



Douglas Partners
Geotechnics | Environment | Groundwater

Report on
Geotechnical Investigation

Lightweight Aggregate Project
Plant 2, Austral Brick Site
720 Wallgrove Road, Horsley Park

Prepared for
Brickworks Ltd

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Integrated Practical Solutions





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The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

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1. Introduction

This report presents the results of a geotechnical investigation undertaken by Douglas Partners Pty Ltd (DP) for a proposed lightweight aggregate facility at Plant 2 in the Austral Brick Site at 720 Wallgrove Road, Horsley Park. The work was commissioned by Ms Megan Kublins of Brickworks Limited on 22 April 2015 and was undertaken generally in accordance with a proposal by DP dated 14 April 2015.

The proposed lightweight aggregate project comprises the installation of new plant and equipment on the southern and western sides of the existing brick factory and existing mill building. The investigation was carried out to provide information on the soil, rock and groundwater characteristics for design and planning purposes.

The investigation included drilling of five rock cored bores, five deep auger bores and five shallow auger bores for pavement design purposes. Laboratory testing was carried out on selected samples to assess the engineering properties of the soil and rock and to enable recommendations to be made on suitable design parameters. Details are provided in the report, together with comments relating to the following:

- Subsurface conditions including groundwater;
- Excavatability of in situ materials and suitability for reuse as structural fill elsewhere on the site;
- Advice on footing design;
- Estimated settlements;
- Maximum slopes for temporary and permanent batters;
- Pavement design parameters; and
- Foundation treatment within the existing dam to enable embankment construction.

2. Site Description

The site is located at the eastern end of the Austral Bricks site at Horsley Park in an area of gently undulating terrain where natural surface slopes are generally less than about 5%. The area, however, has been extensively altered by quarrying for brick making purposes and by the creation of level areas for construction of large industrial buildings.

The site measures about 400 m in an east-west direction and approximately 300 m in a north-south direction with a fall in the overall surface levels in a northerly direction of approximately 10 m. Within the site, however, there are many significant changes in level due to the presence of large stockpiles, an existing dam, and vegetated bunds.

The site location and the position of the bores is given on Drawing 1 in Appendix B.

3. Geology

Reference to the Penrith 100,000 Geological Series Sheet shows Quaternary alluvium has been deposited along the line of the major creeks in the region, including Eastern Creek. It is possible that some alluvial deposits occur over the northern portion of the site where the western Sydney Pipeline crosses through low lying terrain adjacent to Eastern Creek.

The site is mostly located on the lower slopes of a small north-south trending ridge. At the bottom of the slope there are flatter areas near Eastern Creek which probably represent areas of alluvial soil deposits. The remainder of the site is underlain by residual clay and silty clay derived from the weathering of the underlying Bringelly Shale.

The geological sheet indicates that the region is underlain at shallow depth by Bringelly Shale which is part of the Wianamatta Group of Triassic age. The Wianamatta Group consists of three formations of which the Bringelly Shale is stratigraphically the highest. In areas west of Sydney the sedimentary rocks have been gently folded to form a basin like structure with the Bringelly Shale generally occupying the centre.

The Bringelly Shale typically comprises claystone, siltstone, laminite (thinly interbedded siltstone and sandstone) and sandstone units with minor occurrences of coal, carbonaceous claystone and tuff. The various units are typically dark grey and black but also include light grey claystone units.

The Austral Brick Site is located just west of the Prospect intrusion which is a large volcanic intrusion consisting of a basin-shaped, geological feature estimated to be several hundred metres in diameter. Several small volcanic breccia pipes are mapped in the area around Erskine Park, Minchinbury and Marsden Park and have been extensively quarried for road and concrete aggregates. These intrusions are often associated with smaller igneous features such as dykes. During investigations for the adjoining Eastern Creek Waste Management Centre an igneous dyke was mapped on the southern boundary trending in a south westerly direction beneath the easement for the water pipeline onto the Austral Brick site.

An extract from the geological map is shown on Drawing 2 in Appendix B.

4. Field Work Methods

The field work for the current investigation included five deep auger bores (BH1 – BH5), five deep cored bores (BH6 – BH10) and five shallow pavement bores (BH11 – BH15). The bores were all drilled using a truck-mounted auger/rotary drilling rig. The locations of the bores are shown on Drawing 1 in Appendix B.

The bores were drilled through soil and extremely weathered rock using solid flight augers. The deep cored bores were then continued using rotary drilling techniques to obtain continuous core samples of the bedrock. Standard penetration tests were carried out within the soils at 1.5 m depth intervals to assess the soil strength and to obtain samples for laboratory testing. In addition, disturbed bulk samples were collected from the shallow pavement bores to enable testing to be undertaken in the laboratory for compaction characteristics and California bearing ratio.

The bores were logged and sampled by an experienced geotechnical engineer. The rock cores recovered from the bores were photographed, followed by point load strength index tests (Is50) on selected samples.

Groundwater monitoring wells were installed in three boreholes (BH7, BH9 and BH10) to allow for measurement of groundwater levels and permeability testing. The wells comprised Class 18 machine slotted PVC with gravel backfill, a bentonite plug below the surface and a steel protective cap installed flush with the existing surface. Groundwater levels were measured in the wells and in the remaining bores where auger methods were employed. Further groundwater level measurements would be possible in the monitoring wells to provide an indication of long-term fluctuations of the groundwater levels, particularly after periods of heavy rainfall.

Rising head permeability tests were carried out within the wells whereby the water within the wells was pumped out and the rate of inflow or recharge was measured.

The locations of the bores were measured using differential GPS equipment which is normally accurate to within ± 1 m in plan location. Ground surface levels were estimated using the GPS equipment and checked against surface levels provided on drawings supplied by the client.

5. Field Work Results

Details of the subsurface conditions encountered are given on the borehole logs in Appendix C, together with colour photographs of the rock core and notes defining classification methods and descriptive terms.

5.1 Bores

The subsurface materials and layer thicknesses recorded in the bores varied across the site due to the presence of large stockpiles and filling placed during previous construction on the site. The results can be divided into three groups, as indicated in Tables 1, 2 and 3, below:

- Table 1: Deep auger bores in the north-western and western sections of the site (BH 1 to BH5) for the proposed office and the proposed crushing and screening plant. The strata comprised variably compacted ripped shale or siltstone filling with some brick inclusions to depths of 2.8-4.2 m, overlying 1-3 m thick layer of stiff to hard natural clays, and then extremely low or very low strength shale to depths of 5.6–6.0 m where the bores were discontinued;
- Table 2: Deep cored bores in the south-eastern section of the site (BH6 to BH10) for the proposed Kiln Pad No. 1. Some of these bores were drilled from the top of a large spoil heap and intersected 5.7–8.2 m of variably compacted filling over 1-3 m thick layer of residual clay and some extremely low to very low strength shale/siltstone then low to medium strength shale/siltstone; and
- Table 3: Shallow pavement bores along the proposed access roads (BH 11 to BH 15) across the site. These bores all intersected clay and crushed shale filling to the maximum drilled depths of 2.0 m.

The strata intersected by the bores is summarised in the following tables.

Table 1: Summary of Deep Auger Bores in north-western and western sections

	Depths to Strata Boundaries (m) (Levels in brackets)				
Strata Description	BH1	BH2	BH3	BH4	BH5
FILLING – Ripped shale clay and crushed bricks	0.0 (57.9)	0.0 (60.2)	0.0 (61.6)	0.0 (61.7)	0.0 (60.7)
----- SILTY CLAY – Stiff to very stiff silty clay, shaly clay and extremely low strength shale	3.2 (54.7)	2.8 (57.4)	3.5 (58.1)	4.2 (57.5)	2.0 BD
----- SHALES – Very low to low strength shale	5.7 (52.2)	5.3 (54.7)	5.1 (56.5)	5.0 (56.7)	
	6.0 BD	5.7 BD	5.7 BD	5.6 BD	

Note: BD: Bore discontinued

NE: Not encountered

Table 2: Summary of Cored Test Bores in south-eastern section

	Depths to Strata Boundaries (m) (Levels in brackets)				
Strata Description	BH6	BH7	BH8	BH9	BH10
FILLING – Ripped shale, clay and crushed bricks	0.0 (65.8)	0.0 (71.4)	0.0 (71.3)	0.0 (69.6)	0.0 (67.1)
----- SILTY CLAY – Stiff to hard silty clay and shaly clay	2.2 (63.2)	8.2 (63.2)	8.0 (63.6)	5.7 (63.3)	2.6 (64.5)
----- SHALE/SILTSTONE – Variably weathered, extremely low and very low strength with bands of low and medium strength	3.8 (62.0)	9.3 (62.1)	11.1 (60.2)	6.8 (62.8)	NE
----- SHALE/SILTSTONE – Consistently medium strength	6.9 (58.9)	12.5 (58.9)	11.5 (59.8)	9.3 (60.3)	5.8 (61.3)
	7.4 BD	13.0 BD	13.0 BD	10.3 BD	0.4 BD

Note: BD: Bore discontinued

NE: Not encountered

An interpreted section through some of these bores is shown on Drawing 3 in Appendix B.

Table 3: Summary of Pavement Bores along proposed access roads

	Depths to Strata Boundaries (m)				
Strata Description	BH11	BH12	BH13	BH14	BH15
FILLING – Red and grey shaly clay or silty sandy clay with some crushed shale gravel					
	1.5 BD	2.0 BD	1.5 BD	1.5 BD	1.5 BD

Note: BD: Bore discontinued

5.2 Groundwater and Depths

The results of groundwater measurements within the monitoring wells installed in BH7, BH9 and BH10 and observations made in two of the auger bores during drilling are shown in Table 4, below.

Table 4: Measured Groundwater Depths

		Depth to Groundwater (m) (Levels in brackets)				
Date	Time	BH1	BH4	BH7	BH9	BH10
26/5/15	During drilling	3.9 (54.0)	3.8 (57.9)			
12/6/15	2:27pm			12.08 (59.3)		
12/6/15	2:15pm				9.57 (60.0)	
12/6/15	12:50pm					6.8 (60.3)
15/6/15	9:57am			11.80 (59.6)		
15/6/15	10:00am				9.50 (60.1)	
15/6/15	10:05am					6.55 (60.6)

In BH1 and BH4 the water levels were recorded during drilling and it is considered that this water is probably seepage stored within the filling, referred to as perched water. In the three bores where monitoring wells had been installed, the wells were purged of water and then data loggers installed to measure recovery. In each case the overall recovery was less than 0.3 m over more than 3 days so there was insufficient drawdown and recovery for meaningful analysis of strata permeability.

6. Laboratory Testing

The results of the laboratory testing on selected soil samples are given on the detailed results sheets in Appendix D. The results of the Point Load Strength testing on the rock cores are given on the detailed borehole logs.

Typical samples from the bores were submitted for testing for Atterberg Limits and linear shrinkage, compaction properties, California Bearing Ratio, natural moisture content and Emerson dispersion tests. The results are summarised in Tables 5, 6 and 7 below.

Table 5: Results of Atterberg Limits, Linear Shrinkage and Emerson Class tests

Bore No.	Depth (m)	Strata Description	w (%)	w _L (%)	w _p (%)	PI (%)	LS (%)	Emerson Class
BH7	7.0-7.45	FILLING – grey silty clay & crushed shale	14.9	39	20	19	10	2
BH8	4.0-4.45	FILLING – light grey clay and crushed shale	12.6	38	18	20	12.5	2
BH9	5.5-5.95	FILLING and CLAY – light grey mottled brown silty clay	22.4	65	22	43	18	2
BH10	2.5-2.8	SILTSTONE – light grey-brown siltstone	12.9	49	19	30	14.5	2

Note: w = Natural moisture content w_L = Liquid limit w_p = Plastic limit PI = Plasticity index
 LS = Linear shrinkage

The results indicate that the soils and weathered rock on the site contains moderate to high plasticity clays with liquid limits ranging from about 40% to 65%. The clayey soils would therefore have a moderate to high potential for shrinking and swelling with varying moisture contents.

The results of the Emerson Class tests indicated a consistent Class 2, which means the clayey soils have a moderate potential for dispersion and hence could be susceptible to erosion or dispersion if used in a location which is permanently saturated.

Table 6: Results of Compaction and CBR tests

Bore No.	Depth (m)	Strata Description	w (%)	MDD (t/m ³)	OMC (%)	CBR (%)
BH11	0.0-0.5	FILLING – orange brown sandy clay with some gravel	6.3	2.02	8.7	25
BH12	0.0-0.5	FILLING – grey shaly and silty clay	8.1	1.97	11.5	4.0
BH12	1.5-2.0	FILLING – grey shaly silty clay	11.2	1.93	12.1	4.5
BH13	0.5-1.0	FILLING – yellow brown clay with some gravel	5.6	1.99	11.1	9.0
BH14	0.5-1.0	FILLING – dark grey shaly clay	11.4	2.01	11.1	5.0
BH15	0.5-1.0	FILLING – grey silty clay and crushed shale	9.8	2.01	10.8	9.0

Note: w = Natural moisture content MDD = Maximum dry density OMC = Optimum moisture content
 CBR = California bearing ratio

The testing indicates that the filling material on site generally has a low CBR with the exception of one sample from BH11 which provided a higher CBR result of 25%, probably due to the gravel included in the sample tested. as opposed to an expected CBR of 4-6%.

Table 7: Results of Laboratory Testing

Bore No.	Depth (m)	Strata Description	w (%)
BH1	1.0	FILLING – Grey and light grey-brown silty clay & crushed shale	6.2
BH2	1.0	FILLING – Light grey-brown silty sand, crushed sandstone, shale & brick fragments	15.2
BH3	1.0	FILLING – Grey brown and red brown silty sandy clay with some crushed shale & brick fragments	9.3
BH4	1.0	FILLING – Grey crushed shale	6.4
BH7	2.5	FILLING – Grey silty clay with crushed shale & brick fragments	10.8
BH7	4.0	FILLING – Grey silty clay with crushed shale & brick fragments	17.3
BH8	1.0	FILLING - Grey silty clay and crushed shale with some brick fragments	13.8
BH8	5.5	FILLING - Light grey crushed shale & brick gravel	17.6
BH9	4.0	FILLING –Light brown silty sandy clay with some crushed shale fragments	21.6
BH9	7.0	FILLING –Light brown silty sandy clay with some crushed shale fragments	17.9
BH10	1.0	FILLING – Grey and brown silty clay and crushed shale with some brick fragments	6.8

Note: w = Natural moisture content

Selected samples of the rock core were tested in the laboratory to determine the Point Load Strength Index (IS_{50}) values to assist with the rock strength classification. The results of the testing are shown on the detailed borehole logs at the appropriate depths. The IS_{50} values for the rock typically ranged from 0.2 MPa to 0.7 MPa, with an average of 0.45 MPa, indicating that the rock samples tested range from low strength to medium strength.

7. Proposed Development

It is understood that the proposed Lightweight Aggregate project involves the construction of a large kiln and conveyors within the Plant 2 area of the Austral Bricks site. The proposed development will include new plant buildings, associated amenities, access roads and services. The bores were located at the client's request to target the following features:

- BH1 Office building
- BH2-3 Crusher/Screening building
- BH4 Underground conveyor system requiring up to 5m excavation below existing
- BH5-10 Kiln pad area requiring excavation of existing bund/stockpile of up to 10 m
- BH11-15 Future access roads

The kiln structures will have chimney stacks up to 25-30 m high and are expected to have relatively high foundation loads. For this reason it is unlikely that shallow footings founded in either existing or reworked filling would be adequate for these structures.

The development will include the construction of an access road across an existing stormwater detention basin. This would require the basin to be dewatered and any sludge or softened material to be removed below the embankment footprint. Once a firm base has been prepared in this area, earthworks can be carried out using conventional techniques.

The preliminary plans indicate that the level of the proposed kiln pad in the south-eastern section of the site will be at about RL 61.0 m which will require removal of about 5-10 m of an existing stockpile before excavating into the natural soils and weathered rock.

The following sections provide engineering advice and design parameters for the various elements of the proposed construction.

8. Engineering Advice

8.1 Excavation

Excavation to depths of up to 10 m, mainly removing an existing stockpile or bund, will be required to construct Kiln Pad No. 1 to a finished level of RL 61 m AHD. It is expected that most of the excavation will be through filling comprising clay, ripped shale and brick fragments. As indicated in Table 2 the approximate levels of the strata in this area are:

- Filling down to RL 63-64 m; over
- Clay down to RL 62-63 m; over
- Variably weathered shale; with
- Medium strength shale below RL 59-61 m.

The excavation through the filling and the stiff to hard natural clays below the filling should be readily carried out using conventional earthmoving equipment. The variably weathered shale bedrock which includes bands of very low, low and medium strength rock should be rippable with a medium sized bulldozer. If excavation is required into the underlying consistent medium strength shale or siltstone, which is expected below about RL 59-61 m, then this will require heavy ripping or possibly some assistance with rock breaking equipment.

Drawing 3 in Appendix C provides an indication of the possible strata levels on a cross-section through this section of the site.

Excavation of up to 5 m is also required for the proposed underground conveyor system which is to be located in the area adjacent to bore BH4. This bore intersected filling (crushed shale and ripped sandstone) to a depth of 4.2 m, then stiff silty clay to 5.0 m and then very low to low strength shale. It is expected that this material should be readily excavated using conventional equipment, although there could be local higher knobs of harder shale along the line of the conveyor which may require the use of rock hammers.

8.2 Material Re-use

The material excavated from the area of the kiln pads and from the underground conveyor line will be predominantly clay and crushed shale filling. It is considered that this material would be suitable for re-use in engineered filling provided precautions are taken to ensure that the material is adequately compacted and that fill embankments are not allowed to dry once the earthworks is completed.

The materials have a relatively high shrink/swell potential and allowing them to dry out significantly below the optimum moisture content or the equilibrium moisture content for clays will mean that the clays will shrink and then when they become covered by either foundations or buildings, they will have a tendency to swell significantly. Measurement of the swell potential in buildings in the Eastern Creek area recently showed floor slabs in major warehouses had moved upwards by as much as 65 mm due to swelling of clay which had dried out.

The best ways to reduce the risk of shrinkage and swelling movements are to either replace the clay with low plasticity material or to cover the completed earthworks with a granular material to limit evaporation of the moisture from within the compacted clay.

8.3 Embankment over Dam

In order to construct a new road embankment over the existing dam area, it will be necessary to dewater the dam and remove any sludge or softened soils prior to carrying out earthworks in a conventional manner.

Where filling is required to be placed over existing cut slopes then these slopes should be trimmed to form a series of small horizontal steps so that the new filling can be placed and compacted in horizontal layers and keyed into the slope.

The filling should be placed in layers not exceeding 300 mm loose thickness and compacted to a density within 98%-102% of the standard maximum dry density and at a moisture content within 2% of the optimum moisture content. For reasons outlined above, the moisture content should then be maintained within the embankment filling until road pavements are constructed on the embankment or the fills are covered by industrial buildings.

Further comments on embankment slopes are given in Section 8.5.

8.4 Site Preparation and Earthworks

It is suggested that site preparation and placement of engineered fills should incorporate the following:

- Strip to design subgrade level and remove any sludge or softened soils from areas to be constructed over the existing dam;
- Scarify and moisture condition the exposed surface. Where a considerable depth of old filling is located immediately below the subgrade level, further testing should be carried out within the filling to verify whether it is properly compacted before earthworks commence. If the filling is

poorly compacted, it should be excavated down to natural soils and replaced in layers and compacted to form a platform which can provide adequate support for engineering structures;

- Compact the conditioned surface with at least six passes of a minimum 10 tonne dead weight roller. The final pass of the subgrade should be inspected by a geotechnical engineer to detect any soft, wet or highly compressible areas that require further treatment. Any unsatisfactory areas detected during the proof rolling would need to be rectified which would generally include stripping to a stiff base and replacement with engineering fill;
- Place engineering filling in layers of 300 mm maximum loose thickness and compact to a minimum dry density ratio of 98-102% of the standard maximum dry density. The filling should be maintained within 2% of the standard optimum moisture content and, as indicated above, should be protected to prevent drying out after earthworks are completed; and
- Carry out density testing of each layer of compacted filling in accordance with Level 1 standard as defined in Australian Standard AS3798:2007 *Guidelines for Earthworks for Commercial and Residential Developments* to verify that the specified density ratio have been achieved.

Due to the clayey composition of the existing filling on site, some problems may be experienced with trafficability during wet weather, particularly in low-lying areas. For general construction machinery, it is suggested that tracked vehicles should be used where possible in order to avoid such problems.

8.5 Engineering Slopes

8.5.1 Cut Slopes

Where space permits unsupported slopes to be used, the following maximum temporary and permanent batter slopes are recommended for excavations.

Table 8: Maximum Recommended Cut Batter Slopes

Material	Maximum Temporary Slope	Maximum Permanent Slope
Existing variably compacted filling	1.5H : 1V	3H : 1V
Stiff to hard residual clays	1.5H : 1V	2H : 1V
Variably weathered shale	1H : 1V	1.5H : 1V
Consistent medium strength shale	1H : 1V	1H : 1V

Notes: H = horizontal, V = vertical

These recommended maximum slopes are for excavations less than 3 m deep and where there are no surcharges from stockpiled materials, adjacent buildings, vehicles or other loads to a setback distance of at least the excavation depths behind the crest of the excavation. For permanent slopes protection against surface erosion either in the form of vegetation or shotcrete cover is recommended.

For deeper unsupported excavations then additional stability analysis should be undertaken to assess the stability of the proposed cut batters. In general terms, however, either the slopes would need to be flattened or a horizontal bench (berm) should be included in the cut slope which would result in a

flatter overall slope. The horizontal bench should typically be at least 2 m wide to allow for access during slope maintenance.

Where the recommended batter slopes are not feasible the excavation will require both temporary and permanent lateral support during excavation or as part of the final structure. This support may be provided by retaining walls. Earth pressures acting on these walls may be calculated using the parameters given in Table 9 below.

Table 9: Design Parameters for Excavation Support Structures

Material	Bulk Unit Weight (kN/m³)	Coefficient of Active Earth Pressure (K_a)	Coefficient of Passive Earth Pressure (K_p)	Coefficient of Earth Pressure at Rest (K_o)
Existing variably compacted filling	20	0.4	2.5	0.6
Stiff to hard residual clays	20	0.3	3.3	0.45
Variably weathered shale	22	0.2	4.0	0.3
Consistent medium strength shale	22	0.1	5.0	0.2

Additional pressure should be allowed for where the ground surface behind the wall is sloping upwards from the rear of the wall, or where surcharging occurs from stockpiled materials, vehicular traffic or other loads. Provided positive drainage measures can be incorporated to prevent water pressure build up behind the retaining walls, water pressure need not be included in the design.

The drilling indicates that the weathered shale and siltstone contains many joints, dipping at 30-60 degrees below the horizontal. These joints could form unstable wedges if unsupported and they may result in pressures in excess of those calculated using earth pressure coefficients as indicated in Table 9. For this reason it is suggested that retaining walls be checked to ensure that they can also support a rock wedge formed by a joint dipping at 45 degrees below horizontal intersecting the cut face near the base of the excavation. For this load case it is suggested that a lower factor of safety can be adopted as the probability of such wedges running continuously over a significant length of a retaining wall or are oriented directly into the excavation is relatively low. There have, however, been some significant slope failures on nearby sites where excavations have been cut at slopes steeper than 45 degrees (1H:1V).

8.5.2 Fill Slopes

For new compacted filling embankments less than 5 m high, the recommended maximum permanent slope is 2H:1V, provided the surface of these slopes are protected against erosion. Consideration should be given to using flatter slopes to allow for establishment of vegetation and long term maintenance of the slopes.

Higher fill slopes should include horizontal benches generally at not more than 5 m vertical spacing. These horizontal benches should typically be not less than 2 m wide to allow for access, and are required to control down slope surface water flows and to catch any minor slippages or surface erosion.

Where new fill embankments are required around the edge of the existing dam or other new ponds the fill embankment will be subjected to permanent saturation, possible drawdown as the water levels rise and fall, and possible erosion due to wind generated waves. For these reasons it is suggested that generally the fill slopes below the water should be constructed at a maximum slope of 3H:1V and protected against erosion and drawdown by a 0.6 m thick rock protection layer or a concrete filled geofabric mattress. Further analysis is recommended when the total height of the dam embankments and the water storage depth are better defined.

8.6 Foundations

For design of foundations for the proposed new structures the following general recommendations are provided.

Table 10: Recommended Foundation Design Parameters

Material	Ultimate		Allowable (Serviceability)	
	End bearing (kPa)	Shaft Adhesion (kPa)	End bearing (kPa)	Shaft Adhesion (kPa)
Existing variably compacted filling	NA	NA	NA	NA
New controlled compacted filling	400	20	150	15
Stiff to hard residual clays	500	30	200	20
Variably weathered shale	3000	150	1000	100
Consistent medium strength shale	30,000	600	3,500	350

Notes: NA = not applicable – do not found structures on this material

For the proposed kiln structures (BH5-10), reference to Table 2 and the detailed borehole logs indicates that at the proposed pad level of RL 61 m the exposed materials are likely to be the variably weathered shale profile, with consistently medium strength shale expected to be within 0-2 m below the proposed pad level. For the relatively high loads of the kiln structures it is recommended that all the footings be founded on the medium strength shale layer to ensure that differential settlement between footings is minimised. These footings could comprise shallow pad or strip footings where the medium strength rock is at or close to the pad level, or short bored piles where the depth to rock is greater. Footings designed using the allowable bearing pressures given in Table 10 would be expected to have total settlements of less than 1% of the minimum footing width or pile diameter. Differential settlements between adjacent footings are expected to be less than 0.5% of the minimum footing width.

For the proposed office building (BH1) the subsurface conditions comprised 3.2 m of variably compacted filling, then stiff silty clay down to 5.7 m, and then extremely low strength shale. It is not recommended that the office building be founded on the existing variably compacted filling, therefore the options are either to remove and replace the existing filling with controlled compacted filling, or to use bored piles taken down to at least the top of the variably weathered shale of at least extremely low strength.

Whilst drilling BH1, water was encountered at a depth of 3.9 m below existing surface level. Provision should therefore be made to either use temporary casing to support the bores until the reinforcement cage is inserted and the concrete poured to surface level. In addition to using temporary casing, it may also be necessary to either pump the bores immediately before pouring the concrete to remove any seepage water or to use tremie techniques to pour the concrete below water. If there are any delays between the end of drilling and pouring of the concrete then softening of the clays at the base of the pile will occur and therefore it may be necessary to either redrill the bores to remove any softened material or to downgrade the working bearing pressures to allow for potential additional settlement.

For the proposed crusher and screening building (BH2-3), the subsurface conditions comprised variably compacted filling to depths of 2.8-3.5 m, over stiff to very stiff silty clay, with variably weathered shale below depths of 5.1-5.5 m. Again it is not recommended that the new buildings be founded on the existing variably compacted filling. The options are to remove and replace the existing filling with new controlled filling, or to use piles taken down into the stiff residual clays and variably weathered shale. Depending on the structural loads it may be more economical to design the piles to be taken down onto the medium strength shale so that higher bearing pressures can be used, but if this is the case then additional cored boreholes would be required to confirm the depth and quality of the bedrock.

For the proposed underground conveyor system (BH4) it is understood that excavation of up to 5 m will be required. At this depth BH4 intersected very low to low strength shale (below 4.2 m of filling and stiff silty clay) which suggests that the conveyor system may be supported on pad or strip footings founded on the variably weathered shale layer. Seepage was noted at a depth of 3.8 m when drilling this bore. This seepage is expected to be from a perched water table within the filling, but it could cause wet conditions at the base of the proposed excavation and local dewatering in the form of sumps and pumps may be required.

The bores drilled for the future access roads (BH11-15) all intersected variably compacted filling to depths in excess of 2 m. Prior to constructing the new pavements it is recommended that the upper 0.5 m of existing filling below the proposed subgrade level be removed and replaced in compacted layers in order to provide a uniform platform for support of the new pavements. During this process, when the 0.5 m upper layer has been removed and before the new filling is placed, it is recommended that the exposed subgrade is rolled with at least six passes of a minimum 10 tonne dead weight roller. The final pass of the roller should be inspected by a geotechnical engineer to detect any soft, wet or highly compressible areas that require further treatment. Any unsatisfactory areas detected during the proof rolling would need to be rectified which would generally include removing the soft material and replacing with compacted filling.

8.7 Pavement Design

Laboratory testing for CBR and compaction was carried out on six bulk samples recovered from the subgrade soils along the general alignment of the proposed access roads. The samples were all from within the filling which includes clays and crushed shale with some brick fragments. The CBR values ranged from 4% to 25% with the higher values being attributed to the presence of gravel or crushed brick within the predominantly clay filling. It is suggested that a CBR value of 9% is probably not achievable at all locations and therefore a design CBR of 4.5% is suggested for pavements

constructed on the existing filling or natural silty clay. An elastic modulus value of 45 MPa may be adopted for the sub-grade for pavement design.

8.8 Disposal of Excavated Material

Any excavated materials requiring off site disposal will need to be handled in accordance with the provisions of the current legislation and guidelines including the *Waste Classification Guidelines* (EPA, 2014). This includes filling and natural materials that may be removed from the site. Accordingly, environmental testing will need to be carried out to classify any spoil prior to transport from the site.

8.9 Design for Earthquake Loading

In accordance with AS1170-2007 “*Structural Design Actions, Part 4: Earthquake Actions in Australia*” a hazard factor (Z) of 0.08 and a site subsoil Class C_e is considered to be appropriate for the site.

9. Limitations

Douglas Partners Pty Ltd (DP) has prepared this report for this project at Wallgrove Road, Horsley Park in accordance with DP's proposal dated 15 April 2015 and acceptance received on 24 April 2015. This report is provided for the exclusive use of Brickworks Ltd for this project only and for the purposes as described in the report. It should not be used for other projects or by a third party. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions only at the specific sampling or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of anthropogenic influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be limited by undetected variations in ground conditions between sampling locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

This report must be read in conjunction with all of the attached notes and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion given in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instruction for construction.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP.

Douglas Partners Pty Ltd

Appendix A

About this Report

About this Report

Douglas Partners



Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

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

Copyright

This report is the property of Douglas Partners Pty Ltd. The report may only be used for the purpose for which it was commissioned and in accordance with the Conditions of Engagement for the commission supplied at the time of proposal. Unauthorised use of this report in any form whatsoever is prohibited.

Borehole and Test Pit Logs

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

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

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;

- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

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

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

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

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

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

About this Report

Site Anomalies

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

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

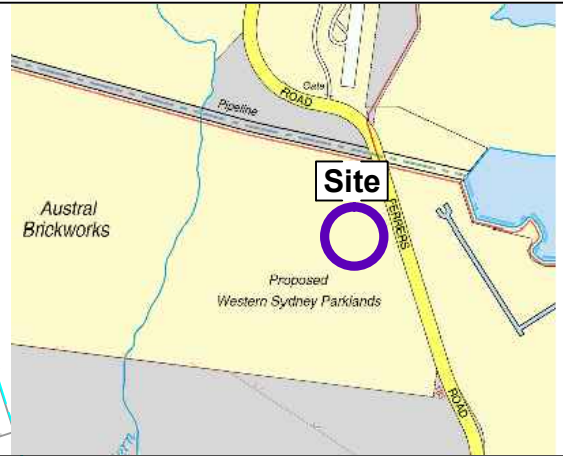
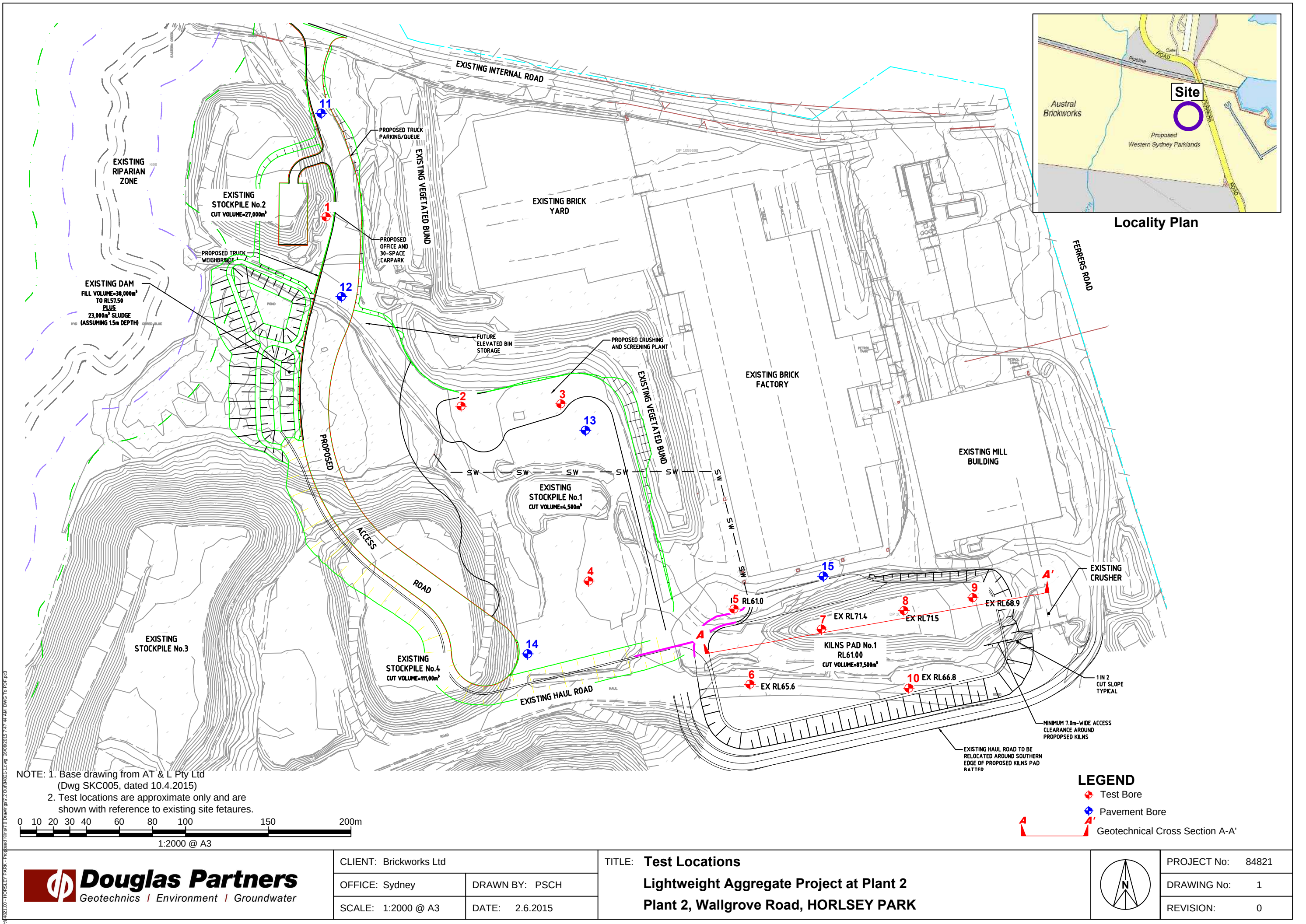
The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Appendix B

Drawing 1 – Test :Locations

Drawing 2 – Extract from Geological Map

Drawing 3 –Cross-Section A-A'



Locality Plan

LEGEND

- Test Bore
- Pavement Bore
- Geotechnical Cross Section A-A'

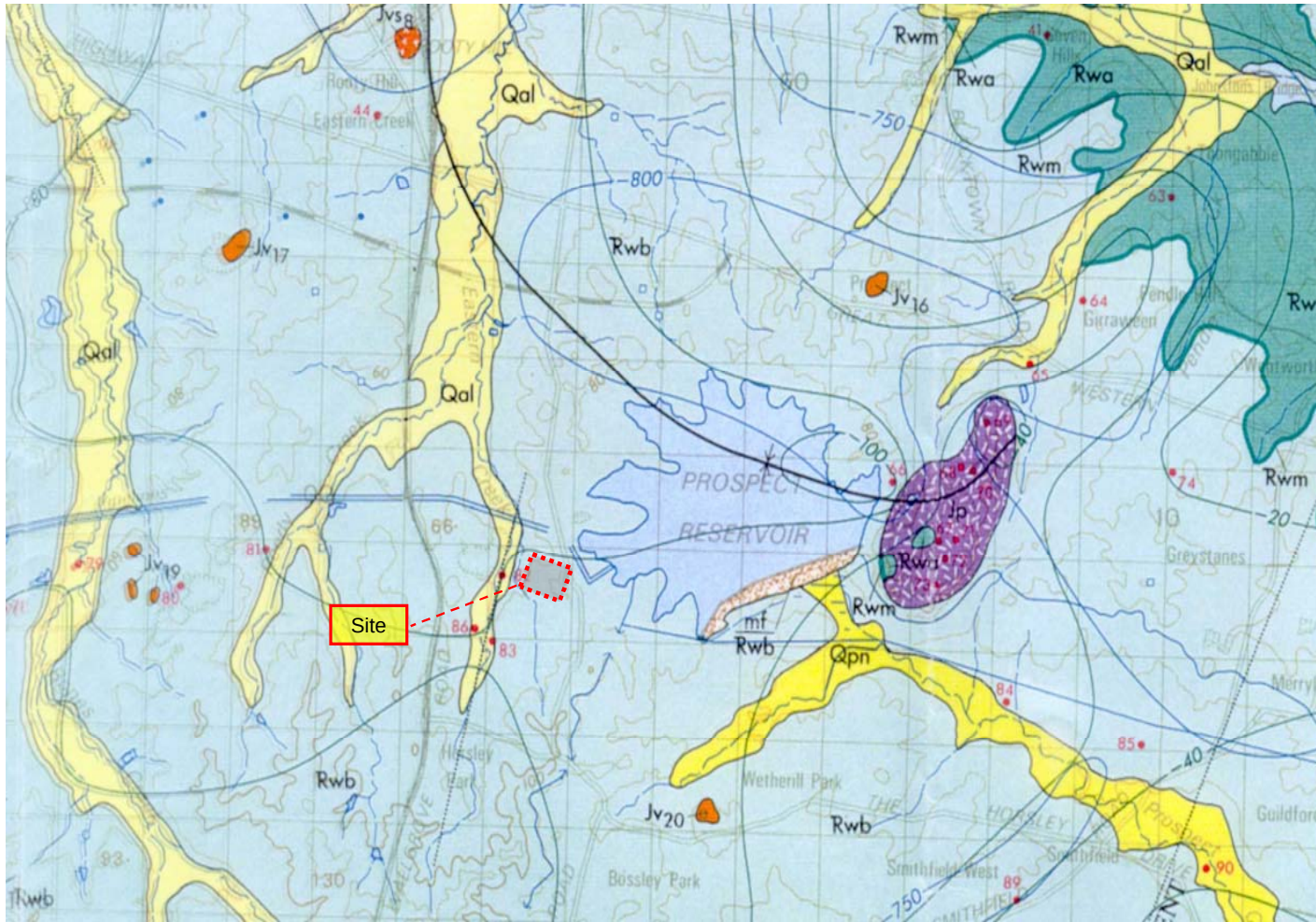


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DRAWING No:	1
REVISION:	0

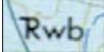
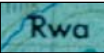
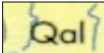


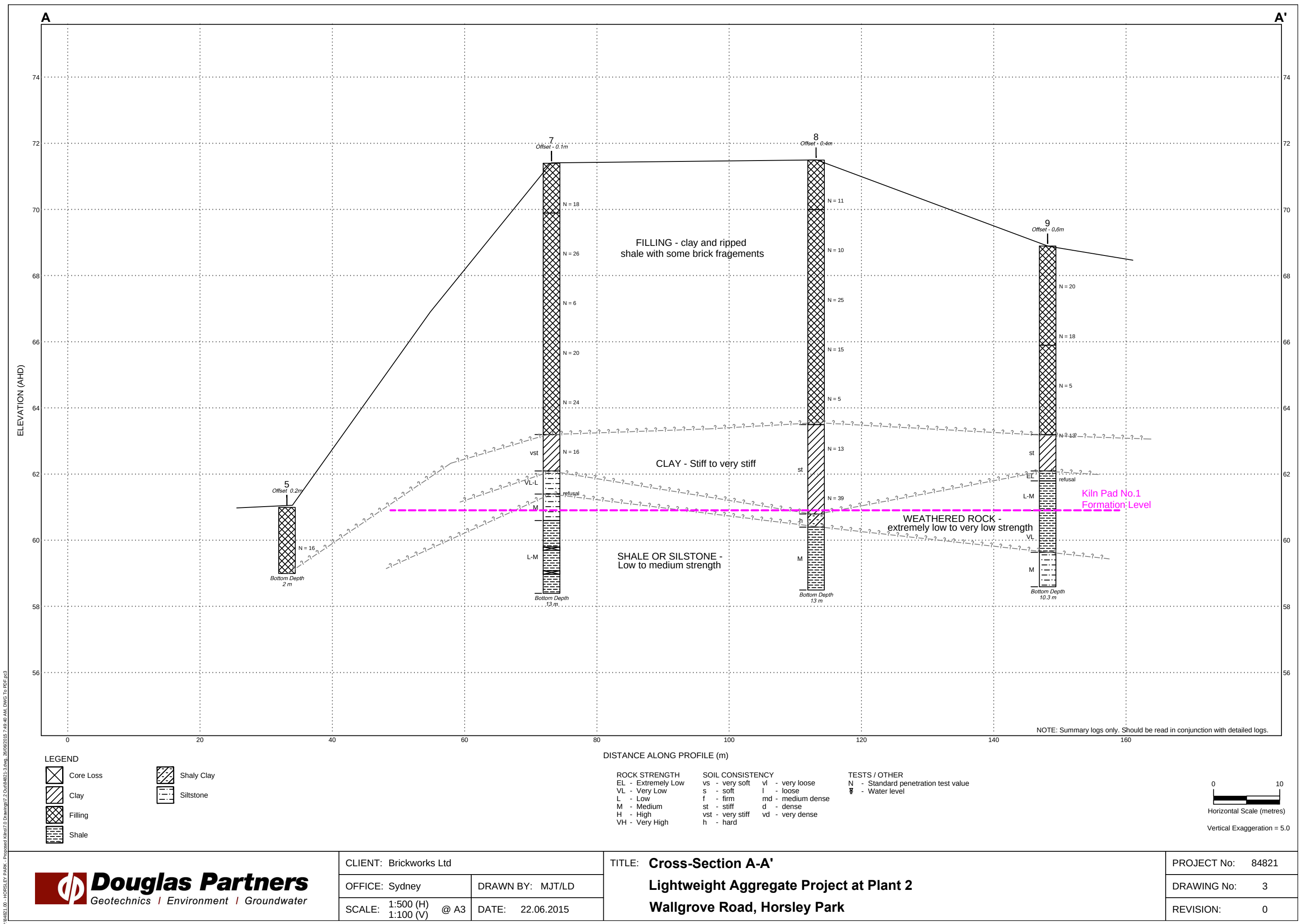
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OFFICE: Sydney	DRAWN BY: PSCH
SCALE: 1:2000 @ A3	DATE: 2.6.2015

TITLE: **Test Locations**
Lightweight Aggregate Project at Plant 2
Plant 2, Wallgrove Road, HORLSEY PARK



LEGEND

-  Bringelly Shale
-  Ashfield Shale
-  Prospect Picrite intrusion
-  Quaternary Alluvium
-  Quaternary Alluvium
-  Volcanic Diatremes



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Appendix C

Field Work Results

BOREHOLE LOG

CLIENT: Brickworks Ltd
PROJECT: Lightweight Aggregate Project at Plant 2
LOCATION: 720 Wallgrove Road, Horsley Park

SURFACE LEVEL: 57.9 AHD
EASTING: 302548
NORTHING: 6255229
DIP/AZIMUTH: 90°/--

BORE No: 1
PROJECT No: 84821
DATE: 26/5/2015
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing			Water	Well Construction Details		
				Type	Depth	Sample				Results & Comments
57 56 55 54 53 52 51 50 49 48	1 2 3	FILLING - variably compacted, grey and light grey-brown, silty clay and crushed shale filling, damp		A	0.1		12,20,23 N = 43			
				A	0.5					
				A	1.0					
				S	1.45					
	3.2 4 5	SILTY CLAY - stiff, light grey mottled brown, silty clay, moist to wet				2.5		3,3,4 N = 7		
					S	2.95				
	5.7 6 7 8 9	SHALE - extremely low strength, light grey to grey-brown shale Bore discontinued at 5.95m				4.0		5,6,9 N = 15		
					S	4.45				
					5.5		8,10,20 N = 30			
				S	5.95					

RIG: Scout 4

DRILLER: RKE

LOGGED: SI

CASING: Uncased

TYPE OF BORING: Solid flight auger to 5.5m

WATER OBSERVATIONS: Free groundwater observed at 3.9m whilst augering

REMARKS:

SAMPLING & IN SITU TESTING LEGEND					
A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	W	Water seep	S	Standard penetration test
E	Environmental sample	W	Water level	V	Shear vane (kPa)

BOREHOLE LOG

CLIENT: Brickworks Ltd
PROJECT: Lightweight Aggregate Project at Plant 2
LOCATION: 720 Wallgrove Road, Horsley Park

SURFACE LEVEL: 60.2 AHD
EASTING: 302629
NORTHING: 6255115
DIP/AZIMUTH: 90°/-

BORE No: 2
PROJECT No: 84821
DATE: 26/5/2015
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Well Construction Details	
				Type	Depth	Sample	Results & Comments			
60.0		FILLING - variably compacted, light grey-brown, silty sand, crushed sandstone, shale and brick fragments filling, damp		A	0.1					
				A	0.5					
1				A	1.0					
59.0				S	1.45		8,6,6 N = 12			
2		2.5m: becoming moist			2.5					
58.0				S	2.95		5,6,8 N = 14			
3		SILTY CLAY - very stiff, light grey and mottled brown, silty clay with a trace of fine sand, wet			4.0					
57.0				S	4.45		5,8,12 N = 20			
4					5.5					
5		5.0m: becoming shaly clay			5.7		10,20/50mm refusal			
55.0		SHALE - low strength, light grey-brown shale		S						
5.7		Bore discontinued at 5.7m								
6										
7										
8										
9										

RIG: Scout 4

DRILLER: RKE

LOGGED: SI

CASING: Uncased

TYPE OF BORING: Solid flight auger to 5.5m

WATER OBSERVATIONS: No free groundwater observed whilst augering

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	W	Water seep	S	Standard penetration test
E	Environmental sample	W	Water level	V	Shear vane (kPa)



Douglas Partners
 Geotechnics | Environment | Groundwater

BOREHOLE LOG

CLIENT: Brickworks Ltd
PROJECT: Lightweight Aggregate Project at Plant 2
LOCATION: 720 Wallgrove Road, Horsley Park

SURFACE LEVEL: 61.6 AHD
EASTING: 302690
NORTHING: 6255116
DIP/AZIMUTH: 90°/-

BORE No: 3
PROJECT No: 84821
DATE: 26/5/2015
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Well Construction Details	
				Type	Depth	Sample	Results & Comments			
61 1 1.3 2 3 3.5 4 5 5.1 5.65 6 7 8 9		FILLING - grey-brown and red-brown, silty sand and crushed brick fragment filling, damp		A	0.1					
				A	0.5					
				A	1.0					
				S	1.45		12,14,14 N = 28			
		FILLING - variably compacted, light grey-brown, sandy silty clay filling with some shale and brick fragments, moist								
				S	2.5		2,3,8 N = 11			
					2.95					
				S						
		SILTY CLAY - stiff, light grey mottled brown, silty clay with a trace of ironstone gravel, moist			4.0		3,5,5 N = 10			
				S	4.45					
		SHALE - very low then low strength, light grey-brown shale			5.5		30/150mm refusal			
		Bore discontinued at 5.65m		S	5.65					

RIG: Scout 4

DRILLER: RKE

LOGGED: SI

CASING: Uncased

TYPE OF BORING: Solid flight auger to 5.5m

WATER OBSERVATIONS: No free groundwater observed whilst augering

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	W	Water seep	S	Standard penetration test
E	Environmental sample	W	Water level	V	Shear vane (kPa)



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BOREHOLE LOG

CLIENT: Brickworks Ltd
PROJECT: Lightweight Aggregate Project at Plant 2
LOCATION: 720 Wallgrove Road, Horsley Park

SURFACE LEVEL: 61.7 AHD
EASTING: 302707
NORTHING: 6255009
DIP/AZIMUTH: 90°/-

BORE No: 4
PROJECT No: 84821
DATE: 27/5/2015
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Well Construction Details	
				Type	Depth	Sample	Results & Comments			
61 1 60 2 59 2.6 3 3.3 4 4.2 5 5.0 5.55 6 5 7 4 8 3 9 2		FILLING - variably compacted, grey, crushed shale filling, damp		A	0.1					
				A	0.5					
				A	1.0					
				S	1.45		6,7,9 N = 16			
					2.5					
		FILLING - light grey-brown, crushed/rippled sandstone filling, damp		S	2.95		3,23,20 N = 43			
		FILLING - apparently poorly compacted, light grey-brown, clay and crushed shale fragments filling, moist to wet								
		3.8m: becoming wet			4.0					
		SILTY CLAY - stiff, brown, silty clay, wet		S	4.45		3,4,6 N = 10			
		SHALE - very low then low strength, light grey to grey shale								
		Bore discontinued at 5.55m		S	5.55		30/50mm refusal			

RIG: Scout 4

DRILLER: RKE

LOGGED: SI

CASING: Uncased

TYPE OF BORING: Solid flight auger to 5.5m

WATER OBSERVATIONS: Free groundwater observed at 3.8m whilst augering

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	W	Water seep	S	Standard penetration test
E	Environmental sample	W	Water level	V	Shear vane (kPa)



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BOREHOLE LOG

CLIENT: Brickworks Ltd
PROJECT: Lightweight Aggregate Project at Plant 2
LOCATION: 720 Wallgrove Road, Horsley Park

SURFACE LEVEL: 60.7 AHD
EASTING: 302794
NORTHING: 6254992
DIP/AZIMUTH: 90°/--

BORE No: 5
PROJECT No: 84821
DATE: 27/5/2015
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Well Construction Details	
				Type	Depth	Sample	Results & Comments			
60 1 59	2.0	FILLING - variably compacted, light grey and grey, silty clay and crushed shale filling, damp		A A A S	0.1 0.5 1.0 1.45		8,7,9 N = 16			
58 3 57 4 56 5 55 6 54 7 53 8 52 9 51		Bore discontinued at 2.0m		A	2.0					

RIG: Scout 1

DRILLER: RKE

LOGGED: SI

CASING: Uncased

TYPE OF BORING: Solid flight auger to 2.0m

WATER OBSERVATIONS: No free groundwater observed whilst augering

REMARKS:

SAMPLING & IN SITU TESTING LEGEND			
A	Auger sample	G	Gas sample
B	Bulk sample	P	Piston sample
BLK	Block sample	U	Tube sample (x mm dia.)
C	Core drilling	W	Water sample
D	Disturbed sample	W	Water seep
E	Environmental sample	W	Water level
		PID	Photo ionisation detector (ppm)
		PL(A)	Point load axial test Is(50) (MPa)
		PL(D)	Point load diametral test Is(50) (MPa)
		pp	Pocket penetrometer (kPa)
		S	Standard penetration test
		V	Shear vane (kPa)



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BOREHOLE LOG

CLIENT: Brickworks Ltd
PROJECT: Lightweight Aggregate Project at Plant 2
LOCATION: 720 Wallgrove Road, Horsley Park

SURFACE LEVEL: 65.8 AHD
EASTING: 302804
NORTHING: 6254946
DIP/AZIMUTH: 90°/-

BORE No: 6
PROJECT No: 84821
DATE: 27/5/2015
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Degree of Weathering EW HW MW SW FS FR	Graphic Log	Rock Strength Ex Low Very Low Low Medium High Very High Ex High	Water	Fracture Spacing (m) 0.01 0.05 0.10 0.50 1.00	Discontinuities B - Bedding J - Joint S - Shear F - Fault	Sampling & In Situ Testing			
									Type	Core Rec. %	RQD %	Test Results & Comments
65.0	1	FILLING - variably compacted, light grey and brown, crushed shale, sandstone and brick fragments filling, humid							A			30/150mm refusal
64.5									A			
64.0									A			
63.5	2.2	SILTY CLAY - very stiff to hard, light grey and mottled red-brown, silty clay with some ironstone gravel, most							S			10, 14, 15 N = 29
63.0												
62.5												
62.0	3.8	SILTSTONE - very low strength, light grey-brown siltstone										35/100mm refusal
61.5	4.1	SILTSTONE - medium strength, highly to moderately weathered, slightly fractured, grey-brown siltstone with some very low strength bands										
61.0												
60.5												PL(A) = 0.4
60.0								4.25 & 4.44m: B0°, fe, cly, Cz 4.51m: J35°, un, ro, fe 4.58m: J70°, un, ro, cln 4.75-4.85m: J65° & 85°, st, ro, cln	C	100	67	
59.5								5.26m: B5°, cly, 2mm 5.35 & 5.5m: Cz, 20mm				
59.0								5.63m: J45°, pl, sm, fe				PL(A) = 0.5
58.5								5.85 & 5.88m: Cs				
58.0								6.15, 6.55 & 6.65m:				
57.5	6.15	SHALE - very low strength, highly weathered, slightly fractured, grey-brown shale										PL(A) = 0.4
57.0	6.85	SHALE - medium strength, slightly weathered, slightly fractured, grey shale							C	100	48	
56.5	7.35	Bore discontinued at 7.35m										
56.0												
55.5												
55.0												
54.5												
54.0												
53.5												
53.0												
52.5												
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3.0												
2.5												
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RIG: Scout 4 **DRILLER:** RKE **LOGGED:** SI **CASING:** HW to 4.0m
TYPE OF BORING: Solid flight auger to 4.0m; Rotary to 4.1m; NMLC-Coring to 7.35m
WATER OBSERVATIONS: No free groundwater observed whilst augering
REMARKS:

SAMPLING & IN SITU TESTING LEGEND			
A	Auger sample	G	Gas sample
B	Bulk sample	P	Piston sample
BLK	Block sample	U	Tube sample (x mm dia.)
C	Core drilling	W	Water sample
D	Disturbed sample	W	Water seep
E	Environmental sample	W	Water level
		PID	Photo ionisation detector (ppm)
		PL(A)	Point load axial test Is(50) (MPa)
		PL(D)	Point load diametral test Is(50) (MPa)
		pp	Pocket penetrometer (kPa)
		S	Standard penetration test
		V	Shear vane (kPa)

DOUGLAS PARTNERS PTY LTD
PROPOSED AGGREGATE FACILITY – HORSLEY PARK
BORE 6 PROJECT 84821 MAY 2015



BOREHOLE LOG

CLIENT: Brickworks Ltd
PROJECT: Lightweight Aggregate Project at Plant 2
LOCATION: 720 Wallgrove Road, Horsley Park

SURFACE LEVEL: 71.4 AHD
EASTING: 302848
NORTHING: 6254980
DIP/AZIMUTH: 90°/--

BORE No: 7
PROJECT No: 84821
DATE: 29/5/2015
SHEET 1 OF 2

RL	Depth (m)	Description of Strata	Degree of Weathering					Graphic Log	Rock Strength					Water	Fracture Spacing (m)				Discontinuities		Sampling & In Situ Testing																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
			EW	HW	MW	SW	FS		FR	Ex Low	Very Low	Low	Medium		High	Very High	Ex High	0.01	0.05	0.10	0.50	1.00	B - Bedding S - Shear	J - Joint F - Fault	Type	Core Rec. %	RQD %	Test Results & Comments																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
71	1.5	FILLING - apparently variably compacted, grey to grey-brown, silty clay and crushed shale filling, damp																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																

RIG: Scout 4 **DRILLER:** RKE **LOGGED:** SI **CASING:** HW to 2.5m; HQ to 10.0m
TYPE OF BORING: Solid flight auger to 2.5m; Rotary to 10.0m; NMLC-Coring to 13.0m
WATER OBSERVATIONS: No free groundwater observed whilst augering
REMARKS: Borehole moved 3.0m. Standpipe installed to 13.0m (screen 11.0-13.0m; gravel 10.0-13.0m; bentonite 9.0-10.0m; backfill to GL; 0.5m stick-up)

SAMPLING & IN SITU TESTING LEGEND			
A Auger sample	G Gas sample	PID Photo ionisation detector (ppm)	
B Bulk sample	P Piston sample	PL(A) Point load axial test Is(50) (MPa)	
BLK Block sample	U Tube sample (x mm dia.)	PL(D) Point load diametral test Is(50) (MPa)	
C Core drilling	W Water sample	pp Pocket penetrometer (kPa)	
D Disturbed sample	> Water seep	S Standard penetration test	
E Environmental sample	≡ Water level	V Shear vane (kPa)	

BOREHOLE LOG

CLIENT: Brickworks Ltd
PROJECT: Lightweight Aggregate Project at Plant 2
LOCATION: 720 Wallgrove Road, Horsley Park

SURFACE LEVEL: 71.4 AHD
EASTING: 302848
NORTHING: 6254980
DIP/AZIMUTH: 90°/-

BORE No: 7
PROJECT No: 84821
DATE: 29/5/2015
SHEET 2 OF 2

RL	Depth (m)	Description of Strata	Degree of Weathering				Graphic Log	Rock Strength						Water	Fracture Spacing (m)	Discontinuities		Sampling & In Situ Testing			
			EW	HW	MW	SW		FS	FR	Ex Low	Very Low	Low	Medium			High	Very High	Ex High	B - Bedding S - Shear	J - Joint F - Fault	Type
61	10.8	SILTSTONE - medium strength, highly to moderately weathered, fractured and slightly fractured, grey-brown siltstone																S			refusal PL(A) = 0.5
11	60	SHALE - low to medium strength, highly to moderately weathered, fractured and slightly fractured, grey-brown shale with some extremely low and very low strength bands																C	94	51	PL(A) = 0.5 PL(A) = 0.3
11.7	12																				
12	12.42																		C	92	58
59	13	Bore discontinued at 13.0m																			
58	14																				
57	15																				
56	16																				
55	17																				
54	18																				
53	19																				
52																					

RIG: Scout 4 **DRILLER:** RKE **LOGGED:** SI **CASING:** HW to 2.5m; HQ to 10.0m
TYPE OF BORING: Solid flight auger to 2.5m; Rotary to 10.0m; NMLC-Coring to 13.0m
WATER OBSERVATIONS: No free groundwater observed whilst augering
REMARKS: Borehole moved 3.0m. Standpipe installed to 13.0m (screen 11.0-13.0m; gravel 10.0-13.0m; bentonite 9.0-10.0m; backfill to GL; 0.5m stick-up)

SAMPLING & IN SITU TESTING LEGEND			
A Auger sample	G Gas sample	PID Photo ionisation detector (ppm)	
B Bulk sample	P Piston sample	PL(A) Point load axial test Is(50) (MPa)	
BLK Block sample	U Tube sample (x mm dia.)	PL(D) Point load diametral test Is(50) (MPa)	
C Core drilling	W Water sample	pp Pocket penetrometer (kPa)	
D Disturbed sample	> Water seep	S Standard penetration test	
E Environmental sample	≡ Water level	V Shear vane (kPa)	

DOUGLAS PARTNERS PTY LTD
PROPOSED AGGREGATE FACILITY – HORSLEY PARK
BORE 7 PROJECT 84821 MAY 2015



BOREHOLE LOG

CLIENT: Brickworks Ltd
PROJECT: Lightweight Aggregate Project at Plant 2
LOCATION: 720 Wallgrove Road, Horsley Park

SURFACE LEVEL: 71.3 AHD
EASTING: 302897
NORTHING: 6254991
DIP/AZIMUTH: 90°/--

BORE No: 8
PROJECT No: 84821
DATE: 29/5/2015
SHEET 1 OF 2

[illegible]

RIG: Scout 4

DRILLER: RKE

LOGGED: SI

CASING: HW to 2.5m: HQ to 11.1m

TYPE OF BORING: Solid flight auger to 2.5m: Rotary to 11.1m: NMLC-Coring to 13.0m

WATER OBSERVATIONS: No free groundwater observed whilst augering

REMARKS:

SAMPLING & IN SITU TESTING LEGEND			
A	Auger sample	G	Gas sample
B	Bulk sample	P	Piston sample
BLK	Block sample	U	Tube sample (x mm dia.)
C	Core drilling	W	Water sample
D	Disturbed sample	W	Water seep
E	Environmental sample	W	Water level
		PID	Photo ionisation detector (ppm)
		PL(A)	Point load axial test (s(50) (MPa)
		PL(D)	Point load diametral test (s(50) (MPa)
		pp	Pocket penetrometer (kPa)
		S	Standard penetration test
		V	Shear vane (kPa)



Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: Brickworks Ltd
PROJECT: Lightweight Aggregate Project at Plant 2
LOCATION: 720 Wallgrove Road, Horsley Park

SURFACE LEVEL: 71.3 AHD
EASTING: 302897
NORTHING: 6254991
DIP/AZIMUTH: 90°/-

BORE No: 8
PROJECT No: 84821
DATE: 29/5/2015
SHEET 2 OF 2

RL	Depth (m)	Description of Strata	Degree of Weathering				Graphic Log	Rock Strength					Water	Fracture Spacing (m)	Discontinuities	Sampling & In Situ Testing					
			EW	HW	MW	SW		FS	FR	Ex Low	Very Low	Low			Medium	High	Very High	Ex High	B - Bedding S - Shear	J - Joint F - Fault	Type
61		CLAY - stiff, light grey and brown clay, moist to wet (<i>continued</i>)																S			8,14,25 N = 39
10.7		SHALY CLAY - hard, light grey mottled brown, shaly clay, damp																			
11																					
11.1		SHALE - medium strength, highly to moderately weathered, fractured then slightly fractured, grey-brown shale with some very low strength bands																C	100	75	PL(A) = 0.4 PL(A) = 0.5
60																					
12																					
59																					
13																					
13.0		Bore discontinued at 13.0m																			
58																					
14																					
57																					
15																					
56																					
16																					
55																					
17																					
54																					
18																					
53																					
19																					
52																					

RIG: Scout 4 **DRILLER:** RKE **LOGGED:** SI **CASING:** HW to 2.5m; HQ to 11.1m
TYPE OF BORING: Solid flight auger to 2.5m; Rotary to 11.1m; NMLC-Coring to 13.0m
WATER OBSERVATIONS: No free groundwater observed whilst augering
REMARKS:

SAMPLING & IN SITU TESTING LEGEND					
A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	W	Water seep	S	Standard penetration test
E	Environmental sample	W	Water level	V	Shear vane (kPa)

DOUGLAS PARTNERS PTY LTD
PROPOSED AGGREGATE FACILITY – HORSLEY PARK
BORE 8 PROJECT 84821 MAY 2015



BOREHOLE LOG

CLIENT: Brickworks Ltd
PROJECT: Lightweight Aggregate Project at Plant 2
LOCATION: 720 Wallgrove Road, Horsley Park

SURFACE LEVEL: 69.0 AHD
EASTING: 302939
NORTHING: 6254999
DIP/AZIMUTH: 90°/--

BORE No: 9
PROJECT No: 84821
DATE: 28/5/2015
SHEET 1 OF 2

[illegible]

RIG: Scout 4

DRILLER: RKE

LOGGED: SI

CASING: HW to 1.5m: HQ to 7.1m

TYPE OF BORING: Solid flight auger to 2.5m: Rotary to 7.1m: NMLC-Coring to 10.3m

WATER OBSERVATIONS: No free groundwater observed whilst augering

REMARKS: Standpipe installed to 10.3m (screen 8.3-10.3m; gravel 7.3-10.3m; bentonite 6.0-7.3m; backfill to GL with gatic cover)

SAMPLING & IN SITU TESTING LEGEND

SAMPLING & IN SITU TESTING LEGEND			
A	Auger sample	G	Gas sample
B	Bulk sample	P	Piston sample
BLK	Block sample	U _s	Tube sample (x mm dia.)
C	Core drilling	W _s	Water sample
D	Disturbed sample	≡	Water seep
E	Environmental sample	≡	Water level
		PID	Photo ionisation detector (ppm)
		PL(A)	Point load axial test Is(50) (MPa)
		PL(D)	Point load diametral test Is(50) (MPa)
		pp	Pocket penetrometer (kPa)
		S	Standard penetration test
		V	Shear vane (kPa)



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Geotechnics | Environment | Groundwater

BOREHOLE LOG

CLIENT: Brickworks Ltd
PROJECT: Lightweight Aggregate Project at Plant 2
LOCATION: 720 Wallgrove Road, Horsley Park

SURFACE LEVEL: 69.0 AHD
EASTING: 302939
NORTHING: 6254999
DIP/AZIMUTH: 90°/--

BORE No: 9
PROJECT No: 84821
DATE: 28/5/2015
SHEET 2 OF 2

RL	Depth (m)	Description of Strata	Degree of Weathering					Graphic Log	Rock Strength					Water	Fracture Spacing (m)				Discontinuities		Sampling & In Situ Testing				
			EW	HW	MW	SW	FS		FR	Ex Low	Very Low	Low	Medium		High	Very High	Ex High	0.01	0.05	0.10	0.50	1.00	B - Bedding S - Shear	J - Joint F - Fault	Type
98	10.3	SILTSTONE - medium strength, slightly weathered, slightly fractured, light grey-brown siltstone (continued) Bore discontinued at 10.3m																		9.9m: J30°- 45°, cu, ro, cln 10.15m: J35°, pl, ro, fe		C	100	80	PL(A) = 0.7
58	11																								
57	12																								
56	13																								
55	14																								
54	15																								
53	16																								
52	17																								
51	18																								
50	19																								

RIG: Scout 4 **DRILLER:** RKE **LOGGED:** SI **CASING:** HW to 1.5m; HQ to 7.1m
TYPE OF BORING: Solid flight auger to 2.5m; Rotary to 7.1m; NMLC-Coring to 10.3m
WATER OBSERVATIONS: No free groundwater observed whilst augering
REMARKS: Standpipe installed to 10.3m (screen 8.3-10.3m; gravel 7.3-10.3m; bentonite 6.0-7.3m; backfill to GL with gatic cover)

SAMPLING & IN SITU TESTING LEGEND			
A	Auger sample	G	Gas sample
B	Bulk sample	P	Piston sample
BLK	Block sample	U	Tube sample (x mm dia.)
C	Core drilling	W	Water sample
D	Disturbed sample	W	Water seep
E	Environmental sample	W	Water level
		PID	Photo ionisation detector (ppm)
		PL(A)	Point load axial test Is(50) (MPa)
		PL(D)	Point load diametral test Is(50) (MPa)
		pp	Pocket penetrometer (kPa)
		S	Standard penetration test
		V	Shear vane (kPa)

DOUGLAS PARTNERS PTY LTD
PROPOSED AGGREGATE FACILITY – HORSLEY PARK
BORE 9 PROJECT 84821 MAY 2015



BOREHOLE LOG

CLIENT: Brickworks Ltd
PROJECT: Lightweight Aggregate Project at Plant 2
LOCATION: 720 Wallgrove Road, Horsley Park

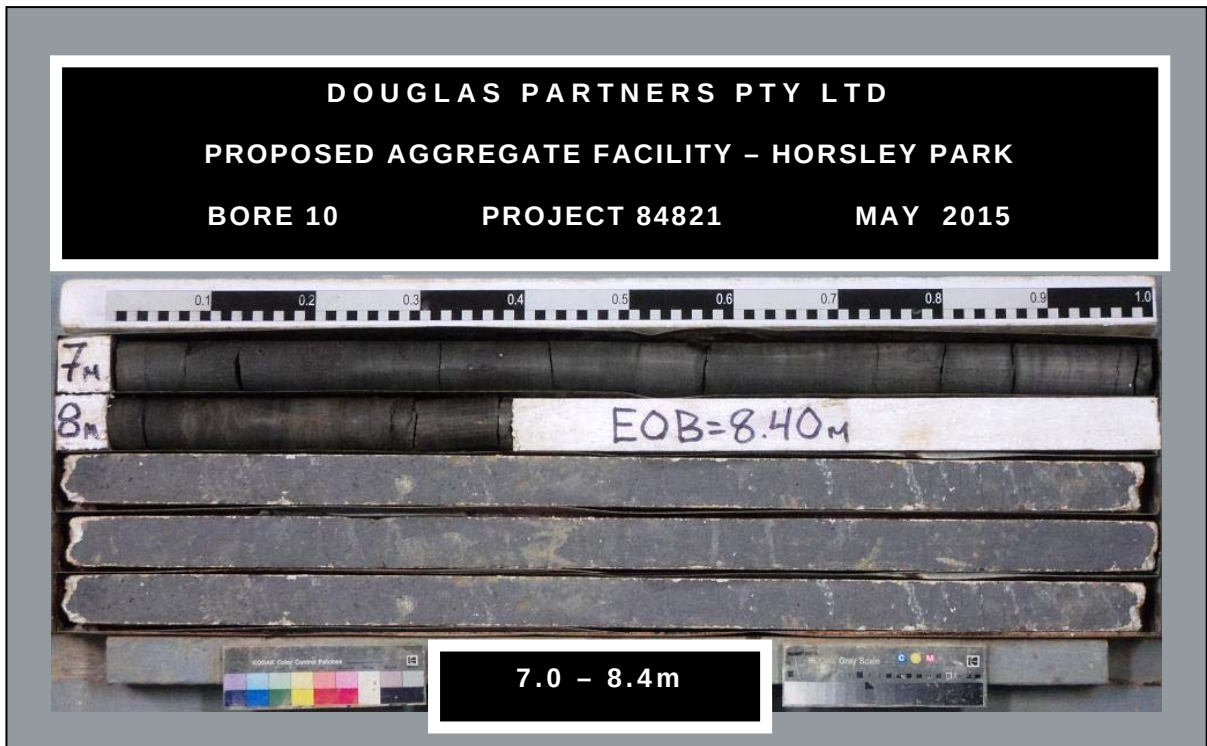
SURFACE LEVEL: 67.1 AHD
EASTING: 302900
NORTHING: 6254945
DIP/AZIMUTH: 90°/-

BORE No: 10
PROJECT No: 84821
DATE: 28/5/2015
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Degree of Weathering				Graphic Log	Rock Strength					Water	Fracture Spacing (m)				Discontinuities		Sampling & In Situ Testing																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
			EW	HW	MW	SW		FS	FR	Ex Low	Very Low	Low		Medium	High	Very High	Ex High	0.01	0.05	0.10	0.50	1.00	B - Bedding S - Shear	J - Joint F - Fault	Type	Core Rec. %	RQD %	Test Results & Comments																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
67		FILLING - variably compacted, grey and brown, silty clay and crushed shale filling with some brick fragments																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		</

RIG: Scout 4 **DRILLER:** RKE **LOGGED:** SI **CASING:** HW to 2.8m
TYPE OF BORING: Solid flight auger to 2.8m; NMLC-Coring to 8.4m
WATER OBSERVATIONS: No free groundwater observed whilst augering
REMARKS: Standpipe installed to 8.4m (screen 5.4-8.4m; gravel 5.0-8.4m; bentonite 4.0-5.0m; backfill to GL with 0.6m stick-up)

SAMPLING & IN SITU TESTING LEGEND			
A	Auger sample	G	Gas sample
B	Bulk sample	P	Piston sample
BLK	Block sample	U	Tube sample (x mm dia.)
C	Core drilling	W	Water sample
D	Disturbed sample	W	Water seep
E	Environmental sample	W	Water level
		PID	Photo ionisation detector (ppm)
		PL(A)	Point load axial test Is(50) (MPa)
		PL(D)	Point load diametral test Is(50) (MPa)
		pp	Pocket penetrometer (kPa)
		S	Standard penetration test
		V	Shear vane (kPa)





Sampling

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

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

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

Test Pits

Test pits are usually excavated with a backhoe or an excavator, allowing close examination of the in-situ soil if it is safe to enter into the pit. The depth of excavation is limited to about 3 m for a backhoe and up to 6 m for a large excavator. A potential disadvantage of this investigation method is the larger area of disturbance to the site.

Large Diameter Augers

Boreholes can be drilled using a rotating plate or short spiral auger, generally 300 mm or larger in diameter commonly mounted on a standard piling rig. The cuttings are returned to the surface at intervals (generally not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube samples.

Continuous Spiral Flight Augers

The borehole is advanced using 90-115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are disturbed and may be mixed with soils from the sides of the hole. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively low

reliability, due to the remoulding, possible mixing or softening of samples by groundwater.

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from the rate of penetration. Where drilling mud is used this can mask the cuttings and reliable identification is only possible from separate sampling such as SPTs.

Continuous Core Drilling

A continuous core sample can be obtained using a diamond tipped core barrel, usually with a 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in weak rocks and granular soils), this technique provides a very reliable method of investigation.

Standard Penetration Tests

Standard penetration tests (SPT) are used as a means of estimating the density or strength of soils and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, Methods of Testing Soils for Engineering Purposes - Test 6.3.1.

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

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150 mm of, say, 4, 6 and 7 as:
4,6,7
N=13
- In the case where the test is discontinued before the full penetration depth, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm as:
15, 30/40 mm

Sampling Methods

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

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

Dynamic penetrometer tests (DCP or PSP) are carried out by driving a steel rod into the ground using a standard weight of hammer falling a specified distance. As the rod penetrates the soil the number of blows required to penetrate each successive 150 mm depth are recorded. Normally there is a depth limitation of 1.2 m, but this may be extended in certain conditions by the use of extension rods. Two types of penetrometer are commonly used.

- Perth sand penetrometer - a 16 mm diameter flat ended rod is driven using a 9 kg hammer dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands and is mainly used in granular soils and filling.
- Cone penetrometer - a 16 mm diameter rod with a 20 mm diameter cone end is driven using a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). This test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various road authorities.



Description and Classification Methods

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

Soil Types

Soil types are described according to the predominant particle size, qualified by the grading of other particles present:

Type	Particle size (mm)
Boulder	>200
Cobble	63 - 200
Gravel	2.36 - 63
Sand	0.075 - 2.36
Silt	0.002 - 0.075
Clay	<0.002

The sand and gravel sizes can be further subdivided as follows:

Type	Particle size (mm)
Coarse gravel	20 - 63
Medium gravel	6 - 20
Fine gravel	2.36 - 6
Coarse sand	0.6 - 2.36
Medium sand	0.2 - 0.6
Fine sand	0.075 - 0.2

The proportions of secondary constituents of soils are described as:

Term	Proportion	Example
And	Specify	Clay (60%) and Sand (40%)
Adjective	20 - 35%	Sandy Clay
Slightly	12 - 20%	Slightly Sandy Clay
With some	5 - 12%	Clay with some sand
With a trace of	0 - 5%	Clay with a trace of sand

Definitions of grading terms used are:

- Well graded - a good representation of all particle sizes
- Poorly graded - an excess or deficiency of particular sizes within the specified range
- Uniformly graded - an excess of a particular particle size
- Gap graded - a deficiency of a particular particle size with the range

Cohesive Soils

Cohesive soils, such as clays, are classified on the basis of undrained shear strength. The strength may be measured by laboratory testing, or estimated by field tests or engineering examination. The strength terms are defined as follows:

Description	Abbreviation	Undrained shear strength (kPa)
Very soft	vs	<12
Soft	s	12 - 25
Firm	f	25 - 50
Stiff	st	50 - 100
Very stiff	vst	100 - 200
Hard	h	>200

Cohesionless Soils

Cohesionless soils, such as clean sands, are classified on the basis of relative density, generally from the results of standard penetration tests (SPT), cone penetration tests (CPT) or dynamic penetrometers (PSP). The relative density terms are given below:

Relative Density	Abbreviation	SPT N value	CPT qc value (MPa)
Very loose	vl	<4	<2
Loose	l	4 - 10	2 - 5
Medium dense	md	10 - 30	5 - 15
Dense	d	30 - 50	15 - 25
Very dense	vd	>50	>25

Soil Descriptions

Soil Origin

It is often difficult to accurately determine the origin of a soil. Soils can generally be classified as:

- Residual soil - derived from in-situ weathering of the underlying rock;
- Transported soils - formed somewhere else and transported by nature to the site; or
- Filling - moved by man.

Transported soils may be further subdivided into:

- Alluvium - river deposits
- Lacustrine - lake deposits
- Aeolian - wind deposits
- Littoral - beach deposits
- Estuarine - tidal river deposits
- Talus - scree or coarse colluvium
- Slopewash or Colluvium - transported downslope by gravity assisted by water. Often includes angular rock fragments and boulders.



Rock Strength

Rock strength is defined by the Point Load Strength Index ($IS_{(50)}$) and refers to the strength of the rock substance and not the strength of the overall rock mass, which may be considerably weaker due to defects. The test procedure is described by Australian Standard 4133.4.1 - 1993. The terms used to describe rock strength are as follows:

Term	Abbreviation	Point Load Index $IS_{(50)}$ MPa	Approx Unconfined Compressive Strength MPa*
Extremely low	EL	<0.03	<0.6
Very low	VL	0.03 - 0.1	0.6 - 2
Low	L	0.1 - 0.3	2 - 6
Medium	M	0.3 - 1.0	6 - 20
High	H	1 - 3	20 - 60
Very high	VH	3 - 10	60 - 200
Extremely high	EH	>10	>200

* Assumes a ratio of 20:1 for UCS to $IS_{(50)}$

Degree of Weathering

The degree of weathering of rock is classified as follows:

Term	Abbreviation	Description
Extremely weathered	EW	Rock substance has soil properties, i.e. it can be remoulded and classified as a soil but the texture of the original rock is still evident.
Highly weathered	HW	Limonite staining or bleaching affects whole of rock substance and other signs of decomposition are evident. Porosity and strength may be altered as a result of iron leaching or deposition. Colour and strength of original fresh rock is not recognisable
Moderately weathered	MW	Staining and discolouration of rock substance has taken place
Slightly weathered	SW	Rock substance is slightly discoloured but shows little or no change of strength from fresh rock
Fresh stained	Fs	Rock substance unaffected by weathering but staining visible along defects
Fresh	Fr	No signs of decomposition or staining

Degree of Fracturing

The following classification applies to the spacing of natural fractures in diamond drill cores. It includes bedding plane partings, joints and other defects, but excludes drilling breaks.

Term	Description
Fragmented	Fragments of <20 mm
Highly Fractured	Core lengths of 20-40 mm with some fragments
Fractured	Core lengths of 40-200 mm with some shorter and longer sections
Slightly Fractured	Core lengths of 200-1000 mm with some shorter and longer sections
Unbroken	Core lengths mostly > 1000 mm

Rock Descriptions

Rock Quality Designation

The quality of the cored rock can be measured using the Rock Quality Designation (RQD) index, defined as:

$$\text{RQD \%} = \frac{\text{cumulative length of 'sound' core sections} \geq 100 \text{ mm long}}{\text{total drilled length of section being assessed}}$$

where 'sound' rock is assessed to be rock of low strength or better. The RQD applies only to natural fractures. If the core is broken by drilling or handling (i.e. drilling breaks) then the broken pieces are fitted back together and are not included in the calculation of RQD.

Stratification Spacing

For sedimentary rocks the following terms may be used to describe the spacing of bedding partings:

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

Symbols & Abbreviations

Douglas Partners



Introduction

These notes summarise abbreviations commonly used on borehole logs and test pit reports.

Drilling or Excavation Methods

C	Core Drilling
R	Rotary drilling
SFA	Spiral flight augers
NMLC	Diamond core - 52 mm dia
NQ	Diamond core - 47 mm dia
HQ	Diamond core - 63 mm dia
PQ	Diamond core - 81 mm dia

Water

▷	Water seep
▽	Water level

Sampling and Testing

A	Auger sample
B	Bulk sample
D	Disturbed sample
E	Environmental sample
U ₅₀	Undisturbed tube sample (50mm)
W	Water sample
pp	pocket penetrometer (kPa)
PID	Photo ionisation detector
PL	Point load strength Is(50) MPa
S	Standard Penetration Test
V	Shear vane (kPa)

Description of Defects in Rock

The abbreviated descriptions of the defects should be in the following order: Depth, Type, Orientation, Coating, Shape, Roughness and Other. Drilling and handling breaks are not usually included on the logs.

Defect Type

B	Bedding plane
Cs	Clay seam
Cv	Cleavage
Cz	Crushed zone
Ds	Decomposed seam
F	Fault
J	Joint
Lam	lamination
Pt	Parting
Sz	Sheared Zone
V	Vein

Orientation

The inclination of defects is always measured from the perpendicular to the core axis.

h	horizontal
v	vertical
sh	sub-horizontal
sv	sub-vertical

Coating or Infilling Term

cln	clean
co	coating
he	healed
inf	infilled
stn	stained
ti	tight
vn	veneer

Coating Descriptor

ca	calcite
cbs	carbonaceous
cly	clay
fe	iron oxide
mn	manganese
slt	silty

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

Other

fg	fragmented
bnd	band
qtz	quartz

Symbols & Abbreviations

Graphic Symbols for Soil and Rock

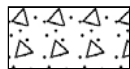
General



Asphalt



Road base



Concrete



Filling

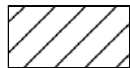
Soils



Topsoil



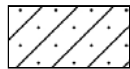
Peat



Clay



Silty clay



Sandy clay



Gravelly clay



Shaly clay



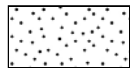
Silt



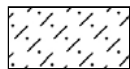
Clayey silt



Sandy silt



Sand



Clayey sand



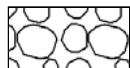
Silty sand



Gravel



Sandy gravel

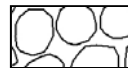


Cobbles, boulders



Talus

Sedimentary Rocks



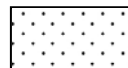
Boulder conglomerate



Conglomerate



Conglomeratic sandstone



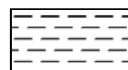
Sandstone



Siltstone



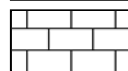
Laminite



Mudstone, claystone, shale

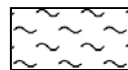


Coal

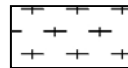


Limestone

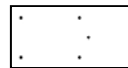
Metamorphic Rocks



Slate, phyllite, schist

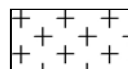


Gneiss

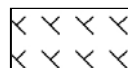


Quartzite

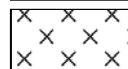
Igneous Rocks



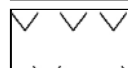
Granite



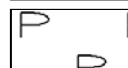
Dolerite, basalt, andesite



Dacite, epidote



Tuff, breccia



Porphyry

Appendix D

Laboratory Test Results

Results of Moisture Content, Plasticity and Linear Shrinkage Tests

Client:	Brickworks Ltd	Project No:	84821
Project:	Geotechnical Investigation	Report No:	1
Location:	780 Wallgrove Rd, Horsley Park	Report Date:	09/06/2015
		Date Sampled:	
		Date of Test:	-
		Page:	04/06/2015
1 of 1			

Test Location	Depth (m)	Description	Code	W _F %	W _L %	W _P %	PI %	*LS %
BH7	7 - 7.45	FILLING - grey, silty clay, crushed shale and brick fragments filling	2,5	14.9	39	20	19	10
BH8	4 - 4.45	FILLING - light grey, clay and crushed shale and brick gravel filling	2,5	12.6	38	18	20	12.5
BH9	5.5 - 5.95	CLAY - light grey mottled brown, slightly silty clay	2,5	22.4	65	22	43	18 CU
BH10	2.5 - 2.8	SILTSTONE - light grey-brown siltstone	2,5	12.9	49	19	30	14.5 CU

Legend:

W_F Field Moisture Content
 W_L Liquid limit
 W_P Plastic limit
 PI Plasticity index
 LS Linear shrinkage from liquid limit condition (Mould length 125mm)

Test Methods:

Moisture Content: AS 1289 2.1.1
 Liquid Limit: AS 1289 3.1.2
 Plastic Limit: AS 1289 3.2.1
 Plasticity Index: AS 1289 3.3.1
 Linear Shrinkage: AS 1289 3.4.1

Code:

Sample history for plasticity tests

1. Air dried
2. Low temperature (<50°C) oven dried
3. Oven (105°C) dried
4. Unknown

Method of preparation for plasticity tests

5. Dry sieved
6. Wet sieved
7. Natural

*Specify if sample crumbled CR or curled CU

Sampling Methods: Sampled by Engineering Department

Remarks:



NATA Accredited Laboratory Number: 828

The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards. Accredited for compliance with ISO/IEC 17025

Tested: LW
 Checked: MM


 Mark Matthews
 Laboratory Manager

Determination of Emerson Class Number of Soil

Client :	Brickworks Ltd	Project No. :	84821
Project :	Geotechnical Investigation	Report No. :	2
Location :	780 Wallgrove Rd, Horsley Park	Report Date :	9/06/2015
		Page:	1 of 1

Sample No.	Depth (m)	Date of Test	Description	Water Type	Water Temp	Class No.
BH10	2.5	5/06/2015	SILTSTONE - light grey-brown siltstone	Distilled	23	2
BH7	7.0	5/06/2015	FILLING - grey, silty clay, crushed shale and brick fragments filling	Distilled	23	2
BH8	4.0	5/06/2015	FILLING - light grey, clay and crushed shale and brick gravel filling	Distilled	23	2
BH9	5.5	5/06/2015	CLAY - light grey mottled brown, slightly silty clay	Distilled	23	2

Test Methods: AS 1289 3.8.1

Sampling Methods: Sampled by Engineering Department

Remarks:



NATA Accredited Laboratory Number: 828

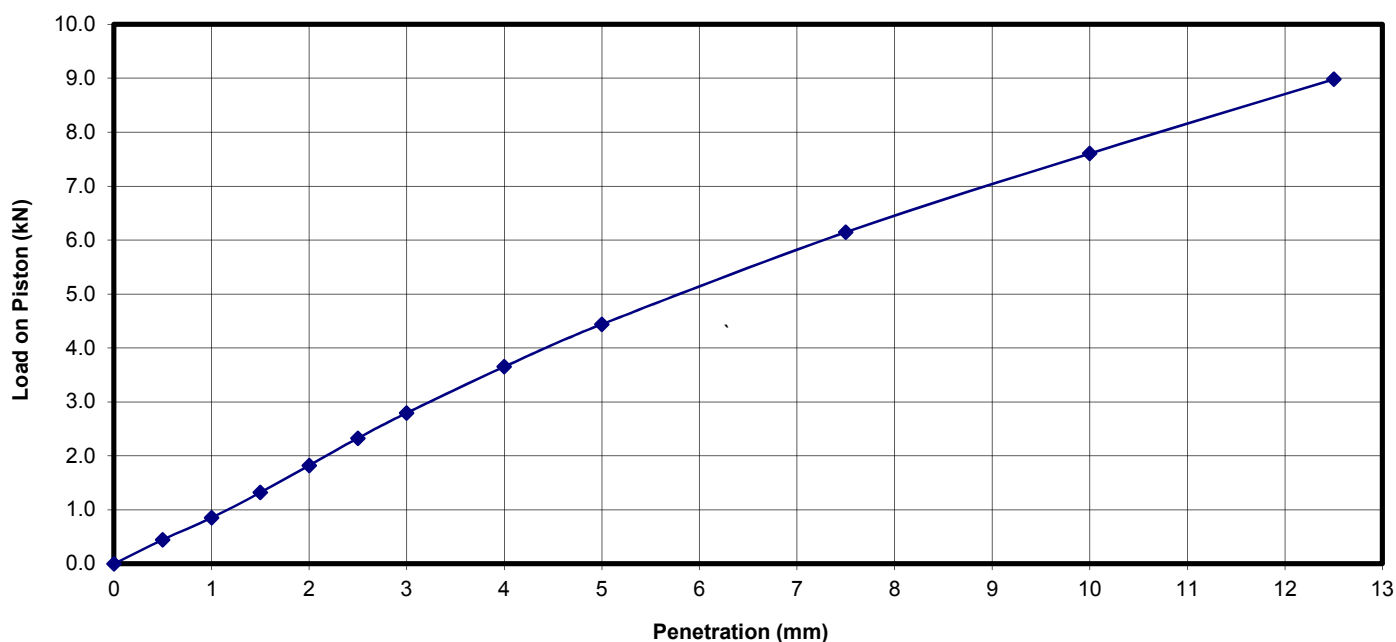
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
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Mark Matthews
Laboratory Manager

Results of California Bearing Ratio Test

Client :	Brickworks Ltd	Project No. :	84821.00
Project :	Geotechnical Investigation	Report No. :	3
Location :	780 Wallgrove Rd, Horsley Park	Report Date :	11/06/2015
Test Location :	BH11	Date Sampled :	29/05/2015
Depth / Layer :	0.0 - 0.5m	Date of Test:	9/06/2015
		Page:	1 of 1



Description: Orange brown sandy clay with some gravel (5-day soak)

Test Method(s): AS1289 6.1.1, AS1289 5.1.1, AS1289 2.1.1

Sampling Method(s): Sampled by Engineering Department

Percentage > 19mm: 5% Excluded

LEVEL OF COMPACTION: 100% of STD MDD

SURCHARGE: 4.5 kg

SWELL: 0.4%

MOISTURE RATIO: 96% of STD OMC

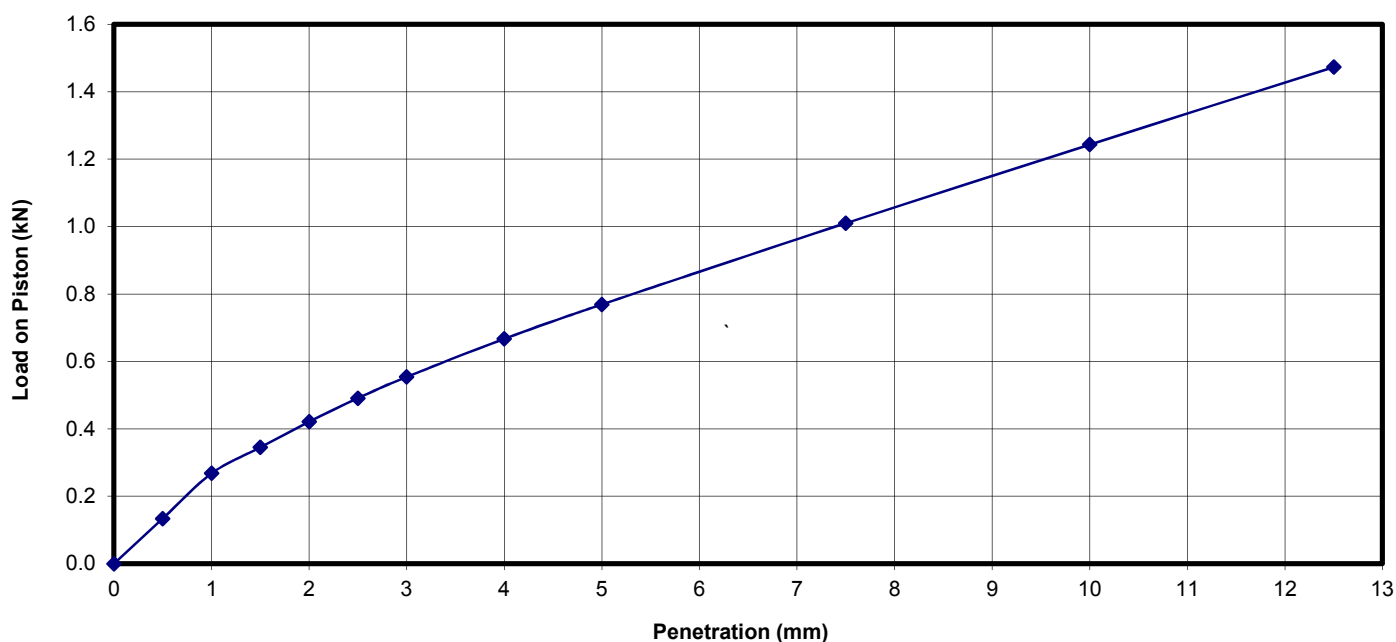
SOAKING PERIOD: 5 days

CONDITION	MOISTURE CONTENT %	DRY DENSITY t/m ³
At compaction	8.3	2.02
After soaking	10.6	2.02
After test		
Top 30mm of sample	9.8	-
Remainder of sample	9.8	-
Field values	6.3	-
Standard Compaction (OMC/MDD)	8.7	2.01

RESULTS		
TYPE	PENETRATION	CBR (%)
TOP	5.0 mm	25

Results of California Bearing Ratio Test

Client :	Brickworks Ltd	Project No. :	84821.00
Project :	Geotechnical Investigation	Report No. :	4
Location :	780 Wallgrove Rd, Horsley Park	Report Date :	11/06/2015
Test Location :	BH12	Date Sampled :	29/05/2015
Depth / Layer :	0.0 - 0.5m	Date of Test:	9/06/2015
		Page:	1 of 1



Description: Grey shaly silty clay (24 hrs curing)

Test Method(s): AS1289 6.1.1, AS1289 5.1.1, AS1289 2.1.1

Sampling Method(s): Sampled by Engineering Department

Percentage > 19mm: 2% Excluded

LEVEL OF COMPACTION: 100% of STD MDD

SURCHARGE: 4.5 kg

SWELL: 1.9%

MOISTURE RATIO: 100% of STD OMC

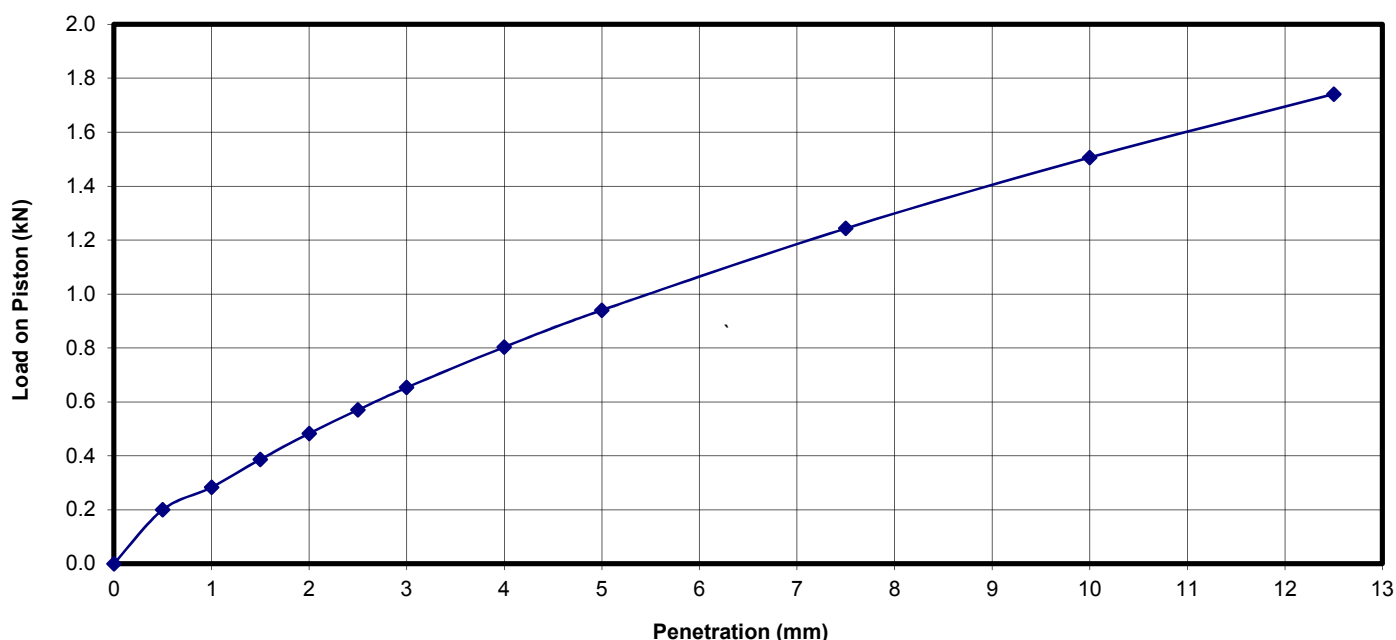
SOAKING PERIOD: 4 days

CONDITION	MOISTURE CONTENT %	DRY DENSITY t/m ³
At compaction	11.5	1.97
After soaking	14.0	1.97
After test		
Top 30mm of sample	15.3	-
Remainder of sample	12.8	-
Field values	8.1	-
Standard Compaction (OMC/MDD)	11.5	1.97

RESULTS		
TYPE	PENETRATION	CBR (%)
TOP	5.0 mm	4

Results of California Bearing Ratio Test

Client :	Brickworks Ltd	Project No. :	84821.00
Project :	Geotechnical Investigation	Report No. :	5
Location :	780 Wallgrove Rd, Horsley Park	Report Date :	11/06/2015
Test Location :	BH12	Date Sampled :	29/05/2015
Depth / Layer :	1.5 - 2.0m	Date of Test:	9/06/2015
		Page:	1 of 1



Description: Grey shaly silty clay (5-day soak)
Test Method(s): AS1289 6.1.1, AS1289 5.1.1, AS1289 2.1.1
Sampling Method(s): Sampled by Engineering Department

Percentage > 19mm: 0%

LEVEL OF COMPACTION: 100% of STD MDD
MOISTURE RATIO: 99% of STD OMC

SURCHARGE: 4.5 kg
SOAKING PERIOD: 5 days

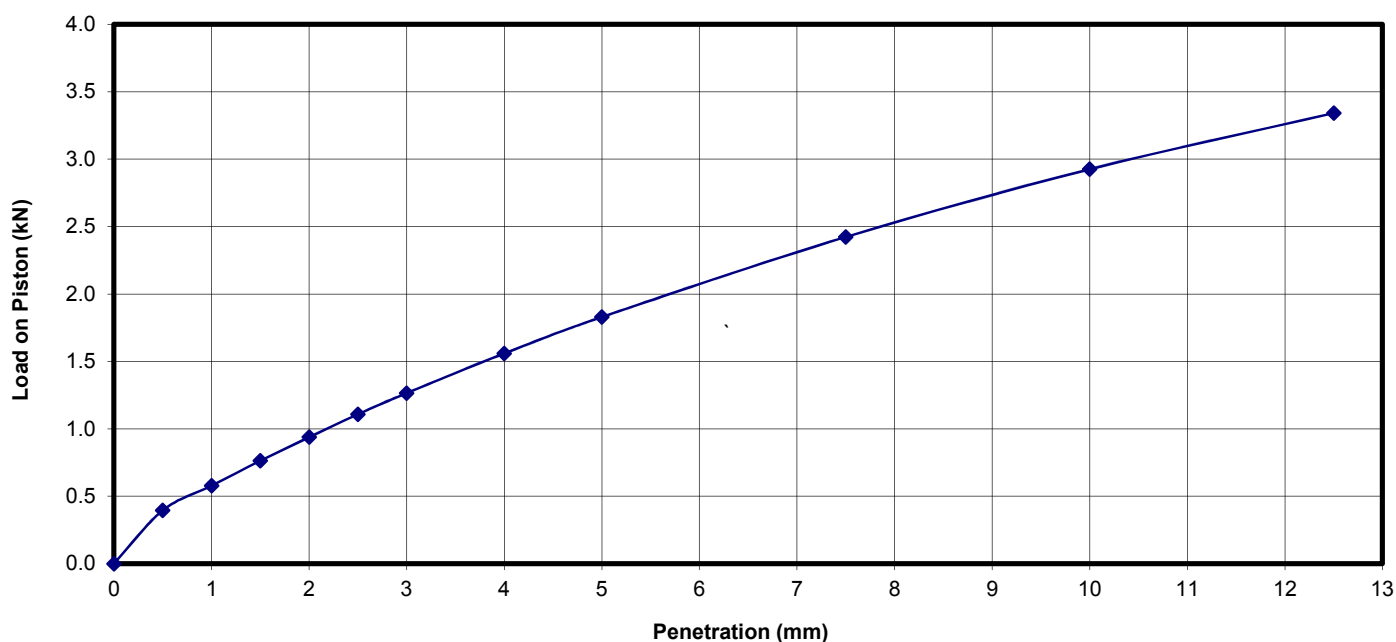
SWELL: 2.6%

CONDITION	MOISTURE CONTENT %	DRY DENSITY t/m ³
At compaction	12.0	1.93
After soaking	15.4	1.93
After test		
Top 30mm of sample	16.7	-
Remainder of sample	14.6	-
Field values	11.2	-
Standard Compaction (OMC/MDD)	12.1	1.93

RESULTS		
TYPE	PENETRATION	CBR (%)
TOP	5.0 mm	4.5

Results of California Bearing Ratio Test

Client :	Brickworks Ltd	Project No. :	84821.00
Project :	Geotechnical Investigation	Report No. :	6
Location :	780 Wallgrove Rd, Horsley Park	Report Date :	11/06/2015
Test Location :	BH13	Date Sampled :	29/05/2015
Depth / Layer :	0.5 - 1.0m	Date of Test:	9/06/2015
		Page:	1 of 1



Description: Yellow brown clay with some gravel

Test Method(s): AS1289 6.1.1, AS1289 5.1.1, AS1289 2.1.1

Sampling Method(s): Sampled by Engineering Department

Percentage > 19mm: 2% Excluded

LEVEL OF COMPACTION: 99% of STD MDD

SURCHARGE: 4.5 kg

SWELL: 0.5%

MOISTURE RATIO: 102% of STD OMC

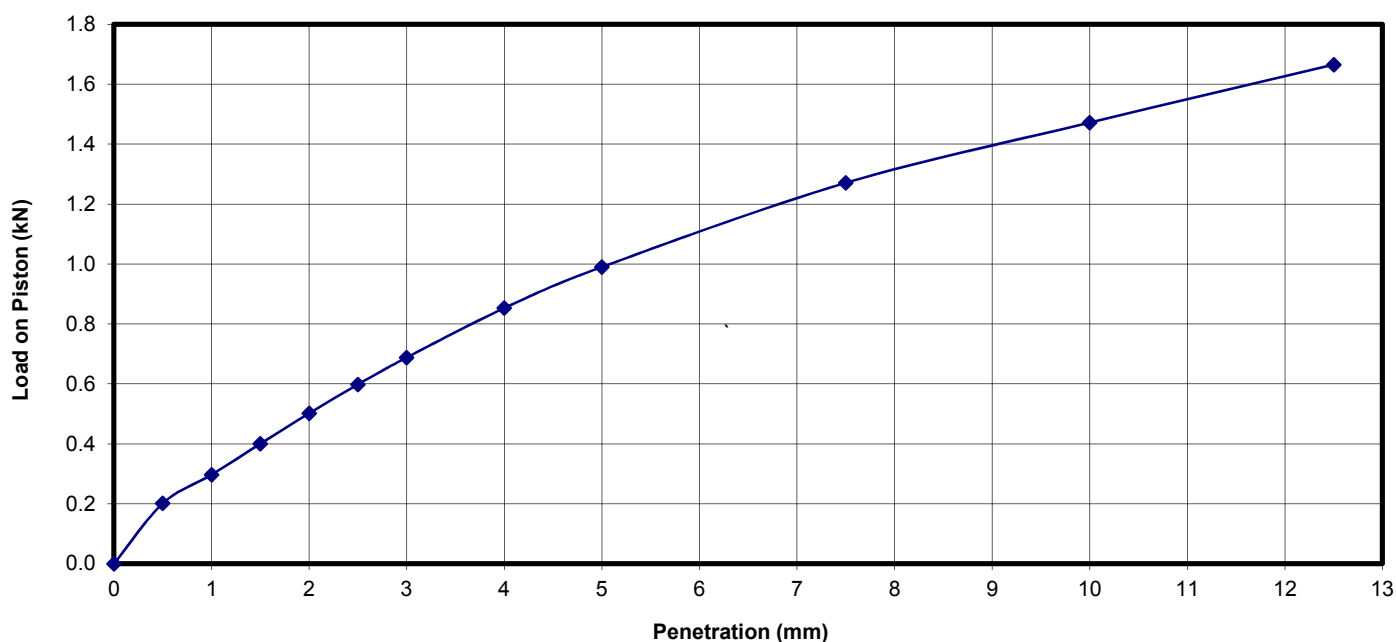
SOAKING PERIOD: 4 days

CONDITION	MOISTURE CONTENT %	DRY DENSITY t/m ³
At compaction	11.3	1.97
After soaking	12.8	1.97
After test		
Top 30mm of sample	12.9	-
Remainder of sample	12.2	-
Field values	5.6	-
Standard Compaction (OMC/MDD)	11.1	1.99

RESULTS		
TYPE	PENETRATION	CBR (%)
TOP	5.0 mm	9

Results of California Bearing Ratio Test

Client :	Brickworks Ltd	Project No. :	84821.00
Project :	Geotechnical Investigation	Report No. :	7
Location :	780 Wallgrove Rd, Horsley Park	Report Date :	11/06/2015
Test Location :	BH14	Date Sampled :	29/05/2015
Depth / Layer :	0.5 - 1.0m	Date of Test:	9/06/2015
		Page:	1 of 1



Description: Dark grey shaly clay (5-day soak)

Test Method(s): AS1289 6.1.1, AS1289 5.1.1, AS1289 2.1.1

Sampling Method(s): Sampled by Engineering Department

Percentage > 19mm: 3% Included

LEVEL OF COMPACTION: 100% of STD MDD

SURCHARGE: 4.5 kg

SWELL: 0.4%

MOISTURE RATIO: 104% of STD OMC

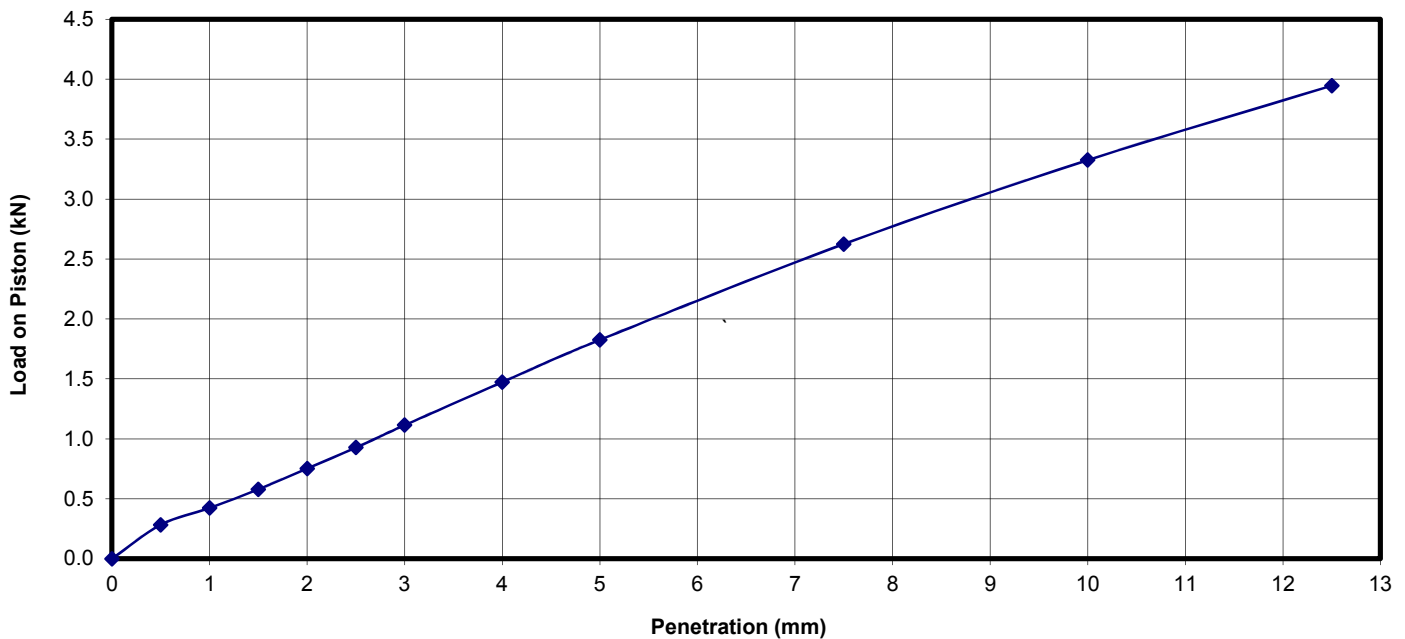
SOAKING PERIOD: 5 days

CONDITION	MOISTURE CONTENT %	DRY DENSITY t/m ³
At compaction	11.5	2.00
After soaking	12.8	2.00
After test		
Top 30mm of sample	12.2	-
Remainder of sample	11.8	-
Field values	11.4	-
Standard Compaction (OMC/MDD)	11.1	2.01

RESULTS		
TYPE	PENETRATION	CBR (%)
TOP	5.0 mm	5

Results of California Bearing Ratio Test

Client :	Brickworks Ltd	Project No. :	84821.00
Project :	Geotechnical Investigation	Report No. :	9
Location :	780 Wallgrove Rd, Horsley Park	Report Date :	16/06/2015
Test Location :	BH15	Date Sampled :	2/06/2015
Depth / Layer :	0.5 - 1.0m	Date of Test:	15/06/2015
		Page:	1 of 1



Description: Filling - light grey to grey, silty clay and crushed shale fragments filling

Test Method(s): AS1289 6.1.1, AS1289 5.1.1, AS1289 2.1.1

Sampling Method(s): Sampled by Engineering Department

Percentage > 19mm: 4% Excluded

LEVEL OF COMPACTION: 100% of STD MDD

SURCHARGE: 4.5 kg

SWELL: 0.2%

MOISTURE RATIO: 105% of STD OMC

SOAKING PERIOD: 4 days

CONDITION	MOISTURE CONTENT %	DRY DENSITY t/m ³
At compaction	11.3	2.01
After soaking	13.1	2.01
After test		
Top 30mm of sample	13.3	-
Remainder of sample	11.9	-
Field values	9.8	-
Standard Compaction (OMC/MDD)	10.8	2.02

RESULTS		
TYPE	PENETRATION	CBR (%)
TOP	5.0 mm	9

Results of Moisture Content Test

Client : Brickworks Ltd				Project No. : 84821	
Project : Geotechnical Investigation				Report No. : 8	
Location : 780 Wallgrove Rd, Horsley Park				Report Date : 15/06/2015	
Test Location	Depth (m)	Date Sampled	Date Tested	Description	Moisture Content (%)
BH1	1.0	29/05/2015	11/06/2015	Grey and light grey-brown silty clay and crushed shale filling	6.2
BH10	1.0	29/05/2015	11/06/2015	Grey and brown silty clay and crushed shale filling with some brick fragments	6.8
BH2	1.0	29/05/2015	11/06/2015	Light grey-brown silty sand crushed sandstone, shale and brick fragments filling	15.2
BH3	1.0	29/05/2015	11/06/2015	Grey-brown and red-brown, silty sandy clay with some shale and crushed brick fragment filling	9.3
BH4	1.0	29/05/2015	11/06/2015	Grey crushed shale filling	6.4
BH7	2.5	29/05/2015	11/06/2015	Grey silty clay, crushed shale and brick fragments filling	10.8
BH7	4.0	29/05/2015	11/06/2015	Grey silty clay, crushed shale and brick fragments filling	17.3
BH8	1.0	29/05/2015	11/06/2015	Grey silty clay and crushed shale fragments filling with some gravel (brick fragments)	13.8
BH8	5.5	29/05/2015	11/06/2015	Light grey and crushed shale and brick gravel filling	17.6
BH9	4.0	29/05/2015	11/06/2015	Light brown silty sandy clay filling with some crushed shale fragments	21.6
BH9	7.0	29/05/2015	11/06/2015	Light brown silty sandy clay filling with some crushed shale fragments	17.9

Test Methods: AS 1289.2.1.1

Sampling Methods: AS 1289.1.2.1, AS 1289.1.1

Remarks:



NATA Accredited Laboratory Number: 828

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Mark Matthews
Laboratory Manager