ROCK TYPE, PLASTICITY, COLOUR, INCLUSIONS, MOISTURE, STRENGTH	DEPTH (metres)	UC Symbol	SOIL / ROCK MATERIAL DESCRIPTION (SOIL OR ROCK NAME, PLASTICITY OR PARTICLE SIZE, COLOUR, SECONDARY COMPONENTS, MOISTURE, STRENGTH)	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
A	M.	-		FILL - silty GRAVEL (GM), f-m grav	SPT	1.0	1.45	9	9	6	15		1.2m silty CLAY (CI), m pl, dk br						
H				brown, dry, MD									& grey, m, St-H						
D			0.3	f-c gravel.	SPT	2.5	2.92	10	22	30/120.			silty clayey SAND / EL TUFF,						
			0.5	clayey SAND (SC), f-m dec sand,									pale grey & orange brown.						
		1.0		brown, m, MD.															
			1.1	cased to 2.0															
			2.0	RD.															
R			2.8	TUFF (XW) / EL?															
D.																			
			3.0	Switch to rock log															
N																			
M																			
L																			
C																			

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2.36
0.58
1.78

FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? Y/N

REPORT OF BOREHOLE: NST257

PROJECT No.: 06632062 SHEET 2 of
CLIENT: LBBJV
PROJECT: NSBT
LOCATION: DEAKIN ST KANGAROO POINT
BOREHOLE LOCATION: E N
SURFACE RL: m DATUM: CO-ORD. SYSTEM
INCLINATION: -90 ° AZIMUTH: ° ZONE:
START: 27/11/6 at 0700 hrs FINISH: / / at hrs
DRILL RIG: FD500 LOGGED: SSchul

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD
3.0	38.0	76	NMLC

OTHER:

GROUNDWATER

☐ Groundwater Observed at ....m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at ....m depth ....hrs
☑ Groundwater Level at 7.5 m on completion of drilling at 0900 hrs
☑ Groundwater Level at 7.5 m at 0900 hrs date 29/11/6
☐ Groundwater Level at ....m at ....hrs date .../.../...
☐ ......
580
☐ Groundwater Not Encountered while ....* to ....m. depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below .....m depth
☑ Total/Partial Drilling Water Loss at/Below 30 m
☐ Borehole baled to ....m depth on completion of drilling
☐ .... mm Standpipe Installed to ....m depth on Completion of Drilling
*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING

DEPTH (m) FROM	DEPTH (m) TO	RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS FROM	CORE LOSS TO
3.0	3.8	0.8	0.8/100		—	—
3.8	5.7	1.9	1.9/100		—	—
5.7	7.0	1.3	1.3/100	0.8/	—	—
7.0	9.0	2.0	2.0/100	2.0/100	—	—
9.0	11.36	2.36	2.36/100	1.75/	—	—
11.36	14.47	3.11	3.11/100	2.93/	—	—
14.47	17.47	3.0	3.0/100	3.0/100	—	—
17.47	20.4	2.93	2.93/100	2/	—	—
20.4	23.5	3.1	3.1/100	3.1/100	—	—
23.5	26.5	3.0	3.0/100	2.74/	—	—
26.5	27.5	1.0	1.0/100	0.5/50	—	—
27.5	28.7	1.2	1.2/	1.1/	—	—
28.7	30.0	1.3	1.3/100	1.1/	—	—
30	32.5	2.5	2.5/100	2.4/	—	—
32.5	34.0	1.5	1.5/100	1.4/	—	—
34.0	36.0	2.0	2.0/100	1.9/	—	—

FIELD MATERIAL DESCRIPTION

DEPTH (m) FROM	DEPTH (m) TO	MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)
3.0	12.5	TUFF, ~~fine~~ & coarse grained, pale grey & brown 6.6 clasts to 15mm, staining adj joints
12.5	14.47	-becoming pale grey, fine-med grained
14.47	17.4	-becoming med-to coase grained
17.4	18.6	-dark grey, coarse grained
18.6	32.62	CONGLOMERATE, fine to coarse grained, clasts to 50mm
32.62	33.73	SANDSTONE, fine to coarse grained, grey
30.		
33.73		CONGLOMERATE : AS PER 18.6 - 32.62

Mask
0403821112

32662068 28 Royal

WEATHERING FROM	WEATHERING TO	WEATHERING CODE
3.0	3.7	XW
3.7	4.0	XW-DW
4.0	6.6	XW-DW
6.6	12.5	DW-SW
12.5	14.47	SW
14.47	27.9	DW-SW
27.0	30.1	DW
30.1		SW

STRENGTH FROM	STRENGTH TO	STRENGTH CODE
3.0	3.7	EL
3.7	4.0	L
4.0	6.6	VL-L
6.6	12.5	H
12.5	14.47	H-VH
14.47	18.6	M-H
18.6	20.46	H
20.46		M-H

DEFECT INFORMATION

DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	ADS ☐ FF ☐ DEFECT FREQUENCY FROM	TO	No./(m)	FREQU-ENCY	COMMENTS SAMPLES, IN-SITU TESTS, DRILLING NOTES
6.66	J, 5°, Un, Ro, Sn.					
6.73	DZ, 0°, Un, Ro, 50mm.					
7.26	J, 30°, Un, Ro.					
7.44	CZ, 10°, Un, Ro, fine to medium gravel, 10mm					
7.79	CS, 0-5°, Un, Ro, Vn, Sn, 10mm					
7.88	CS, 0-5° Un, Ro, Vn, 10mm					
7.94	J, 5°, Un, Ro, Vn, 5mm					
8.22	CZ, 10°, Un, Ro, fine to medium gravel, Vn, 20mm					
9.4	J, 0-5°, Un, Ro.					
9.54	J, 0°, Un, Ro, Vn, 5mm.					
9.58	J, 0°, Un, Ro, Vn, 5mm					
9.7	J, 10°, Un, Ro, 2mm					
9.82	J, 5°, Un, Ro, 10mm					
9.9	J, 5°, Pl, Ro, Vn, Sn, 1mm					
10.1	J, 0°, Pl, Ro, Vn, Sn.					
10.2	J, 0°, Pl, Ro, 2mm					
10.28	CZ, 0°, Un, Ro, fine to medium gravel, 15mm					
10.4	J, 5°, Un, Ro, Vn, Sn, 12mm.					
10.55	J, 10°, Un, Ro, Sn.					
10.95	J, 0-5°, Un, Ro, Vn, Sn, 5mm					
11.05	J, 20°, Pl, Ro, Sn.					
11.28	DZ, 25°, Un, Ro, , 100mm					
11.63	J, 5°, Un, Ro.					
11.65	J, 0-5°, Un Ro.					
11.91	J, 5°, Un, Ro, Sn, 5mm					
12.51	SZ, 0-10°, Un, Ro, Sn, Vn, fine to med gravel, 15mm					
12.64	SZ, 5°, Un, Ro, Sn, Vn, fine to med gravel, 10mm					
13.07	J, 30°, Pl, Ro, Vn, Sn, 2mm					
13.32	J, 0°, Un, Ro, Vn.					
13.34	J, 20°, Un, Ro, Vn.					

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FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? Y/N

REPORT OF BOREHOLE: NST 257

PROJECT No.: 06632062 SHEET 3 of

CLIENT: LBBTV

PROJECT: NSBT

LOCATION: DEAKIN STREET, KANGAROO POINT.

BOREHOLE LOCATION: E N

SURFACE RL: m DATUM: CO-ORD. SYSTEM

INCLINATION: -90 ° AZIMUTH: ° ZONE:

START: 28/11/16 at hrs FINISH: / / at hrs

DRILL RIG: FD500 LOGGED: SSchul

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD

OTHER:

GROUNDWATER

☐ Groundwater Observed at ....m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at ....m depth ....hrs
☐ Groundwater Level at ......m on completion of drilling at .....hrs
☐ Groundwater Level at ....m at ....hrs date .../...../......
☐ Groundwater Level at ....m at ....hrs date .../...../......
☐ ....
☐ Groundwater Not Encountered while ....* to ....m. depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below .....m depth
☐ Total/Partial Drilling Water Loss at/Below ..m...
☐ Borehole baled to ....m depth on completion of drilling
☐ ....mm Standpipe Installed to ....m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING DEPTH (m) FROM	DRILLING DEPTH (m) TO	RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS FROM	CORE LOSS TO	FIELD MATERIAL DESCRIPTION DEPTH (m) FROM	DEPTH (m) TO	MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING FROM	WEATHERING TO	WEATHERING CODE	STRENGTH FROM	STRENGTH TO	STRENGTH CODE	DEFECT INFORMATION DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	ADS ☐ FF ☐ DEFECT FREQUENCY FROM	DEFECT FREQUENCY TO	No./(m)	FREQU-ENCY	COMMENTS SAMPLES, IN-SITU TESTS, DRILLING NOTES
																13.91	DZ, 15°, Un, Ro, 10mm					
																14.15	J, 20°, Un, Ro, Vn, 2mm					
																14.26	J, 60°, Un, Ro, Vn					
																14.71	J, 15°, Un, Ro, Vn, 3mm					
																14.93	CS, 10°, Un, Ro, clay & sand, 25mm					
																15.1	J, 0°, Un, Ro					
																15.57	SZ, 5°, Un, Ro, Vn, fine gravel, 5mm					
																15.69	J, 15°, Un, Ro, Vn, 5-6 mm					
																16.29	J, 40°, Un, Ro, Vn, 4mm					
																16.38	J, 70°-90°, Un, Ro, Vn, 2mm					
																17.35	J, 50°, Pl, Ro, Vn					
																17.53	J, 30°, Pl, Ro, Vn					
																17.96	J, 0°, Un, Ro, Vn					
																17.96	J, 40°, Pl, Ro, Vn					
																18.02	J, 5°, Un, Ro, Vn					
																18.42	CS, 5°, Un, Ro, 30mm					
																18.57	CS, 0°, Un, Ro, 20mm					
																18.75	J, 30°, Un, Ro, Sn.					
																19.0	DZ, 30°, Pl, Ro, 45mm					
																19.21	DZ, 25°, Un, Ro, 35mm					
																19.37	CZ, 20°, Pl, Ro, 10mm					
																19.9	J, 70°, Pl, Ro.					
																20.03	J, 40°, Un, Ro, 10mm					
																20.42	DZ, 15°, Un, Pl, 120mm					
																22.35	J, 60°, Un, Ro, [illegible]					
																22.45	J, 35°, Un, Ro.					
																23.71	J, 25°, Un, Ro, 25mm					
																24.82	CS, 5°, Un, Ro, clay & fine sand, 210mm					
																26.86	CS, 70, Un, Ro, 20mm					
																27.0	DZ, 0°, Ro, 460mm					

04326200 Pete Bork

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FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? Y/N

REPORT OF BOREHOLE: NST257

PROJECT No.: 06632062 SHEET 4 of ....
CLIENT: LBBJV
PROJECT: NSBT
LOCATION: DEAKIN ST, KANGAROO PT
BOREHOLE LOCATION: .... E.......... N
SURFACE RL: ....m DATUM: .... CO-ORD. SYSTEM ....
INCLINATION: -90 ° AZIMUTH: ....° ZONE: ....
START: .../.../... at ....hrs FINISH: .../.../... at ....hrs
DRILL RIG: FD500 LOGGED: SSchul

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD

OTHER: ....

GROUNDWATER

☐ Groundwater Observed at ....m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at ....m depth ....hrs
☐ Groundwater Level at ......m on completion of drilling at .....hrs
☐ Groundwater Level at ....m at ....hrs date .../.../...
☐ Groundwater Level at ....m at ....hrs date .../.../...
☐ ....
☐ Groundwater Not Encountered while ....* to ....m. depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below ......m depth
☐ Total/Partial Drilling Water Loss at/Below ..m...
☐ Borehole baled to ....m depth on completion of drilling
☐ ....mm Standpipe Installed to ....m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING							FIELD MATERIAL DESCRIPTION										DEFECT INFORMATION		ADS ☐ FF ☐ DEFECT FREQUENCY				COMMENTS
DEPTH (m)		RUN LENGTH	TCR	RQD	CORE LOSS		DEPTH (m)		MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING			STRENGTH			DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)						SAMPLES, IN-SITU TESTS, DRILLING NOTES
FROM	TO	(m)	(m)/(%)	(m)/(%)	FROM	TO	FROM	TO		FROM	TO	CODE	FROM	TO	CODE			FROM	TO	No./(m)	FREQU-ENCY		
																27.67	J, 75°, Un, Ro, Vn, 5mm						
																28.53	IS, 5°, Un, Ro, fine sand & coal, 80mm						
																28.85	J, 60°, Un, Ro, 4mm.						
																29.27	CZ, 5°, Un, Ro, fine gravel, sand & coal, 100mm						
																30.0	CZ, 60°, St, Ro, fine to med gravel & coarse sand, 100mm						
																32.43	J, 65°, Un, Ro.						
																33.21	J, 5°, Un, Ro, Vn, Sn.						
																33.3	J, 5°, Un, Ro, Vn, Sn						
																33.37	J, 5°, Un, Ro, Vn, Sn						
																33.54	CZ, 0°, Un, Ro, coarse sand & fine gravel, 100mm						
																33.73	J, 20°, Un, Ro.						
																33.82	J, 60°, Un, Ro.						
																34.05	J, 15°, Un, Ro, fine gravel & coarse sand, 30mm						
																34.22	J, 15°, St, Ro, Sn						
																35.46	DZ, 20°, Un, Ro, 40mm						

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FIELD DRILLING REPORT

(SOIL OR
SOIL & ROCK)

REPORT OF BOREHOLE: NST 347

PROJECT No.: 66632062 SHEET 1 of
CLIENT: LBBJV
PROJECT: NSBT
LOCATION:
BOREHOLE LOCATION: E. N
SURFACE RL: m DATUM: CO-ORD. SYSTEM
INCLINATION: -90° AZIMUTH: ° ZONE:
START: 20/11/6 at hrs FINISH: at hrs
DRILL RIG: 20x LOGGED: SS-hu

DRILLING METHOD

CONTRACTOR: Schneider
DIATUBE CORE/DTHH: m to. m
AUGER (V, [✓ T–C], HAND): 0 mm dia. to. 4.5 m
ROTARY (BLADE/TRICONE): m to. m
ROTARY (AIR/[✓ WATER]): 4.5 m to 10.7 m
MUD P, N: m to m
[✓ NMLC]/ /CORE: 10.7 m to m
CASING HW to m NW to m
OTHER:

GROUNDWATER

☐ Groundwater Observed at m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at m depth hrs
☐ Groundwater Level at m on completion of drilling at hrs
☐ Groundwater Level at m at hrs date / /
☐ Groundwater Level at m at hrs date / /
☐
☐ Groundwater Not Encountered while * to m. depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below m depth
☐ Total/Partial Drilling Water Loss at/Below m
☐ Borehole baled to m depth on completion of drilling
☐ mm Standpipe Installed to m depth on Completion of Drilling
*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DRILLING OBSERVATIONS DESCRIPTION OF CUTTINGS, DETAILS OF STRATA CHANGES MINOR PROPERTIES, DRILL METHOD, DRILL REFUSAL ETC.
A	M			- BITUMEN -
H			03	silty GRAVEL (GM), f-c gravel
D				Some fine sand, brown, dry
				MD (FILL).
	L		1.8	gravelly clayey SAND - FILL.
			3.0	?? clay ?Yes. Silty clay See SPT.
			4.5	
R				
D			5.5	- Soft. / m to wet.
			6.0	CH, / Sand lenses
	H		10.7	rock.
				START Coring
			10.7	See Rock log

FIELD SAMPLING AND TESTING

TYPE	DEPTH FROM	DEPTH TO	RESULTS 0–150mm or Run Length	150–300 or Rec. Length	300–450 or R.Q.D. Length	N VALUE	P.P. kPa	SAMPLE DESCRIPTION FIELD ASSESMENT OF RECOVERED SAMPLE e.g. SOIL OR ROCK TYPE, PLASTICITY, COLOUR, INCLUSIONS, MOISTURE, STRENGTH
SPT	1.0	1.45	4	9	6	15		gravelly CLAY (CI), m.pl., br., f-c gravel, ~~dark~~ moist, VST. (FILL-
SPT	2.5	2.95	3	3	2	5		gravelly clayey SAND (SC-GM), f-c Sand, dk br., h. pl. fines, f-c gravel, dry to moist, loose
SPT	4.0	4.45	1	2	3	5		silty CLAY (CI-CH) m-h pl., grey br., trace f. sand, firm, moist
U50	5.5	5.95					60.	AS ABOVE
SPT	7.0	7.45	1 →					silty CLAY (CH), h.pl, grey, wet, Soft, / banded Sand lenses - leaf material
CPT	8.5	8.95	1	2	2	4		"ditto"
SPT	10.0	10.45	1 →		6.	7		Sandy CLAY (CH), h.pl, f.m-c Sand, grey, firm-soft

FIELD MATERIAL DESCRIPTION

DEPTH (metres)	UC Symbol	SOIL / ROCK MATERIAL DESCRIPTION (SOIL OR ROCK NAME, PLASTICITY OR PARTICLE SIZE, COLOUR, SECONDARY COMPONENTS, MOISTURE, STRENGTH)	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
0		Bitumen Pavement.			
0.3	GM	FILL- silty GRAVEL (GM), fine to coarse gravel, brown, some fine sand, ~~brown~~, dry, medium dense	D	MD	
1.0	CI	gravelly CLAY (CI), medium plasticity, brown, fine to coarse gravel, moist, very stiff	m	VSt.	
1.8	SC	gravelly clayey SAND (SC), fine to coarse sand, dark brown, fine to coarse gravel, dry to moist, loose	D to m	Loose	
3.0	CI-CH	silty CLAY (CI-CH), medium to high plasticity, grey & brown, trace fine sand, firm, moist	m	firm	NATURAL
5.5		becoming soft, moist to wet	m to we	So	
6.0	CH	silty CLAY (CH), high plasticity, grey, wet, soft.			occassional sand lenses & organic leaf matter.
10.0	CH	sandy CLAY (CH), high plasticity, ~~medium~~ grey, medium to coarse sand, moist, firm-soft	m	firm to soft (RS).	
10.7		TUFF — see Rock log			

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FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? Y/N

REPORT OF BOREHOLE: NST347

PROJECT No.: 06632062 SHEET 2 of 3

CLIENT: LBBJV

PROJECT: NSBT

LOCATION:

BOREHOLE LOCATION: .... E........ N

SURFACE RL: .... m DATUM: .... CO-ORD. SYSTEM ....

INCLINATION: -90 ° AZIMUTH: .... ° ZONE: ....

START: 20/11/6 at.... hrs FINISH: ..../..../.... at.... hrs

DRILL RIG: FOX LOGGED: Richard

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD
10.7	15.9	80	NMLC

OTHER:

GROUNDWATER

☐ Groundwater Observed at ~4.0 m depth during drilling

☐ SURFACE SEEPAGE ☒ SEEPAGE ☐ STRONG INFLOW

☐ Sample Wet at .... m depth .... hrs

☐ Groundwater Level at 1.0 m on completion of drilling at 1155 hrs

☒ Groundwater Level at .... m at .... hrs date .../.../...

☐ Groundwater Level at .... m at .... hrs date .../.../...

☐ ....

☐ Groundwater Not Encountered while ....* to .... m. depth

☒ Groundwater Not Observed due to introduction of Drilling Water Below ..... m depth

☐ Total/Partial Drilling Water Loss at/Below .. m...

☐ Borehole baled to .... m depth on completion of drilling

☐ .... mm Standpipe Installed to .... m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING							FIELD MATERIAL DESCRIPTION										DEFECT INFORMATION						COMMENTS
DEPTH (m)		RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS		DEPTH (m)		MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING			STRENGTH			DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	ADS ☐ FF ☐ DEFECT FREQUENCY				SAMPLES, IN-SITU TESTS, DRILLING NOTES
FROM	TO				FROM	TO	FROM	TO		FROM	TO	CODE	FROM	TO	CODE			FROM	TO	No./(m)	FREQU-ENCY	
																10.84	CS, 0-5°, Un, Ro, Vn, 5mm					
																10.90	DZ, 20°, Un, Ro, Vn, 240mm					
																11.15	CZ, 5°, Un, Ro, fine gravel, Vn, 10mm					
10.7	13.8	3.1	3.1/100		–	–	10.7	15.9	TUFF, fine to medium grained,	10.07	11.07	XW	10.7	11.07	EL	11.2	J, 35°, Un, Ro, Vn, 3mm					
									pinkish grey, clasts to 10mm	11.07	15.9	DW–SW	11.07	15.9	H–VH	11.25	SZ, 10°, Un, Ro, fine gravel, 5-10mm					
																11.47	J, 5°, Un, Ro, 1mm					
13.8	15.9	2.1	2.1/100		–	–										11.50	CS, 5°, Un, Ro, high plasticity clay, 35mm	10.84	11.50	7/0.66	10.6	
																11.71	DZ, 5-10°, Un, Ro, 50mm					
																11.92	SZ, 5°, Un, Ro, fine gravel, 6mm					
																12.15	SZ, 0°, Un, Ro, fine gravel, 10mm					
																12.48	J, 30°, Un, Ro, Sn, healed, 5mm	11.5	12.48	4/1.0	4.0	
																12.53	J, 10°, Un, Ro, Sn, healed, 5mm					
																12.56	J, 70°, Un, Ro, 2mm	12.48	13.06	6/0.58	10.3	
																12.73	J, 15°, Un, Sm					
																12.82	J, 5°, Un, Ro, Sn, 1mm	13.06	14.3	6/1.24	4.8	
																12.90	J, 35°, St, Ro, Sn, 5mm					
																13.06	J, 10°, Un, Ro, 8mm	14.3	15.05	10/0.75	13.3	
																13.37	CZ, 10°, Un, Ro, fine gravel, Vn, 10mm					
																13.45	J, 60°, Un, Ro, fine sand + fine gravel, Vn, 4mm	15.05	15.82	2/0.77	2.6	
																13.6	J, 30°, St, Ro, Sn, 20mm					
																13.9	CZ, 0°, Un, Ro, 200mm					
																14.16	SZ, 5°, Un, Ro, laminar gravel, 120mm					
																14.3	DZ, 5°, Un, Ro, 140mm					
																14.44	J, 15°, Un, Ro,					
																14.5	J, 15°, St, Ro, fine gravel, Vn, 5mm					
																14.52	J, 0°, Un, Ro, Sn, 3mm					
																14.58	J, 0°, Un, Ro, 10mm					
																14.62	J, 0°, Un, Ro, Vn					
																14.67	CZ, 10°, Un, Ro, fine gravel, Vn, 10mm					
																14.81	J, 15°, Un, Ro, 2mm					

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FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? Y/N

REPORT OF BOREHOLE: NST347

PROJECT No.: 06632062 SHEET 3 of 3

CLIENT: LBBJV

PROJECT: NSBT

LOCATION:

BOREHOLE LOCATION: E N

SURFACE RL: m DATUM: CO-ORD. SYSTEM

INCLINATION: -90 ° AZIMUTH: ° ZONE:

START: / / at hrs FINISH: / / at hrs

DRILL RIG: Fox LOGGED:

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD

OTHER:

GROUNDWATER

☐ Groundwater Observed at ....m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at ....m depth ....hrs
☐ Groundwater Level at ......m on completion of drilling at .....hrs
☐ Groundwater Level at ....m at ....hrs date .../...../.......
☐ Groundwater Level at ....m at ....hrs date .../...../.......
☐ ....
☐ Groundwater Not Encountered while ....* to ....m. depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below ......m depth
☐ Total/Partial Drilling Water Loss at/Below ..m...
☐ Borehole baled to ....m depth on completion of drilling
☐ ....mm Standpipe installed to........m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING							FIELD MATERIAL DESCRIPTION										DEFECT INFORMATION						COMMENTS
DEPTH (m)		RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS		DEPTH (m)		MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING			STRENGTH			DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	ADS ☐ FF ☐ DEFECT FREQUENCY				SAMPLES, IN-SITU TESTS, DRILLING NOTES
FROM	TO				FROM	TO	FROM	TO		FROM	TO	CODE	FROM	TO	CODE			FROM	TO	No./(m)	FREQU-ENCY	
																14.86	J, 8°, Un, Ro, Sn					
																14.93	J, 0°, Un, Ro, Sn					
																15.05	J, 5°, Un, Ro, Sn.					
																15.4	J, 85°, Un, Ro, healed, 5mm					
																15.82	J, 5°, Un, Ro, Sn					

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FIELD DRILLING REPORT (SOIL OR SOIL & ROCK)

REPORT OF BOREHOLE: NST348
PROJECT No.: 06632067 SHEET 1 of 2
CLIENT: LBBJV
PROJECT: NSBT
LOCATION:
BOREHOLE LOCATION: 10503219 E 6964151 N (GPS)
SURFACE RL: ~8m m DATUM: CO-ORD. SYSTEM WGS84
INCLINATION: -90° AZIMUTH: N/A ZONE:
START: 21/11/06 at 0710hrs FINISH: 21/11/06 at 1330hrs
DRILL RIG: Fox LOGGED: S Schl / AGS

DRILLING METHOD

CONTRACTOR: Schnetler
DIATUBE CORE/DTHH: m to m
AUGER (V, [✓ T-C,] HAND): 0 mm dia. to 5.5 m
ROTARY [✓ (BLADE/TRICONE)]: 5.5 m to 16.3 m
ROTARY (AIR/WATER): m to m
MUD P, N: m to m
[✓ NMLC] /CORE: 16.3 m to 21.5 m
CASING HW to 5.5 m NW to m
OTHER:

GROUNDWATER

☑ Groundwater Observed at 4.0 m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☑ Sample Wet at 4.0 m depth hrs
☐ Groundwater Level at m on completion of drilling at hrs
☐ Groundwater Level at m at hrs date / /
☐ Groundwater Level at m at hrs date / /
☐
☐ Groundwater Not Encountered while * to m. depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below m depth
☐ Total/Partial Drilling Water Loss at/Below m
☐ Borehole baled to m depth on completion of drilling
☐ mm Standpipe Installed to m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING / FIELD SAMPLING AND TESTING

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DRILLING OBSERVATIONS DESCRIPTION OF CUTTINGS, DETAILS OF STRATA CHANGES MINOR PROPERTIES, DRILL METHOD, DRILL REFUSAL ETC.	TYPE	DEPTH FROM	DEPTH TO	0–150mm or Run Length	150–300 or Rec. Length	300–450 or R.Q.D. Length	N VALUE or % Rec. / RQD	P.P. kPa	SAMPLE DESCRIPTION FIELD ASSESMENT OF RECOVERED SAMPLE e.g. SOIL OR ROCK TYPE, PLASTICITY, COLOUR, INCLUSIONS, MOISTURE, STRENGTH
A	M		0	Bitumen [illegible]									
H			0.3	Silty GRAVEL (GM), f-m									
D				gravel, br, [illegible] d	SPT	1.0	1.45	4	3	3	refusal on timber		clayey sandy GRAVEL (GP), f-m
			1.35	timber /steel									gravel dk br, some f-m sand,
	H												lo, dry to moist.
			1.5		SPT	2.5	2.95	2	2	2	4		CLAYEY SAND, coarse grained sand,
	M			Clayey sand,									dark ~~grow~~ brown, moist
			4.0	- note water table at 4.0m	SPT	~~3.5~~ 4	4.45	2	1	2	3		CLAYEY SAND, coarse grained sand,
													dark brown, wet (FILL)
	N		4.6										
				Clay, CH		5.5	5.95	1	1	1	2		Clay, high plasticity(?), CH, (natural)
			5.8										grey, [illegible], with some wood,
R					U50	7.0	TWT	[illegible]				55, 45	clay, high plasticity, grey, ~~very~~ soft
D			12.3										to very soft
				Gravelly clay? clayey	SPT	8.5	8.95	0	HW			N=0	"
				sand, medium grained, [illegible]									
				grey, wet, very soft	U50	10	10.45					55	"
			14.0	gravelly clay (residual),									
				high plasticity, brown, moist, stiff	SPT	11.5	11.95	HW →			0		CLAY, high plasticity, grey, with
													some organics/wood, wet/soft
			16	EW TUFF grey/green, moist	SPT	13.0	13.45	1	1	1	1		~~GRAVELLY~~ clayey SAND/sandy CLAY,
				very low strength									~~grey~~ fine to medium grained sand,
													grey, wet & ~~[illegible]~~ very soft
					SPT	14.5	14.95	3	4	5	9		gravelly ~~clay~~ clay, high plasticity, brown
			16.3	Change to coring (rock log)									moist, stiff, (residual clay)
					SPT	16 m	16.5	4	30/105		30 (105)		EW Tuff, grey/green, moist,
													very low strength

FIELD MATERIAL DESCRIPTION

DEPTH (metres)	UC Symbol	SOIL / ROCK MATERIAL DESCRIPTION (SOIL OR ROCK NAME, PLASTICITY OR PARTICLE SIZE, COLOUR, SECONDARY COMPONENTS, MOISTURE, STRENGTH)	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
0		Bitumen	M	H	
0.3	GM	FILL/clayey sandy GRAVEL (GM)		MD	
		fine to medium grained, brown			
		medium dense dry			
1.35		with some timber/steel			
1.5	SC	FILL/clayey SAND, coarse grained		L	
		dark brown, moist, loose			
4			W		
4.6	CH	CLAY, high plasticity, grey, with		S-	marine sediments
		some wood, wet, soft to very soft		VS	
12.3	SC	clayey SAND, medium to coarse grained		VS	
		grey, wet, very soft			
14.0	CH	gravelly CLAY, high plasticity,	M	St	residual soil
		brown, moist, stiff			
16		extremely weathered TUFF,		VL/	
		grey/green, moist, very low/extremely		EL	
		low strength			

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GOLDER FORM GA BQ-108 VERSION No. 10 REVISED 30/05/06

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FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? [✓ Y]/N

REPORT OF BOREHOLE: NSB348

PROJECT No.: 06632062 SHEET 2 of 2
CLIENT: ~~NSBTP~~ LBBJV
PROJECT: NSBT
LOCATION:
BOREHOLE LOCATION: 10503219 E 6964151 N
SURFACE RL: ~8m m DATUM: CO-ORD. SYSTEM UGS84
INCLINATION: -90° AZIMUTH: ° ZONE:
START: 21/11/06 at 0700 hrs FINISH: 21/11/06 at 1336 hrs
DRILL RIG: FOX LOGGED: AGS

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD
16.3	21.5	50	NMLC

OTHER:

GROUNDWATER

☑ Groundwater Observed at 5 m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at ..... m depth ..... hrs
☐ Groundwater Level at ..... m on completion of drilling at ..... hrs
☐ Groundwater Level at ..... m at ..... hrs date .../.../...
☐ Groundwater Level at ..... m at ..... hrs date .../.../...
☐ .....
☐ Groundwater Not Encountered while .....* to ..... m. depth
☐ Groundwater Not Observed due to introduction of Drilling Water Below ..... m depth
☐ Total/Partial Drilling Water Loss at/Below ..... m...
☐ Borehole baled to ..... m depth on completion of drilling
☐ ..... mm Standpipe Installed to ..... m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

EL, VL, L, M H, VH, EH

DRILLING							FIELD MATERIAL DESCRIPTION									DEFECT INFORMATION						COMMENTS
DEPTH (m)		RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS		DEPTH (m)		MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING			STRENGTH			DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	ADS ☐ FF ☑ DEFECT FREQUENCY				SAMPLES, IN-SITU TESTS, DRILLING NOTES
FROM	TO				FROM	TO	FROM	TO		FROM	TO	CODE	FROM	TO	CODE			FROM	TO	No./(m)	FREQUENCY	
16.3	19.36	3.06	100	97%	—	—	16.3		TUFF, fine to coarse grained, grey with	16.3	18.5	DW	16.3	17	H	16.5	J~~&~~, 80°, ~~[illegible]~~, UN, Ro, Clay, 2mm	16.3	17.42		400	
19.36	21.50	2.14	100	100%					orange staining, with clasts smaller	18.5	19.52	SW	17	21.5	VH	16.93	J, 45°, St, Ro, Clay, 1mm	17.42	18.42		1000	
									than 5mm.	19.52	21.5	SW-FR				16.97	DZ, 0°, UN, Ro, clay/VL tuff, 35mm	18.42	19.23		250	
							21.25		with 20mm breccia piece							17.42	J, 80°, UN, Ro, Clay, 2mm	19.23	20.75		1000	
							21.42		black vein, 15mm, dipping at 70°							18.42	J, 75°, UN, Ro, clay, veneer, partially healed	2075	21.5		250	
																18.75	J, 25°, Pl, Ro, limonite, veneer					
																18.78	J, 10°, Pl, Ro, limonite, veneer					
																19.07	J, 5°, UN, Ro, limonite, veneer					
																17.66	CS, 10°, UN, Ro, sandy clay, 6mm					
																19.23	J, 50°, ~~UN~~ UN, Ro, clean					
																19.46	J, 80°, UN, Ro, healed					
																~~[illegible]~~	~~J, 10°, UN, Ro~~					
																20.75	J, 10°, St, Ro, limonite, veneer					
																20.89	J, 5°, UN, Ro, limonite, veneer					
																21.26	J, 25°, UN, Ro, limonite, 2mm					
																~~[illegible]~~						

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FIELD DRILLING REPORT (SOIL OR SOIL & ROCK)

REPORT OF BOREHOLE: NST349

PROJECT No.: 06632062 SHEET 1 of 2
CLIENT: LBBJV
PROJECT: NSBT
LOCATION:
BOREHOLE LOCATION: E N
SURFACE RL: m DATUM: CO-ORD. SYSTEM
INCLINATION: -90 ° AZIMUTH: ° ZONE:
START: 9/11/6 at 0700 hrs FINISH: / / at hrs
DRILL RIG: FOX LOGGED: SSchuh

DRILLING METHOD

CONTRACTOR: Schneider Drilling
DIATUBE CORE/DTHH: m to m
AUGER (V, [✓ T-C], HAND): 80 mm dia. to 2.5 m
ROTARY (BLADE/[✓ TRICONE]): 2.5 m to 20.7 m
ROTARY (AIR/WATER): m to m
MUD R. N: m to m
[✓ NMLC] /CORE: 20.7 m to 25.92 m
CASING HW to m NW to m
OTHER:

GROUNDWATER

☐ Groundwater Observed at m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at m depth hrs
☐ Groundwater Level at m on completion of drilling at hrs
☐ Groundwater Level at m at hrs date / /
☐ Groundwater Level at m at hrs date / /
☐
☐ Groundwater Not Encountered while * to m. depth
☑ Groundwater Not Observed due to introduction of Drilling Water Below 2.5 m depth
☐ Total/Partial Drilling Water Loss at/Below m
☐ Borehole baled to m depth on completion of drilling
☐ mm Standpipe Installed to m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DRILLING OBSERVATIONS DESCRIPTION OF CUTTINGS, DETAILS OF STRATA CHANGES MINOR PROPERTIES, DRILL METHOD, DRILL REFUSAL ETC.
A	L.		0.	FILL - gravelly clayey SAND (SC)
H				f-m sand, brown, hpl fines,
D				f-c gravel, moist, loose -
			0.8	Silty CLAY (CH), brown & grey
			2.0	NATURAL (CH), grey
2.5				- sand lenses in (CH) clay
R				
D.			5.0	fine alluvial gravel lenses.
	M.		6.5	silty clay (CH) grey
				yellow-br, hpl, firm.
			8.0	- becoming stiff.
			11.0	becoming firm.
			16	- becoming stiff (sandy clay)
			16.6	- gravel bands
	H.		17	gravelly SAND (SP) / drilling as gravel
			18.	- rock?? very hard either
	1.			quartz gravel or rock
			19.5	- gravel drilling
			20.1	- rock XW, greenish grey & brown
				Rock Log.

FIELD SAMPLING AND TESTING

TYPE	DEPTH FROM	DEPTH TO	0-150mm or Run Length	150-300 or Rec. Length	300-450 or R.Q.D. Length	N VALUE or % Rec. RQD	P.P. kPa	SAMPLE DESCRIPTION FIELD ASSESMENT OF RECOVERED SAMPLE e.g. SOIL OR ROCK TYPE, PLASTICITY, COLOUR, INCLUSIONS, MOISTURE, STRENGTH
SPT	1.0	1.45	2	4	5	9		Silty CLAY (CH), hpl, brown & grey, moist, firm
SPT	2.5	2.95	1	2	2	4		Silty CLAY (CH), hpl, grey, soft-firm
U50	4.0	4.45			-> Sand at Base (CH) & SP clay			
SPT	5.5	5.95	4	3	1	4.		50% (CH), grey / 50% fine sand/gravel (banded) fill in.
SPT	7.0	7.45	1	2	4	6		7-7.2 SAND (SP) 7.2-7.45 Silty CLAY (CH), grey & yellow br, stiff.
SPT	8.5	8.95	3	4	6	10	250	Silty CLAY (CH), hpl, grey & yellow br stiff, moist
SPT	10.0	10.45	3	3	5	8	210	"ditto"
SPT	11.5	11.95	2	2	4	6	150	"ditto"
SPT	13.0	13.45	3	2	5	7	163	"ditto", some fine ironstone gravel
SPT	14.5	14.95	3	3	2	5		"ditto" / 50% sand lenses
SPT	16.0	16.45	2	5	8	13		Sandy CLAY (CH), hpl, grey & brown, fine sand, stiff
SPT	17.5	17.93	9	13	30/130mm	SPT refusal		gravelly SAND (SP) f-c sand, brown, f-m gravel, lo-MD, wet
SPT	19.0	19.45	10	17	25	42		clayey sandy GRAVEL (GC), f-c gravel, coarse sand, hpl fines, MD
SPT	20.5	20.73	22	30/80mm				> silty CLAY (CI) / XW, mpl, greenish grey & brown, hard XW TUFF (RS), hard, dry.

FIELD MATERIAL DESCRIPTION

DEPTH (metres)	UC Symbol	SOIL / ROCK MATERIAL DESCRIPTION (SOIL OR ROCK NAME, PLASTICITY OR PARTICLE SIZE, COLOUR, SECONDARY COMPONENTS, MOISTURE, STRENGTH)	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
0	SC	FILL - gravelly clayey SAND (SC), fine to medium sand, brown, high plasticity fines, fine to coarse gravel, moist, loose	m	Lo	
0.8	CH	Silty CLAY (CH), high plasticity, grey, moist, soft-firm	m	So-Firm	
2.0	CH	NATURAL - Silty CLAY (CH), high plasticity, grey, occasional sand lenses, moist to wet, soft-firm.	m/w	So-firm	
5.0		fine gravel and coarse sand bands			
6.2		becoming grey & yellow brown, moist, stiff.	m	St	
11.0		becoming firm	m	firm	
13.0		- Some fine ironstone gravel			
14.5		- increase in sand lenses			
16.0	CH	Sandy CLAY (CH), high plasticity, grey & brown, fine sand, moist, stiff	m	St	
17	SP	gravelly SAND (SP), fine to coarse sand, brown, fine gravel, wet, loose to medium dense.	w	Lo-MD	
18	GC	clayey sandy GRAVEL (GC), fine to coarse gravel, coarse sand, high plasticity fines, wet, medium dense	w	MD	
20.5	CI	silty CLAY (CI), medium plasticity, greenish grey & brown, friable, dry, hard	D	H	Residual Soil
20.7		TUFF - medium to coarse grained SEE Rock Log.			

Golder Associates

611 Coronation Drive
Toowong, QLD 4066
&
Unit1/51 Secam Street
Mansfield, QLD 4122

FIELD DRILLING REPORT (ROCK)

CONTINUED FROM SOIL LOG? Y/N

REPORT OF BOREHOLE: NST.349

PROJECT No.: 06632062 SHEET 2 of 2

CLIENT: LBBJV

PROJECT: NSBT-

LOCATION:

BOREHOLE LOCATION: .... E........ N

SURFACE RL: -90 m DATUM: .... CO-ORD. SYSTEM ....

INCLINATION: -90 ° AZIMUTH: .... ° ZONE: ....

START: 10 / 11 / 6 at .... hrs FINISH: 11 / 11 / 6 at .... hrs

DRILL RIG: FOX LOGGED: SSchul

DRILLING METHOD

FROM (m)	TO (m)	DIAMETER (mm)	METHOD
20.7	25.92	80	NMLC

OTHER: ....

GROUNDWATER

☐ Groundwater Observed at .... m depth during drilling
☐ SURFACE SEEPAGE ☐ SEEPAGE ☐ STRONG INFLOW
☐ Sample Wet at .... m depth .... hrs
☐ Groundwater Level at .... m on completion of drilling at .... hrs
☐ Groundwater Level at .... m at .... hrs date ..../..../....
☐ Groundwater Level at .... m at .... hrs date ..../..../....
☐ ....
☐ Groundwater Not Encountered while ....* to .... m. depth
☒ Groundwater Not Observed due to introduction of Drilling Water Below 2.5 m depth
☐ Total/Partial Drilling Water Loss at/Below .... m...
☐ Borehole baled to .... m depth on completion of drilling
☐ .... mm Standpipe Installed to .... m depth on Completion of Drilling

*Insert Drilling Method e.g. Augering, Hammering etc.

DRILLING							FIELD MATERIAL DESCRIPTION									DEFECT INFORMATION						COMMENTS
DEPTH (m)		RUN LENGTH (m)	TCR (m)/(%)	RQD (m)/(%)	CORE LOSS		DEPTH (m)		MATERIAL DESCRIPTION (Type, Grain Size, Texture, Colour, Other)	WEATHERING			STRENGTH			DEPTH (m)	DEFECT DESCRIPTION (Type, Orientation, Planarity, Roughness, Coating, Thickness)	ADS ☐ FF ☐ DEFECT FREQUENCY				SAMPLES, IN-SITU TESTS, DRILLING NOTES
FROM	TO				FROM	TO	FROM	TO		FROM	TO	CODE	FROM	TO	CODE			FROM	TO	No./(m)	FREQU-ENCY	
							20.7	25.92	TUFF, medium to coarse grained,	20.7	21.6	XW	20.7	21.6	EL-VL							
20.7	22.82	2.12	2.12/100	1.15/	–	–			greenish grey.													
22.82	25.92	3.1	3.1/100	3.1/100	–	–				21.6	25.92	SW	21.6	25.92	M							
									EoH = 25.92													

Golder Associates

PRELIMINARY REPORT OF BOREHOLE: NST249

				SHEET: 1 OF 3	
CLIENT:	LBBJV	COORDS: 53691 m E 158051 m N BCSG02		DRILL RIG: FD500	
PROJECT:	NSBT	SURFACE RL: 17.50 m DATUM: AHD		DRILLER: Foundril	
LOCATION:	Shaftston Avenue	INCLINATION: -90°		LOGGED: SS	DATE: 29/6/06
JOB NO:	06632062	HOLE DIA: 100/76 mm	HOLE DEPTH: 10.18 m	CHECKED: LBM (C)	DATE: 30/9/06

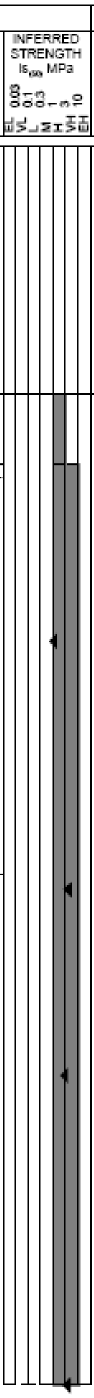
Drilling					Sampling	Field Material Description						
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USC Symbol	SOIL / ROCK MATERIAL DESCRIPTION	MOISTURE	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
ADT	L		0	17.50 *0.50*				SM	Silty SAND - TOPSOIL - FILL Fine sand, dark brown, loose to medium dense, building rubble including concrete and boulders	M		
			1	17.00 *1.50*	SPT 1.00-m 6,6,8 N = 14			CH	Silty CLAY High plasticity, grey and yellow brown, trace fine gravel		VSt	
	M			16.00 *2.00*					TUFF Extremely to distinctly weathered, yellow brown, very low to low strength			
RD	H		2									
				15.50					For Continuation Refer to Sheet 2			
			3									
			4									
			5									
			6									
			7									
			8									
			9									
			10									

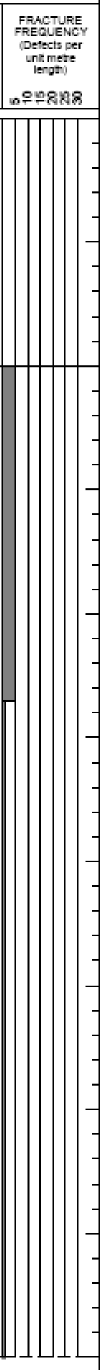
Golder Associates

PRELIMINARY REPORT OF BOREHOLE: NST249

CLIENT:	LBBJV	COORDS: 53691 m E 158051 m N BCSG02	SHEET: 2 OF 3	
PROJECT:	NSBT	SURFACE RL: 17.50 m DATUM: AHD	DRILL RIG: FD500	
LOCATION:	Shaftston Avenue	INCLINATION: -90°	DRILLER: Foundril	
JOB NO:	06632062	HOLE DIA: 100/76 mm HOLE DEPTH: 10.18 m	LOGGED: SS	DATE: 29/6/06
			CHECKED: LBM (C)	DATE: 30/9/06

Drilling					Field Material Description		Defect Information
METHOD	WATER	TCR %	RQD %	DEPTH RL	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	DEFECT DESCRIPTION & Additional Observations
				2.00	Continuation of Sheet 1		
NMLC	Goundwater not observed due to introduction of drilling water below 2.0m	100	71	15.50	TUFF Fine grained, pale pinkish grey, massive	DW	2.30m: J, 40°, Pl, Ro, Vr, silt 2.31m: J, 40°, Pl, Ro, Vr, silt 2.43m: J, subhorizontal°, Un, Ro, Sn
				2.57 14.93	. fresh, pinkish pale grey and yellow brown	SW-FR	2.56m: CZ, subhorizontal°, Ro, 70mm 2.69m: J, 15°, Sm, Vr, 2mm 3.07m: J, 30°, Pl-Un, Vr, 1mm silt 3.08m: J, subhorizontal°, Un, Ro 3.15m: J, 10°, Un, Ro
				3.60 13.90	Point Load at 3.60m $I_{s(50)}$ = 2.13 MPa (D), 3.01 MPa (A)		
				4.00 13.50	Point Load at 4.00m $I_{s(50)}$ = 0.96MPa (D)		4.16m: J, subhorizontal°, Un, Ro, pale grey, healed 4.18m: J, 20°, Un, Ro, Cn 4.27m: J, 50°, Pl-Un, Ro, yellow brown, healed 4.45m: CS, subhorizontal°, Un, Ro, 30mm 4.66m: J, subhorizontal°, Pl, Sm, Vr, clay 4.70m: J, subhorizontal°, Pl, Sm, Vr, clay
		100	100	5.88	. pale grey	FR	
				6.00 11.50	Point Load at 6.00m $I_{s(50)}$ = 3.59MPa (D)		
				6.40 11.10	Point Load at 6.40m $I_{s(50)}$ = 4.68 MPa (D), 4.90 MPa (A)		
				7.00 10.50	. occasional clasts in rock matrix to 15mm		
		100	100	7.50 10.00	Point Load at 7.50m $I_{s(50)}$ = 2.67MPa (D)		
				9.50	Point Load at 10.00m $I_{s(50)}$ = 3.33MPa		
				9.70 7.80	Point Load at 9.70m		





This report of borehole must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

PRELIMINARY REPORT OF BOREHOLE: NST249

Golder Associates

SHEET: 3 OF 3

CLIENT: LBBJV
PROJECT: NSBT
LOCATION: Shaftston Avenue
JOB NO: 06632062

COORDS: 53691 m E 158051 m N BCSG02
SURFACE RL: 17.50 m DATUM: AHD
INCLINATION: -90°
HOLE DIA: 100/76 mm HOLE DEPTH: 10.18 m

DRILL RIG: FD500
DRILLER: Foundril
LOGGED: SS DATE: 29/6/06
CHECKED: LBM (C) DATE: 30/9/06

Drilling						Field Material Description				Defect Information	
METHOD	WATER	TCR %	RQD %	DEPTH (metres)	DEPTH RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH $Is_{(50)}$ MPa 0.03 0.1 0.3 1 3 10 EL VL L M H VH EH	DEFECT DESCRIPTION & Additional Observations	FRACTURE FREQUENCY (Defects per unit metre length) 5 10 15 20 30
				10	10.16		$I_{s(50)}$ = 4.84 MPa (D), 5.30 MPa (A)		▨▨		
							END OF BOREHOLE @ 10.18 m				
				11							
				12							
				13							
				14							
				15							
				16							
				17							
				18							
				19							
				20							

GAP6_0-1BETA_BRIS.GLB CORED BOREHOLE J:\BRISBANE 06\GEOTECH 06\06632062_NSBT_SITE_INVESTIGATION\3062-2.GPJ GAP5_1.GDT 01/05/2007 10:37:10 AM

APPENDIX D– POINT LOAD TESTING

POINT LOAD STRENGTH TEST RESULTS

Client : LBBJV
Project : NSBT
Location : RNA
Tested by : SS
Test Method : AS 4133.4.1 - 1993
Sample History :
Preliminary Results Given : No : Date :

Job No : 06632062
Report No : NST 207
Date Drilled : 3/10/2006

Borehole Number	Depth (m)	Rock Type	Weathering	Sample Length (mm)	Sample Diameter (mm)	Test Type [1]	Platen Separation (mm)	Gauge Load (kN)	Actual Load [2] (kN)	I_s (MPa)	**$I_{s(50)}$ (MPa)**	**Descriptive Strength Classification**
NST207	1.85	Tuff	SW	70.0	52.0	A	69.0	9.2	9.20	2.01	**2.31**	H
NST207	2.76	Tuff	SW-FR	73.0	52.0	A	65.0	13.3	13.31	3.09	**3.49**	VH
NST207	3.07	Tuff	SW-FR	92.0	52.0	D	49.0	4.9	4.91	2.04	**2.03**	H
NST207	4.00	Tuff	SW-FR	63.0	52.0	A	60.0	16.8	16.78	4.22	**4.69**	VH
NST207	6.92	Tuff	SW-FR	71.0	52.0	A	66.0	19.6	19.60	4.49	**5.09**	VH
NST207	8.72	Tuff	SW-FR	70.0	52.0	A	64.0	18.8	18.76	4.43	**4.99**	VH
NST207	11.75	Tuff	FR	60.0	52.0	D	55.0	12.6	12.60	4.17	**4.35**	VH
NST207	15.00	Tuff	FR	54.0	52.0	A	50.0	14.6	14.56	4.40	**4.69**	VH
NST207	18.00	Tuff	FR	70.0	52.0	A	63.0	13.0	12.95	3.10	**3.48**	VH
NST207	20.93	Tuff	FR	70.0	52.0	A	68.0	10.0	10.02	2.23	**2.54**	H
NST207	21.40	Tuff	FR	68.0	52.0	A	59.0	16.4	16.38	4.19	**4.64**	VH
NST207	24.94	Tuff	FR	60.0	52.0	A	58.0	12.2	12.18	3.17	**3.49**	VH

NOTES :

1 D= Diametral A= Axial
2 Gauge calibrated on 22/9/05

Laboratory : BRISBANE
Checked By : BJF

POINT LOAD STRENGTH TEST RESULTS

Client : LBBJV
Project : NSBT
Location : RNA
Tested by: SS
Test Method : AS
Sample History :
Preliminary Results Given :

Job No : 06632062
Report No : NST206
Date Drilled : 14/09/2006

Date :

Borehole Number	Depth (m)	Rock Type	Weathering	Sample Length (mm)	Sample Diameter (mm)	Test Type ^{1}	Platen Separation (mm)	Gauge Load (kN)	Actual Load ^{2} (kN)	I_s (MPa)	**$I_{s(50)}$ (MPa)**	**Descriptive Strength Classification**
NST206	2.60	Tuff	SW	100.0	52.0	D	48.0	6.4	6.37	2.76	**2.71**	H
NST206	2.60	Tuff	SW	45.0	52.0	A	45.0	11.2	11.20	3.76	**3.91**	VH
NST206	6.60	Tuff	SW	110.0	52.0	D	48.0	11.7	11.74	5.10	**5.00**	VH
NST206	6.60	Tuff	SW	30.0	52.0	A	25.0	10.2	10.17	6.14	**5.60**	VH
NST206	11.70	Tuff	SW	110.0	52.0	D	44.0	14.7	14.67	7.58	**7.15**	VH
NST206	11.70	Tuff	SW	30	52.0	A	30.0	13.4	13.39	6.74	**6.40**	VH
NST206	17.10	Tuff	SW	160	52.0	D	47.0	6.7	6.65	3.01	**2.93**	H-VH
NST206	17.10	Tuff	SW	30	52.0	A	29.0	8.1	8.12	4.23	**3.99**	VH
NST206	23.90	Tuff	FR	200	52.0	D	49.0	8.0	7.98	3.32	**3.29**	VH
NST206	23.90	Tuff	FR	15	52.0	A	27.0	9.0	8.98	5.02	**4.66**	VH
NST206	28.70	Tuff	FR	200	52.0	D	45.0	10.7	10.67	5.27	**5.03**	VH
NST206	28.7	Tuff	FR	30.0	52.0	A	25.0	7.3	7.25	4.38	**3.99**	VH

NOTES :

1 D= Diametral A= Axial

2 Gauge calibrated on 22/9/05

Laboratory : BRISBANE
Checked By : MSC/10.4.07

Golder Associates

POINT LOAD STRENGTH TEST RESULTS

Client : LBBJV
Project : NSBT
Location : RNA
Tested by: SS
Test Method : AS 4133.4.1 - 1993
Sample History :
Preliminary Results Given : No : Date :

Job No : 06632062
Report No : NST 213
Date Drilled : 5/10/2006

Borehole Number	Depth (m)	Rock Type	Weathering	Sample Length (mm)	Sample Diameter (mm)	Test Type [1]	Platen Separation (mm)	Gauge Load (kN)	Actual Load [2] (kN)	I_s (MPa)	**$I_{s(50)}$ (MPa)**	**Descriptive Strength Classification**
NST213	2.61	Tuff	SW	100.0	52.0	A	49.0	9.7	9.67	2.98	**3.16**	VH
NST213	3.85	Tuff	SW	60.0	52.0	A	57.0	12.9	12.90	3.42	**3.75**	VH
NST213	6.00	Tuff	SW-FR	60.0	52.0	D	58.0	10.2	10.20	3.03	**3.24**	VH
NST213	9.10	Tuff	FR	70.0	52.0	A	67.0	25.5	25.51	5.75	**6.54**	VH
NST213	12.00	Tuff	FR	60.0	52.0	A	58.0	13.1	13.06	3.40	**3.75**	VH
NST213	14.76	Tuff	FR	69.0	52.0	A	67.0	15.9	15.89	3.58	**4.08**	VH
NST213	17.00	Tuff	FR	74.0	52.0	D	47.0	12.4	12.43	5.63	**5.47**	VH
NST213	20.05	Tuff	FR	70.0	52.0	A	66.0	21.8	21.79	4.99	**5.65**	VH
NST213	23.00	Tuff	FR	120.0	52.0	A	50.0	20.9	20.88	6.31	**6.72**	VH
NST213	25.94	Tuff	FR	55.0	52.0	A	46.0	12.1	12.06	3.96	**4.14**	VH
NST213	28.00	Tuff	FR	80.0	52.0	A	50.0	12.2	12.15	3.67	**3.91**	VH
NST213	29.75	Tuff	FR	57.0	52.0	A	55.0	16.4	16.42	4.51	**4.91**	VH
NST213	32.94	Tuff	FR	60.0	52.0	A	58.0	21.2	21.21	5.52	**6.08**	VH
NST213	36.74	Tuff	FR	55.0	52.0	A	53.0	18.0	17.95	5.12	**5.52**	VH
NST213	40.00	Tuff	FR	87.0	52.0	A	50.0	14.8	14.75	4.46	**4.75**	VH
NST213	42.74	Tuff	FR	55.0	52.0	A	53.0	15.8	15.84	4.51	**4.87**	VH

NOTES :

1 D= Diametral A= Axial

2 Gauge calibrated on 22/9/05

Laboratory : BRISBANE
Checked By : BJF

GOLDER ASSOCIATES

POINT LOAD STRENGTH TEST RESULTS

Client : LBBJV
Project : NSBT
Location : Sneyd St
tested by: SS
Test Method : AS 4133.4.1 - 1993
Sample History :
Preliminary Results Given : No : Date :

Job No : 06632062
Report No : NST 241
Date Drilled : 7/11/2006

Borehole Number	Depth (m)	Rock Type	Weathering	Sample Length (mm)	Sample Diameter (mm)	Test Type[1]	Platen Separation (mm)	Gauge Load (kN)	Actual Load[2] (kN)	I_s (MPa)	**$I_{s(50)}$ (MPa)**	**Descriptive Strength Classification**
NST 241	1.00	Tuff	DW-SW	62.0	52.0	D	51.0	11.2	11.23	4.32	**4.36**	VH
NST 241	5.00	Tuff	DW-SW	68.0	52.0	A	66.0	14.7	14.74	3.37	**3.82**	VH
NST 241	8.00	Tuff	DW-SW	80.0	52.0	D	51.0	13.5	13.48	5.18	**5.23**	VH
NST 241	11.94	Tuff	SW	57.0	52.0	A	56.0	12.2	12.17	3.28	**3.59**	VH
NST 241	15.00	Tuff	SW	65.0	52.0	D	51.0	12.7	12.71	4.89	**4.93**	VH
NST 241	18.00	Tuff	SW	100.0	52.0	D	51.0	13.1	13.09	5.03	**5.08**	VH
NST 241	21.00	Tuff	SW	65.0	52.0	A	62.0	15.4	15.39	3.75	**4.19**	VH
NST 241	24.05	Tuff	SW	105.0	52.0	D	51.0	14.7	14.68	5.64	**5.69**	VH

NOTES :
1 D= Diametral A= Axial
2 Gauge calibrated on 22/9/05

Laboratory : BRISBANE
Checked By : BJF

GOLDER ASSOCIATES

POINT LOAD STRENGTH TEST RESULTS

Client : LBBJV
Project : NSBT
Location : Shafston Ave

Job No : 06632062
Report No : NS249
Date Drilled : 29/06/2006

Test Method : AS 4133.4.1 - 1993
Sample History :
Preliminary Results Given : No : Date :

Borehole Number	Depth (m)	Rock Type	Weathering	Sample Length (mm)	Sample Diameter (mm)	Test Type [1]	Platen Separation (mm)	Gauge Load (kN)	Actual Load [2] (kN)	I_s (MPa)	**$I_{s(50)}$ (MPa)**	**Descriptive Strength Classification**
NST249	3.60	Tuff	SW-FR	170.0	50.0	D	49.0	5.2	5.15	2.14	**2.13**	
NST249	3.60	Tuff	SW-FR	35.0	50.0	A	33.0	6.6	6.57	3.13	**3.01**	
NST249	6.40	Tuff	FR	300.0	50.0	D	47.0	10.6	10.64	4.82	**4.68**	
NST249	6.40	Tuff	FR	40.0	50.0	A	38.0	11.9	11.94	4.94	**4.90**	
NST249	9.70	Tuff	FR	75.0	50.0	D	40.0	8.6	8.56	5.35	**4.84**	
NST249	9.70	Tuff	FR	30	50.0	A	31.0	11.0	11.04	5.59	**5.30**	

NOTES :
1 D= Diametral A= Axial
2 Gauge calibrated on 22/9/05

Laboratory : BRISBANE
Checked By : MSC/18.04.07

Golder Associates

POINT LOAD STRENGTH TEST RESULTS

Client : LBBJV
Project : NSBT
Location : Deakin Street
Tested by SS

Job No : 06632062
Report No : NST257
Date Drilled : 27/11/2006

Test Method : AS 4133.4.1 - 1993
Sample History : Stored 2 weeks under tarp prior to testing
Preliminary Results Given : No : Date :

Borehole Number	Depth (m)	Rock Type	Veatherin	Sample Length (mm)	Sample Diameter (mm)	Test Type [1]	Platen Separation (mm)	Gauge Load (kN)	Actual Load [2] (kN)	I_s (MPa)	**$I_{s(50)}$ (MPa)**	**Descriptive Strength Classification**
NST257	3.06	Tuff	EW	32.0	51.0	A	30.0	0.35	0.35	0.18	**0.17**	L
NST257	3.94	Tuff	EW-DW	40.0	51.0	D	49.0	0.10	0.10	0.04	**0.04**	VL
NST257	4.77	Tuff	EW-DW	35.0	51.0	D	50.0	0.10	0.10	0.04	**0.04**	VL
NST257	4.77	Tuff	EW-DW	42.0	51.0	A	31.0	1.41	1.41	0.70	**0.67**	M
NST257	6.64	Tuff	DW-SW	30.0	51.0	D	50.0	0.90	0.90	0.36	**0.36**	M
NST257	6.64	Tuff	DW-SW	26.0	51.0	A	19.0	1.25	1.25	1.02	**0.87**	M
NST257	7.95	Tuff	DW-SW	45.0	51.0	A	38.0	0.14	0.14	0.06	**0.06**	VL
NST257	8.15	Tuff	DW-SW	35.0	51.0	D	50.0	0.71	0.71	0.28	**0.28**	L
NST257	8.20	Tuff	DW-SW	30.0	51.0	A	25.0	1.49	1.49	0.92	**0.84**	M
NST257	10.15	Tuff	DW-SW	35.0	51.0	D	50.0	0.53	0.53	0.21	**0.21**	L
NST257	10.15	Tuff	DW-SW	30.0	51.0	A	26.0	0.83	0.83	0.49	**0.45**	M
NST257	13.05	Tuff	SW	30.0	51.0	D	50.0	2.55	2.56	1.02	**1.02**	H
NST257	13.05	Tuff	SW	45.0	51.0	A	40.0	3.18	3.19	1.23	**1.24**	H
NST257	14.52	Tuff	DW-SW	35.0	51.0	D	50.0	1.47	1.47	0.59	**0.59**	M
NST257	14.52	Tuff	DW-SW	29.0	51.0	A	26.0	3.33	3.34	1.98	**1.81**	H
NST257	16.00	Tuff	DW-SW	26.0	51.0	A	22.0	1.49	1.49	1.05	**0.92**	M
NST257	17.00	Tuff	DW-SW	36.0	51.0	A	34.0	1.70	1.71	0.77	**0.75**	M
NST257	17.84	Tuff	DW-SW	35.0	51.0	D	50.0	0.56	0.56	0.22	**0.22**	L
NST257	17.84	Tuff	DW-SW	29.0	51.0	A	25.0	1.07	1.07	0.66	**0.60**	M
NST257	18.80	Cgl	DW-SW	29.0	51.0	A	24.0	1.97	1.98	1.27	**1.14**	H
NST257	18.80	Cgl	DW-SW	35.0	51.0	D	50.0	0.63	0.63	0.25	**0.25**	L
NST257	21.05	Cgl	DW-SW	50.0	51.0	D	50.0	1.70	1.71	0.68	**0.68**	M
NST257	21.05	Cgl	DW-SW	45.0	51.0	A	44.0	2.03	2.04	0.71	**0.73**	M
NST257	23.95	Cgl	DW-SW	40.0	51.0	D	50.0	0.27	0.27	0.11	**0.11**	L
NST257	23.95	Cgl	DW-SW	38.0	51.0	A	35.0	1.83	1.84	0.81	**0.79**	M
NST257	26.41	Cgl	DW-SW	40.0	51.0	D	50.0	1.51	1.51	0.61	**0.61**	M
NST257	26.41	Cgl	DW-SW	40.0	51.0	A	35.0	2.10	2.11	0.93	**0.91**	M
NST257	30.17	Cgl	SW	50.0	51.0	D	49.0	2.29	2.30	0.96	**0.95**	M
NST257	30.17	Cgl	SW	51.0	51.0	A	47.0	2.67	2.68	0.88	**0.92**	M
NST257	32.20	Cgl	SW	26.0	51.0	D	50.0	2.48	2.49	1.00	**1.00**	M
NST257	32.20	Cgl	SW	38.0	51.0	A	35.0	3.56	3.57	1.57	**1.54**	H
NST257	32.95	Sst	SW	40.0	51.0	D	50.0	2.55	2.56	1.02	**1.02**	H
NST257	32.95	Sst	SW	40.0	51.0	A	35.0	4.34	4.35	1.92	**1.87**	H
NST257	34.13	Cgl	SW	50.0	51.0	D	49.0	1.41	1.41	0.59	**0.58**	M

NOTES :
1 D= Diametral A= Axial
2 Gauge calibrated on 22/9/05

Laboratory : BRISBANE
Checked By : MSC/18.04.2007

Golder Associates

POINT LOAD STRENGTH TEST RESULTS

Client :	LBBJV	Job No :	06632062
Project :	NSBT	Report No :	NST257
Location :	Deakin Street	Date Drilled :	27/11/2006

Test Method : AS 4133.4.1 - 1993

Sample History : Stored 2 weeks under tarp prior to testing

Preliminary Results Given : No : Date :

Borehole Number	Depth (m)	Rock Type	Weathering	Sample Length (mm)	Sample Diameter (mm)	Test Type [1]	Platen Separation (mm)	Gauge Load (kN)	Actual Load [2] (kN)	I_s (MPa)	**$I_{s(50)}$ (MPa)**	**Descriptive Strength Classification**
NST257	34.13	Cgl	SW	37.0	51.0	A	36.0	0.90	0.90	0.39	**0.38**	M
NST257	34.13	Cgl	SW	35.0	51.0	D	50.0	1.39	1.39	0.56	**0.56**	M
NST257	37.31	Cgl	SW	26.0	51.0	D	50.0	2.64	2.65	1.06	**1.06**	H
NST257	37.31	Cgl	SW	31.0	51.0	A	29.0	2.63	2.64	1.40	**1.31**	H

NOTES :

1 D= Diametral A= Axial

2 Gauge calibrated on 22/9/05

Laboratory : BRISBANE

Checked By : MSC/18.04.2007

Golder Associates

POINT LOAD STRENGTH TEST RESULTS

Client : LBBJV
Project : NSBT
Location : Horace Street
Tested by: SS
Test Method : AS 4133.4.1 - 1993
Sample History :
Preliminary Results Given : No : Date :

Job No : 06632062
Report No : NST347
Date Drilled : 21/11/2006

Borehole Number	Depth (m)	Rock Type	Weathering	Sample Length (mm)	Sample Diameter (mm)	Test Type [1]	Platen Separation (mm)	Gauge Load (kN)	Actual Load [2] (kN)	I_s (MPa)	**$I_{s(50)}$ (MPa)**	**Descriptive Strength Classification**
NST347	10.78	Tuff	EW	70(35)	52.0	D	51.0	0.4	0.37	0.14	**0.14**	L
	11.35	Tuff	DW-SW	120(47)	52.0	D	50.0	3.4	3.43	1.37	**1.37**	H
	11.35	Tuff	DW-SW	51.5	52.0	A	51.0	5.6	5.62	1.66	**1.78**	H
	12.40	Tuff	DW-SW	80(37)	52.0	D	50.0	6.4	6.38	2.55	**2.55**	H
	12.40	Tuff	DW-SW	40.5	52.0	A	35.0	13.8	13.81	5.96	**5.86**	VH
	13.69	Tuff	DW-SW	120(35)	52.0	D	49.5	4.3	4.29	1.75	**1.74**	H
	13.69	Tuff	DW-SW	33.5	52.0	A	30.0	2.5	2.50	1.26	**1.20**	H
	14.61	Tuff	DW-SW	45(26)	52.0	D	50.0	5.6	5.59	2.24	**2.24**	H
	14.61	Tuff	DW-SW	29	52.0	A	25.0	5.3	5.30	3.20	**2.92**	H
	15.85	Tuff	DW-SW	50(35)	52.0	D	50.0	3.0	2.95	1.18	**1.18**	H
	15.85	Tuff	DW-SW	23	52.0	A	19.5	7.6	7.55	5.85	**5.04**	VH

NOTES :
1 D= Diametral A= Axial
2 Gauge calibrated on 22/9/05

Laboratory : BRISBANE
Checked By : MSC/10.05.07

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GOLDER ASSOCIATES

Golder Associates

POINT LOAD STRENGTH TEST RESULTS

Client :	LBBJV	Job No :	06632062
Project :	NSBT	Report No :	NST348
Location :		Date Drilled :	21/11/2006

Tested by: SS

Test Method : AS 4133.4.1 - 1993

Sample History :

Preliminary Results Given : No : Date :

Borehole Number	Depth (m)	Rock Type	Weathering	Sample Length (mm)	Sample Diameter (mm)	Test Type [1]	Platen Separation (mm)	Gauge Load (kN)	Actual Load [2] (kN)	I_s (MPa)	**$I_{s(50)}$ (MPa)**	**Descriptive Strength Classification**
NST348	16.70	Tuff	DW	140(32)	52.0	D	51.0	0.3	0.27	0.10	**0.10**	L
	16.70	Tuff	DW	37.5	52.0	A	30.0	0.8	0.79	0.40	**0.38**	M
	17.58	Tuff	DW	80(35)	52.0	D	50.0	2.5	2.53	1.01	**1.01**	H
	17.58	Tuff	DW	37.5	52.0	A	30.0	1.6	1.57	0.79	**0.75**	M
	18.78	Tuff	SW	40(32)	52.0	D	50.0	3.2	3.16	1.26	**1.26**	H
	18.78	Tuff	SW	35.0	52.0	A	30.0	6.0	6.03	3.04	**2.88**	H
	19.24	Tuff	SW	120(34)	52.0	D	50.0	5.5	5.46	2.18	**2.18**	H
	19.24	Tuff	SW	36.50	52.0	A	31.0	7.5	7.50	3.65	**3.50**	VH
	20.90	Tuff	SW-FR	100(37)	52.0	D	50.0	3.0	2.96	1.18	**1.18**	H
	21.00	Tuff	SW-FR	50(33)	52.0	D	50.0	10.2	10.20	4.08	**4.08**	VH
	21.00	Tuff	SW-FR	31.00	52.0	A	25.0	9.8	9.79	5.91	**5.39**	VH

NOTES :

1 D= Diametral A= Axial

2 Gauge calibrated on 22/9/05

Laboratory : BRISBANE

Checked By : MSC/10.05.07

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GOLDER ASSOCIATES

Golder Associates

POINT LOAD STRENGTH TEST RESULTS

Client :	LBBJV	Job No :	06632062
Project :	NSBT	Report No :	NST349
Location :	adj Campbell Street	Date Drilled :	9/11/2006
Tested by:	SS		

Test Method : AS 4133.4.1 - 1993

Sample History :

Preliminary Results Given : No : Date :

Borehole Number	Depth (m)	Rock Type	Weathering	Sample Length (mm)	Sample Diameter (mm)	Test Type [1]	Platen Separation (mm)	Gauge Load (kN)	Actual Load [2] (kN)	I_s (MPa)	**$I_{s(50)}$ (MPa)**	**Descriptive Strength Classification**
NST349	21.90	Tuff	SW	58.0	52.0	A	56.0	3.0	2.95	0.80	**0.87**	M
NST349	25.00	Tuff	SW	53.0	52.0	A	50.0	2.9	2.92	0.88	**0.94**	M

NOTES :

1 D= Diametral A= Axial

2 Gauge calibrated on 22/9/05

Laboratory : BRISBANE

Checked By : BJF

Golder Associates

POINT LOAD STRENGTH TEST RESULTS

Client : LBBJV
Project : NSBT
Location : Shaftston Ave
Tested by: SS
Test Method : AS 4133.4.1 - 1993
Sample History :
Preliminary Results Given : No : Date :

Job No : 06632062
Report No : NST 228
Date Drilled : 22/06/2006

Borehole Number	Depth (m)	Rock Type	Weathering	Sample Length (mm)	Sample Diameter (mm)	Test Type [1]	Platen Separation (mm)	Gauge Load (kN)	Actual Load [2] (kN)	I_s (MPa)	**$I_{s(50)}$ (MPa)**	**Descriptive Strength Classification**
NST228	5.80	Tuff	DW-SW		52.0	D	50.0	2.5	2.50	1.00	**1.00**	H
NST228	7.80	Tuff	SW		52.0	D	50.0	2.0	2.00	0.80	**0.80**	M
NST228	9.80	Tuff	SW		52.0	D	47.0	5.8	5.80	2.63	**2.55**	H
NST228	11.80	Tuff	DW-SW		52.0	D	49.0	6.6	6.60	2.75	**2.72**	H
NST228	13.80	Tuff	DW-SW		52.0	D	49.0	5.5	5.50	2.29	**2.27**	H
NST228	15.80	Tuff	DW-SW		52.0	D	48.0	5.9	5.90	2.56	**2.51**	H
NST228	17.80	Tuff	DW-SW		52.0	D	45.0	4.8	4.80	2.37	**2.26**	H
NST228	19.80	Tuff	DW-SW		52.0	D	47.0	11.4	11.40	5.16	**5.02**	VH
NST228	21.80	Tuff	SW-FR		52.0	D	48.0	13.7	13.70	5.95	**5.84**	VH
NST228	23.90	Tuff	SW-FR		52.0	D	49.0	3.1	3.10	1.29	**1.28**	H

NOTES :
1 D= Diametral A= Axial
2 Gauge calibrated on 22/9/05

Laboratory : BRISBANE
Checked By : BJF

GOLDER ASSOCIATES

APPENDIX E – DEGREE OF STAINING for (8) BOREHOLES

	Depth (m)	Test Type	Is (50) MPa	*Observed Degree of Staining by (%)*
NST207	2.76	A	3.49	**SS**
	8.72	A	4.99	**SS**
	11.75	D	4.35	**SS**
	3.07	D	2.03	**TS**
	6.92	A	5.09	**TS**
	15.00	A	4.69	**TS**
	18.00	A	3.48	**TS**
	20.93	A	2.54	**TS**
	21.40	A	4.64	**TS**
	24.94	A	3.49	**TS**
	1.85	A	2.31	**XS**
	4.00	A	4.69	**XS**
NST228	5.80	D	1.00	**TS**
	7.80	D	0.80	**TS**
	9.80	D	2.55	**TS**
	11.80	D	2.72	**XS**
	13.80	D	2.27	**DS**
	15.80	D	2.51	**TS**
	17.80	D	2.26	**XS**
	19.80	D	5.02	**TS**
	21.80	D	5.84	**DS**
	23.90	D	1.28	**DS**
NST241	1.00	D	4.36	**XS**
	5.00	A	3.82	**DS**
	8.00	D	5.23	**DS**
	11.94	A	3.59	**TS**
	15.00	D	4.93	**TS**
	18.00	D	5.08	**TS**
	21.00	A	4.19	**TS**
	24.05	D	5.69	**TS**
NST249	3.60	A	3.01	**TS**
	6.40	A	4.90	**TS**
	9.70	A	5.30	**TS**
NST257	3.06	A	0.17	**Disregard (decomposed)**
	3.94	D	0.04	**Disregard (decomposed)**
	4.77	A	0.04	**Disregard (decomposed)**
	6.64	A	0.67	**DS**
	7.95	A	0.06	**SS**
	8.15	D	0.28	**SS**
	8.20	A	0.84	**DS**
	10.15	A	0.45	**SS**
	13.05	A	1.24	**TS**
	14.52	A	1.81	**TS**
	16.00	A	0.82	**TS**
	17.00	A	0.75	**TS**
	17.84	A	0.60	**TS**
NST347	10.78	D	0.14	**TS**
	11.35	A	1.78	**SS**
	12.40	A	5.86	**DS**
	13.69	A	1.20	**SS**
	14.61	A	2.92	**DS**

	15.85	A	5.04	**DS**
	16.70	A	0.38	**TS**
	17.58	A	0.75	**DS**
NST348	18.78	A	2.88	**DS**
	19.24	A	3.50	**XS**
	20.90	D	1.18	**TS**
	21.00	A	5.39	**TS**
	21.90	A	0.87	**TS**
	25.00	A	0.94	**TS**
NST349	0.90	D	3.06	**TS**
	5.90	D	3.34	**TS**
	8.00	D	5.12	**SS**
	10.00	D	4.11	**TS**
	12.20	D	2.33	**TS**
	14.00	D	3.26	**TS**
	16.60	D	2.09	**SS**
	18.00	D	3.45	**TS**
	20.00	D	3.30	**TS**
	22.00	D	3.88	**TS**
	24.00	D	3.41	**TS**
	26.00	D	4.27	**SS**
	28.00	D	4.15	**TS**
	30.00	D	4.27	**TS**