Douglas Partners
Geotechnics / Environment / Groundwater

Report on
Geotechnical Investigation

Redevelopment of Cessnock Correctional Centre
Lindsay Street, Cessnock

Prepared for
NBRS & Partners Pty Ltd

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Report on Geotechnical Investigation
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1. Introduction

This report presents the results of a geotechnical investigation undertaken for a redevelopment of Cessnock Correctional Centre, located at Lindsay Street, Cessnock. The investigation was commissioned in an email dated 12 July 2016 by Brett Shearson of NBRS & Partners Pty Ltd, acting on behalf of NSW Department of Justice and was undertaken in accordance with Douglas Partners' proposal NCL160276 dated 11 April 2016.

The proposed development comprises the extension of both the existing maximum and minimum security facilities and relocation of the existing admin building and staff car park at the Cessnock Correctional Centre, as follows:

- **Area 1:** Additional 280 bed minimum security facility and ancillary supporting infrastructure on the vacant land to the south of the existing centre;
- **Area 2:** Additional 320 bed maximum security facility and ancillary supporting infrastructure on the land west of the existing centre;
- **Area 3:** Construction of a new staff amenities building, admin building and car park to the south of the existing maximum security facility;
- **Area 4:** Construction of approximately 250 m of new access road connecting the proposed car park to the existing Alunga Ave, and;
- **Area 5:** Construction of a new max industries building within the existing minimum security area.

The aim of the investigation was to provide information on the following:

- Subsurface conditions;
- Site classification;
- Excavation conditions;
- Earthquake loading factors;
- Geotechnical design parameters for shallow footings and piles;
- Geotechnical parameters for retaining walls;
- Pavement thickness design for the car park and proposed access road.

The investigation included the drilling of fifteen boreholes and laboratory testing of selected samples. The details of the field work are presented in this report, together with comments and recommendations on the issues listed above.

DP has carried out a concurrent Preliminary Site Investigation (Contamination), the results of which have been reported under a separate cover (Ref 1).

2. Previous Relevant Investigations

Douglas Partners Pty Ltd (DP) has undertaken a number of previous investigations at Cessnock Correctional Centre (CCC) including the following:

- Desktop geotechnical assessment for the proposed redevelopment of Cessnock Correctional Facility, Project 43326 dated 16 September 2005;
- Geotechnical investigation for the proposed new chapel, Project 39632 dated 13 September 2006;
- Geotechnical Investigation for a previously proposed upgrade of facilities, Project 39632-1 dated February 2007 (Ref 1);
- Preliminary contamination assessment for a previously proposed upgrade of facilities, Project 39632-1 dated February 2007; and
- Pavement thickness design for a previously proposed upgrade of facilities, Project 39632.02 dated 20 February 2009.

Information from these investigations has been used to supplement the current investigation.

3. Site Description

Cessnock Correctional Centre is located within Lot 3 in DP 76202, situated at the northern end of Lindsay Street, Cessnock. Investigations took place to the west and south of the existing correctional facility within five development areas (Refer
Figure 1 and Drawing 1).

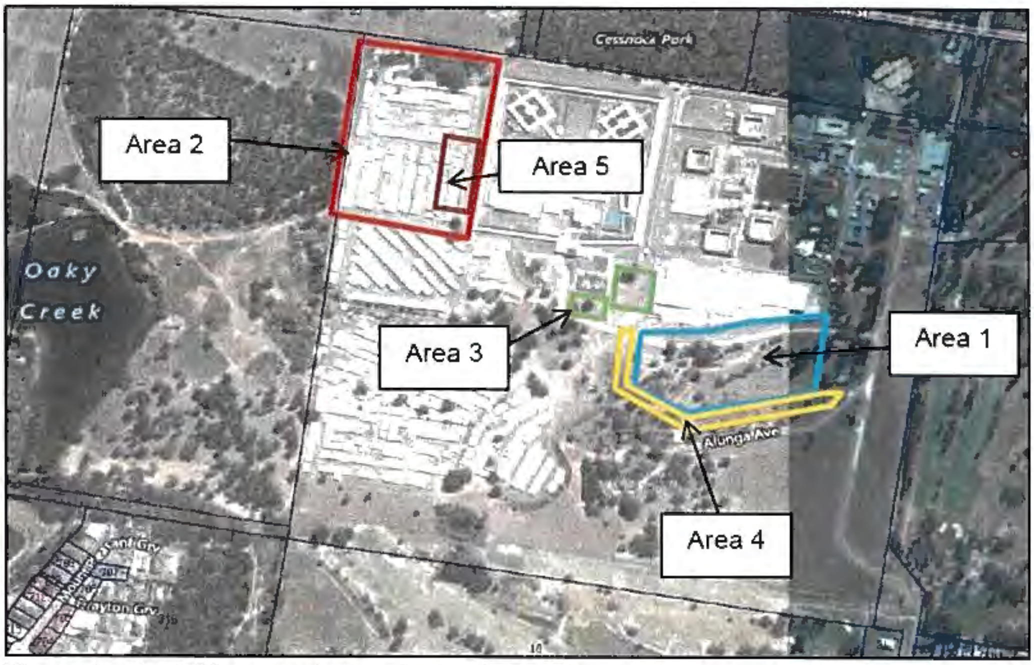


Figure 1: Aerial image of site with cadastre

A brief site description of the area for each area of development is presented in Sections 3.1 to 3.5 below.

3.1 Area 1 – 280 Bed Minimum Security

The proposed 280 bed minimum security unit will be constructed south of the existing correctional facility between the existing Industries Building to the north and existing residential housing on Alunga Avenue, as shown in Figure 2 and Figure 3.

The area is typically grass covered with scattered trees. An existing concrete access road passes in an east/west direction through the northern portion of the proposed development site.

The site slopes generally fall to the south-east at about 3° - 5°. Several water diversion bunds extending to the east and west have been constructed perpendicular to the site slope.

Figure 2: Area 1 - Facing north towards existing Industries Buildings

Figure 3: Area 1 – Facing south-west towards residential housing on Alunga Avenue

3.2 Area 2 – 320 Bed Maximum Security

The proposed 320 bed maximum security unit will be constructed to the west of the existing correctional facility, as shown in Figure 4. This area is bounded by the existing maximum security unit to the east, a cluster of demountable buildings to the south and security fencing to the north and west with bushland beyond. The site slopes fall to the north and west at about 3 - 5°.

At the time of the investigation, the site mostly exposed soil filling at the surface with occasional grassy patches. A number of near-level terraces are present across the area which appear to have been formed to allow placement of the previously stored demountable buildings (refer Figure 5). The previously stored demountable buildings are shown on Drawing 1 in Appendix D, which is based on a 2010 Google Earth image of the site. Concrete and cement block footing piers and other building materials associated with the demountable buildings previously stored within this area were scattered across the site, as shown in Figure 5.

Figure 4: Area 2 – Facing north-east towards existing correctional centre

Figure 5: Area 2 – Demountable building piers and filling terraces

3.3 Area 3 – Staff amenities building, admin building and car park

The proposed staff amenities and car park will be constructed immediately south of the existing maximum security entrance, adjacent to the existing staff and visitor car park areas (refer Figure 6). The area was generally grassed areas with some scattered trees. The existing car parking areas were asphalt sealed with a combination of asphalt and concrete access roads.

Figure 6: Area 3 – Facing west towards existing visitor car park

An outcrop of rock, comprising weathered siltstone and sandstone, was present toward the south-eastern extent of Area 3 (refer Figure 7).

Figure 7: Area 3 – Rock outcrop towards south-east boundary of Area 3

The site slopes typically fall at about 3° to the east in the grassed areas and approximately 1° to the east in car park areas. The surface slopes increase to between 10° to 20° along the northern and eastern boundaries of the area (refer Figure 8).

Figure 8: Area 3 – Facing north along eastern perimeter of Area 3 with increased site slopes

3.4 Area 4 – Access road

Details on the exact alignment of the road have not been provided to DP at the time of preparing this report. It has been assumed that the road will connect the intersection of Alunga Avenue and the main access road to the proposed car parking area. It is likely, therefore that the road will pass to the south of the new minimum security unit and then continue north along the western boundary of the minimum security unit.

This possible alignment passes through areas typically grassed with scattered trees (refer Figure 3).

3.5 Area 5 – Max industries building

The max industries building will lie close to the eastern boundary of Area 2, within an area which contains surficial filling, predominantly gravelly or sandy clay associated with the near-level terraces which are present through Area 1.

4. Regional Geology

Reference to the Newcastle Coalfield Regional Geology 1:100 000 Sheet indicated that the site is underlain by the Farley Formation within the Dalwood Group. The Farley Formation typically comprises silty sandstone with siltstone, mudstone, shale, conglomerate and basalt also present.

5. Field Work Methods

The field work for the current geotechnical investigation was undertaken during the period from 25 May 2016 to 27 May 2016. The test locations were set out by a geotechnical engineer from DP in consultation with the client. The engineer also logged the subsurface conditions encountered and collected samples for identification and laboratory testing purposes.

A total of fourteen (14) bore were drilled using a 4WD-mounted rotary drilling rig to depths ranging from 0.4 m to 6 m. Standard penetration tests (SPTs) were performed at selected depths and locations. NMLC coring of the bedrock was undertaken in four of the bores. Dynamic Cone Penetrometer (DCP) testing was undertaken at all borehole locations.

The approximate test locations are shown on Drawing 1 in Appendix D.

The MGA coordinates were recorded at each bore location using a hand held GPS unit which is normally accurate to within about ±5 m depending on satellite coverage. The approximate coordinates of the bore locations are shown on the individual borehole logs in Appendix B. Approximate surface levels at bore locations provided on the logs were interpolated from topographic imagery, and are therefore indicative only.

A summary of the field investigations is shown in Table 1, together with relevant investigation locations from previous investigation undertaken by DP.

Table 1: Summary of Field Investigations

Test Location	Development Area	Type of Drilling	Investigation Depth (m)
301	Area 2 - 280 Bed Minimum Security	150mm V-bit auger	1.9
302		150mm V-bit auger	1.95
303		150mm V-bit auger	2.15
304		150mm V-bit auger	1.8
305		150mm V-bit auger / NMLC	3.0 / 6.0
315		100mm V-bit auger / NMLC	1.0 / 4.0
306	Area 1 - 320 Bed Maximum Security	150mm V-bit auger / NMLC	1.0 / 6.0
307		150mm V-bit auger / NMLC	2.5 / 6.0
308	Area 3 - Staff amenities building, admin building and car park	150mm V-bit auger	1.7
309		300mm auger	0.4
310		150mm V-bit auger	1.0
311		150mm V-bit auger	1.2
312		150mm V-bit auger	1.1
313		300mm auger	1.25
314		150mm V-bit auger	1.6

6. Field Work Results

The subsurface conditions encountered in the bores are presented in detail in the borehole logs in Appendix B. Relevant boreholes from previous investigations are also provided in Appendix B. These should be read in conjunction with the accompanying notes in Appendix A which explain the descriptive terms and classification methods used in the logs. Photos of the recovered core are provided on Plates 1 to 3 in Appendix B.

The site stratigraphy can be divided into the following units, as summarised in below in Table 2.

Table 2: Summary of Site Stratigraphy

Geotechnical Unit	Stratum	Description
1	Filling or Topsoil	Organic clayey silt / silty clay/ silty sand topsoil or clay filling
2	Silty Clay / Sandy Clay / Gravelly Clay / Clay	Very stiff to hard
3.1	Weathered bedrock	Initially extremely low strength sandstone or claystone becoming very low strength
3.2	Bedrock	Medium strength and occasionally high strength

No free groundwater was observed in the bores during the time they remained open. It should be noted that groundwater conditions are transient and depend on climatic conditions and soil / rock permeability.

Table 3, below, provides a summary of the subsurface conditions encountered in the bores. The relevant results from previous investigations have been included.

Table 3: Summary of Test Locations and Site Stratigraphy

Test Location	Depth to Base of Unit (m)				Investigation Depth (m)
	Unit 1	Unit 2	Unit 3.1	Unit 3.2	
Area 2 - 280 Bed Minimum Security					
301	0.6	0.82	1.9(3)	-	1.9
302	0.1	0.78	1.95(3)	-	1.95
303	0.1	1.46	2.15(3)	-	2.15
304	0.1	1.6	1.8(3)	-	1.8
305	0.05	0.6	3.01	>6.0	6.0
315	-	1.0(1)	2.62	>4.0	4.0
Area 1– 320 bed maximum security					
214(2)	0.1	1.1	1.3(3)	-	1.3
217(2)	0.2	0.8	0.9(3)	-	0.9
218(2)	0.3	1.0	1.45(3)	-	1.45
219(2)	0.15	1.8	1.9(3)	-	1.9
220(2)	0.4	1.5	-	-	1.5
221(2)	0.12	1.0	1.5(3)	-	1.5
223(2)	0.1	1.9	2.2(3)	-	2.2
306	-	0.8	2.8	>6.0	6.0
307	0.5	2.5	2.65	>6.0	6.0
Area 3 – Staff amenities building, admin building and car park					
308	0.4	1.2	1.7(3)	-	1.7
309	0.15	0.25	0.4(3)	-	0.25
310	0.25	1.0	-	-	1.0
311	0.4	1.0	1.2(3)	-	1.2
312	0.25	0.9	1.1(3)	-	1.1
313	0.15	1.15	1.25(3)	-	1.25
314	0.35	1.4	1.6(3)	-	1.6
Area 4 – 250 m access road connecting Alunga Ave to the proposed car park					
221(2)	0.12	1.0	1.5(3)	-	1.5
223(2)	0.1	1.9	2.2(3)	-	2.2

Notes to Table 3:

1. Core loss from 1.0 m to 1.58 m
2. 100 and 200 series bores are from previous DP report on Geotechnical Investigation, Proposed Upgrade of Cessnock Correctional Facility, Project 39632-1, February 2007 (Ref 1)
3. Inferred base of unit from auger refusal

7. Laboratory Testing

7.1 Geotechnical Testing

Two bulk samples of the subgrade retrieved from the bores were submitted to the laboratory for measurement of California bearing ratio (CBR), including Standard Compaction and Field Moisture Content. Three samples of cohesive soils were also submitted for shrink-swell or Atterberg limits determination.

Each CBR sample was compacted to approximately 100% Standard dry density ratio at the estimated optimum moisture content and then soaked for four days under a surcharge loading of 4.5 kg prior to testing. Detailed results of laboratory testing are provided in Appendix C and summarised in Table 4 and Table 5.

Table 4: Summary of California Bearing Ratio Testing and Moisture Content Determinations

Bore	Depth (m)	Description	FMC (%)	MDD (t/m^3)	OMC (%)	CBR (%)	Swell During Soaking (%)
Present Investigation							
310	0.25 – 0.60	Orange brown CLAY	18.2	1.62	22.5	2.5	2.7
313	0.15 – 0.45	Red brown CLAY	15.7	1.71	19.5	2.0	3.4
Previous DP Investigation 1999							
208	0.25 – 0.3	Light grey mottled orange SILTY CLAY	7.8	1.95	11.5	20	NR
211	0.3 – 0.7	Brown mottled orange GRAVELLY CLAY	14.0	1.84	11.5	1.5	NR
212	0.5 – 0.7	Light grey mottled orange SANDY CLAY	9.6	1.89	11.0	5	NR
214	0.6 – 0.7	Light grey mottled orange SILTY CLAY	18.8	1.73	20.0	1.5	NR

Notes to Table 4

FMC = Field moisture content

MDD = Maximum dry density

OMC = Optimum moisture content

CBR = California bearing ratio

NR = Not recorded

Table 5: Summary of Atterberg Limit Determination and Shrink Swell Testing

Bore	Depth (m)		Description	FMC (%)	LL (%)	PL (%)	PI (%)	LS (%)	Iss (% per ΔpF)	Swell During Soaking (%)
	From	To								
304	0.50	0.70	Brown CLAY with trace gravel	16.0	-	-	-	-	1.8	-
314	0.35	0.55	Red brown CLAY with trace gravel	15.6	-	-	-	-	1.8	-
307	0.50	0.95	Brown red GRAVELLY CLAY	-	31	12	19	8.5	-	-
Relevant Results from Previous Investigations										
223	0.50	0.80	Mottled orange brown SILTY CLAY	21.8	-	-	-	-	2.6	3.6
210	0.5	-	Red brown SILTY CLAY	11.3	40	16	26	-	-	-
211	1.0	1.45	Brown mottled red CLAY	11.4	39	14	25	-	-	-
203	0.50	0.80	Brown red SILTY CLAY	11.7	44	18	26	12.5	-	-

Notes to Table 5:

FMC - Field moisture content	LL - Liquid Limit
PL - Plastic Limit	PI - Plasticity Index
LS = Linear Shrinkage from liquid limit condition (Mould length 250 mm)	
MDD - Maximum dry density	OMC - Optimum moisture content
CBR - California bearing ratio	- Not tested

7.2 Asbestos Testing

Testing for the presence of asbestos in soil was undertaken on eight surface samples. Laboratory testing for the soil assessment was undertaken by Envirolab Services, a National Association of Testing Authorities Australia (NATA) registered laboratory. Analytical Methods used are shown on the laboratory sheets in Appendix C.

Detailed results are provided in Appendix C and summarised in Table 6.

Table 6: Results of Asbestos in Soil Testing

Bore	Depth (m)	Description	Result
301	Surface	Clay filling	No asbestos detected
302		Clay filling	No asbestos detected
303		Brown clay topsoil	No asbestos detected
306		Brown silty clay	No asbestos detected
307		Brown silty sand filling	No asbestos detected
308		Brown silty gravel filling	No asbestos detected
309		Brown silty sand filling	No asbestos detected
310		Brown silty sand filling	No asbestos detected

8. Proposed Development

The project is in the concept stage of design and hence only limited information has been provided in relation to the proposed development. Based on discussion with the client, the following is understood:

- Excavation of up to 5 m may be required in Area 2 (Maximum Security Unit);
- Placement of filling within Area 1 (Minimum Security Unit) to create a level platform; and
- The pavements are likely to be concrete.

No information in relation to design traffic loading for the pavements, the exact alignment of the proposed access pavement or footing loads for the proposed structures have been provided.

9. Comments

9.1 Excavation

Based on preliminary information provided by the client, it is understood that excavation of up to 5 m may be required in Area 2. Elsewhere, excavation is anticipated to be less than 2 m.

Based on the results of the bores, filling, clay and extremely weathered rock were encountered within the depth of investigation. Auger refusal was encountered at depths ranging between 0.4 m and 3.0 m. Based on the auger refusal and point load index testing of the recovered core (where taken), the underlying bedrock increases in strength to medium and high strength. Point load index values (I_{s5}) in excess of 1 were recorded, which is indicative of high strength bedrock.

The majority of the filling and clays, together with the extremely low to very low strength rock are expected to be readily excavated using conventional equipment such as hydraulic excavators with light ripping to aid pick-up although with a lower rate of production in the stronger materials, as encountered at depths ranging from 1.8 m to 3 m in the bores undertaken within Area 2.

Excavation of the medium to high strength bedrock is expected to require medium to heavy earthmoving equipment, such as Caterpillar D8 to D9 bulldozer or similar is expected for ripping.

The use of pneumatic or hydraulic hammers on excavators for rock excavation may be required for detailed excavation, such as trimming batters, service trenches and footings.

9.2 Excavation Batters

Excavation depths may be up to 5 m in Area 2 although the location of the excavations is not known. Based on the conditions encountered in the bores, it is expected that it would be practicable to allow for battering of excavations at some locations. Ongoing inspection of the excavation face during construction will be necessary to assess the continuity and degree of fracturing of the bedrock, although the batter slopes outlined in Table 7 below are suggested for preliminary design purposes.

Table 7: Suggested Preliminary Safe Batter Slopes

Material	Safe Batter Slope (H:V)	
	Short Term Temporary	Long Term Permanent
Filling and clay	1.5:1	2:1
Extremely low and very low strength rock	0.75:1	1:1
Low strength or stronger rock	0.25:1*	0.5:1*

Note to Table 7:

* - subject to further investigation and detailed inspection by an engineering geologist during construction

Adoption of the batter slopes for low or stronger rock shown in Table 7 must be accompanied by geological inspection to assess any adverse jointing which could give rise to localised instability such as block fallout or wedge failure. The support of these locally unstable blocks and wedges, or extremely low and very low strength bands, can then be provided (if needed) by in-situ stabilisation techniques utilising dowelled mesh, rock bolts and sprayed concrete.

If excavation faces are protected from weathering by overhead construction and sprayed concrete facing, the short term temporary safe batter slopes shown in Table 7 may be incorporated into the permanent excavation construction, as long as unstable blocks are pinned or anchored to the slope.

9.3 Retaining Wall Parameters

It is understood that retaining walls may be required at the site, although the location of such walls is not known at this stage.

Retaining walls designed to support buildings or floor slabs (i.e. not free to move at the top of the wall) should be designed for 'at rest' earth pressures.

It is suggested that walls be designed for natural clay or compacted clay geotechnical parameters as shown in Table 8, assuming a level surface behind the wall.

Table 8: Recommended retaining wall parameters

Stratum	Bulk Density γ (kN/m^3)	K_a
Filling and clay	20	0.35
Extremely low and very low strength sandstone	18	0.3
Low and medium strength sandstone	22	0.2

Notes to Table 8.

K_a = coefficient of active earth pressure

Additional pressures should be allowed for where surcharging of the wall system results from the proximity of the proposed structure itself near changes in excavation level, to reduce the risk of damage occurring to these structures. To increase the wall stiffness and thereby reduce lateral (inward) wall deflection, the active earth pressure coefficients shown in Table 8 should be increased by 50% to represent the "at rest" condition. Further, allowance should be made in the wall design for estimated footing loads.

The parameters given above are based on the provision of full drainage behind the retaining walls, such as 10 mm to 20 mm aggregate protected by a filter geofabric, and a slotted pipe connected to the site stormwater disposal system. The slotted pipe should contain an access point for routine maintenance flushing.

9.4 Excavation Vibration

It would be prudent to allow for dilapidation surveys to be carried out on any nearby buildings and existing services to document their condition prior to the commencement of all work in order to respond to any spurious claims for damage arising from construction activities.

It is expected that the rock encountered in the bores should break readily along natural partings and joint, such as encountered in the recovered core at 0.05 m – 0.50 m spacings. However, the presence of high strength bedrock may require the use of heavy equipment, rock breaking tools and pneumatic equipment which has the potential to affect structures adjoining the proposed excavation.

As a guide, the damage threshold due to vibration is dependent on the quality of the building foundations and construction of the building as well as the wavelength of the vibration and the source distance. The longer the wavelength, the more likely a building is to resonate and suffer damage. For construction equipment (generally in the high frequency or short wavelength range), the damage threshold is 40 mm/sec to 50 mm/sec for buildings founded on rock. Most vibration codes set safe limits for building vibrations at lower levels.

The Standards Australia explosives code recommends the maximum peak particle velocities for various structures subjected to blasting vibration (generally a low frequency vibration) as set out in Table 9 below.

Table 9: Recommended Maximum Peak Particle Velocity (from AS 2187.2 – 1993)

Type of Building or Structure	Peak Particle Velocity (v_p) (mm/sec)
Houses and low-rise residential buildings: commercial buildings not included below	10
Commercial and industrial buildings or structures of reinforced concrete or steel construction	25

Notes to Table 9

1. In a specific instance, where substantiated by careful investigation, a value of peak particle velocity other than that recommended in the Table 9 may be used.
2. The peak particle velocities in the Table 9 have been selected taking into consideration both human discomfort and structural integrity together with the effect on sensitive equipment located within buildings.

For buildings around this site it is suggested that 10 mm/sec be adopted as peak particle velocity.

It should be noted that humans are very sensitive to vibration and consequently may be disturbed by vibration levels which are considered relatively insignificant for buildings. It may therefore be beneficial to carry out vibration monitoring to confirm vibration levels during site works.

9.5 Re-Use of Cut Material

It is understood that the material cut from the site might be used as filling beneath the building areas to regrade the site where necessary. It is considered that the soil material removed would be suitable for re-use as filling provided that the compaction requirements and material specifications, detailed above in Section 9.6, are satisfied, and that the substantial characteristic surface movements associated with the use of reactive clay filling, as discussed below in Section 9.7.1, are considered.

It should be noted, however, that excavation preparation by ripping may result in large pieces of rock which may not be suitable for reuse as filling, unless the oversize material can be selectively removed or broken down using heavy pad foot rollers. Alternatively, it may be preferable to use pneumatic or hydraulic hammers on excavators for rock excavation; this method, although slower, may result in smaller pieces of rock better suited for re-use as engineered fill. This method may also be required for detailed excavation, i.e. trimming batters, service trenches or high level footings.

9.6 Site Preparation

Preparation of areas to receive controlled filling should include clearance of vegetation and surface organic matter followed by excavation of all topsoil and filling. The topsoil could be stockpiled for possible re-use for landscaping purposes. It may be suitable for the existing filling to remain in place if the buildings are to be supported by piles founded in the underlying bedrock and appropriate consideration has been given to possible swell pressures on the underside of floor slabs.

Following stripping of topsoil and existing fill materials, the exposed surface in fill areas should be proof rolled using a minimum 8 tonne roller to identify any 'soft' spots. Any such 'soft' spots should be either tyned, dried and uniformly re-compacted or excavated and replaced with compacted select filling.

Filling to be placed on site to achieve design levels should be placed in near–horizontal layers not exceeding 300 mm loose thickness. Any filling placed beneath building floor slab or for footing support should be compacted to a dry density ratio of at least 98% Standard at a moisture content within the range OMC ±2% under Level 1 inspection and testing, as defined in AS 3798-2007 (Ref 3).

The maximum particle size of the filling material should not exceed two – thirds of the compacted layer thickness, i.e. rock fragments not greater than 200 mm. Trafficability across the site is expected to be reasonable for conventional rubber tyred and compaction plant except during and after periods of 'wet' weather.

9.7 Foundations

9.7.1 Site Classification

Site classification of foundation soil reactivity provides an indication of the propensity of the ground to move under seasonal variation in moisture. Characteristic surface movements (y_s) were estimated based on the typical profiles revealed in the bores, the procedures presented in AS 2870-2011 (Ref 3) and the results of the laboratory testing. Whilst the procedures outlined in AS 2870-2011 apply to residential construction the principles of design, construction and maintenance should be taken into consideration for development of the site.

Some interpolation between data points was required. In the event that conditions encountered during construction are different to those presented in this report, it is recommenced that advice be obtained from this office.

The development areas within the site have been classified as Class M (Moderately reactive) with an estimated y_s up 35 mm.

It should be noted that filling of up to 0.6 m was encountered in the bores located in Area 2 and deeper filling (possibly up to about 1.2 m) may be associated with the near-level terraces in this area. Consequently, this area has been classified as Class P in accordance with the procedures of AS2870.

Please note that the standard footing designs presented in AS 2870-2011 make no allowance for changes in soil suction, and hence shrink-swell movement, caused by trees / gardens located neither near the building area nor for the effects of tree removal prior to construction. The latter can result in appreciable swelling movements as the clay soil trends to a new equilibrium moisture condition following tree removal. Free surface movements in the areas affected by trees could be greater than those indicated.

The structures should be designed to accommodate the reactive clay movements. This would include articulation in the structure in accordance with TN61 (Ref 6).

It should be noted that site classification is dependent on proper site maintenance particularly with respect to drainage and vegetation, which should be carried out in accordance with the attached CSIRO BFT 18," Guide to Home Owners on Foundation Maintenance and Footing Performance".

If filling is used beneath building areas or if the existing fill is re-compacted, the placement of engineered clay filling (i.e. cut to fill) can result in a more severe classification of the site. The use of ripped bedrock or low permeability, low plasticity granular material (i.e. quarry overburden) could be used to maintain the site classification provided compaction requirements are satisfied.

9.7.2 Footings

Pad or strip footings founded on either the very stiff or stronger clay or the underlying weathered bedrock may be suitable for support of the structural loads. Footings could also be supported within controlled filling provided the filling has been placed and compacted in accordance with the procedures detailed in AS3798 -2007 for Level 1 inspection and testing.

For design of shallow footings founded at 0.5 m depth, the following maximum allowable bearing pressures in Table 10 are recommended, which are based on the results of laboratory and in situ testing:

Table 10: Recommended Allowable Bearing Pressures for Shallow Footings

Bearing Stratum	Maximum Allowable Bearing Pressure (kPa)
Medium strength or stronger bedrock	2500[(1)]
Extremely low to low strength bedrock	600
Very stiff or hard clay	150
Compacted engineered controlled filling	150

Notes to Table 10:

[1] Use of these allowable bearing pressures for medium strength bedrock would require inspection of all footing excavations by a geotechnical engineer to confirm suitable strata is exposed

Settlements will depend on the size, location, and load on the footing and on the bearing stratum, however for footings of less than 2 m by 2 m subject to the loading conditions outlined above, settlements are anticipated to be less than 15 mm. This estimate of settlements does not take into account movements associated with reactive clay soils.

Alternatively, the use of bored piles founded within the weathered bedrock could be considered to support the proposed structures. Such footings should be designed for a maximum end bearing pressures outlined in

Table 11: Recommended Allowable End Bearing Pressures for Bored Piles

Bearing Stratum	Maximum Allowable Bearing Pressure (kPa)
Medium strength or stronger bedrock	2500[(1)]
Extremely low to low strength bedrock	600

Notes to Table 11

(1) Use of these allowable bearing pressures for medium strength bedrock would require inspection of all footing excavations by a geotechnical engineer to confirm suitable strata is exposed

For bored piles designed for the above parameters, the total settlement would be of the order of 1% to 2% of the pile diameter.

9.8 Pavements

9.8.1 Design Traffic

It is understood that the proposed development includes the construction of new car parking areas (Area 3) and a new access road (Area 4). The following sections provide comments on subgrade conditions, subgrade preparation, pavement thickness design, material quality and compaction requirements. It is understood rigid (concrete) pavements are proposed for the site. Design information has also been provided for flexible pavements should they be considered further.

No design traffic loading has been provided for the proposed pavements. In absence of such information the traffic loadings outlined in Table 12 have been assumed:

Table 12: Design Traffic Loading

Pavement	Construction Type	
	Flexible	Rigid (Concrete)
Access Road	2×10^4 ESA	6×10^4 HVAG
Car Park	1×10^3 ESA	3.3×10^3 HVAG

A value of approximately 0.3 ESA (equivalent standard axles) per HVAG (heavy vehicle axle group) has been used in the above traffic loadings.

In the event that a different traffic loading is applicable, the pavement thickness designs presented in the following sections should be revised.

9.8.2 Anticipated Subgrade Conditions

The expected subgrade conditions for the internal pavements generally comprise silty clay or clay, and perhaps extremely low to very low strength rock in areas of cut.

Results of the laboratory testing on the clay subgrade indicate a soaked CBR of 2% to 3%. Testing undertaken during a previous investigation (Project 39632) included five CBR tests on samples of the natural clay and returned 4 day soaked CBR results ranging from 3% to 5%.

The samples tested during the present investigation recorded swells during the soaking phase of 2.7% and 3.4%, which indicates a high propensity for expansion. In addition, testing of the clay indicated the material was susceptible to soften upon inundation or exposure to moisture, hence care should be taken to protect excavations / subgrades from inclement weather or prolonged exposure to the elements.

Based on the above, a design CBR of 2% was adopted for the pavement thickness design for the internal pavements, provided adequate subsoil drains are included in the design of the pavement, as detailed below.

Depending on the final site regrading some pavement areas may expose bedrock at subgrade level. Similarly, in areas of fill, it may be possible to place ripped sandstone in the zone immediately below pavements. In these instances, it may be possible to construct a thinner pavement that outlined in the following sections. It is recommended that once the site regrading details are known, the pavement thickness designs are revised.

9.8.3 Pavement Thickness Design - Internal Pavements

The following pavement thickness designs have been carried out in accordance to procedures outlined in "A Guide to Pavement Technology, Part 2: Pavement Structural Design", Austroads, AGPT02-12 February 2012 (Ref 5) and a 95% confidence limit.

Details on the design traffic loading have not been provided for the current assessment.

Table 13 below provides a flexible pavement thickness based on an access road used by light commercial vehicles and cars.

Table 13: Flexible Pavement Thickness Design

Pavement	Access Road	Car Park
Design Traffic (ESA)	2×10^4	1×10^3
Layer	Thickness (mm)	
Wearing course	2 coat flush seal or 30 mm asphalt	2 coat flush seal or 30 mm asphalt
Base course	100	100
Subbase	320	220
TOTAL	**420 plus wearing course**	**320 plus wearing course**

Notes to Table 13:

Where asphalt is to be used as a wearing course, a 7 mm prime seal should first be laid. Where asphalt is used the thickness of the asphalt may be deducted from the subbase.

Table 14 below provides a rigid pavement thickness based on an access road used by light commercial vehicles and cars and is based on the procedures given in AUSTROADS 2012 (Ref 5), and subgrade preparation in accordance with Section 9.8.5. The design is also based on a load safety factor (LSF) of 1.05 which relates to a project design reliability of 80%.

Table 14: Rigid Pavement Thickness Design

Pavement	Access Road	Car Park
Design Traffic (HVAG)	6×10^4	3.3×10^3
Layer	Thickness (mm)	
Concrete Base	160	140
Bound Sub base	100	100
TOTAL	**260**	**240**

Placement and compaction of a thicker subbase layer may be required to assist with pavement construction.

The base should comprise 40 MPa concrete and include SL 62 (car park) or SL 82 (access road) reinforcing mesh. Detailing of the joints would need to be done by others. Subbase material should comprise DGS20 (20 mm sized dense graded subbase) gravel or better, bound with 3-5% cementitious material.

Adequate surface and subsurface drainage should be provided and maintained to protect the pavements from excessive soaking, otherwise the pavements may be prone to severe damage when trafficked.

The select subgrade is dependent on the prevailing moisture condition of the clay subgrade at the time of construction and this should be assessed by geotechnical inspection once the subgrade is exposed.

9.8.4 Material Quality and Compaction Requirements

Table 15, below, presents the material quality and compaction requirements for the respective pavement layers within the flexible pavement.

Table 15: Material Quality and Compaction Requirements – Flexible Pavement

Pavement Layer	Material Quality	Compaction
Basecourse	CBR > 80%, PI ≤ 6%, Material quality to meet Ref 7	Minimum 95% Modified Compaction (AS 1289 5.2.1)
Subbase	CBR > 30%, PI ≤ 12%, Material quality to meet Ref 7	Minimum 95% Modified Compaction (AS 1289 5.2.1)
Select Material (where required)	CBR > 15%, maximum particle size 150 mm	Compact to at least 100% dry density ratio Standard (AS 1289.5.2.1)
Subgrade	Minimum Soaked CBR of 2%	Compact to at least 100% dry density ratio Standard (AS 1289.5.1.1)

Table 16, below, presents the material quality and compaction requirements for the respective pavement layers within the rigid pavement.

Table 16: Material Quality and Compaction Requirements – Concrete Pavement

Layer	Material Quality	Compaction
Concrete Base	Minimum 40 MPa 28 day compressive strength	-
Subbase Course	Conform to AP – T36/06 and a minimum soaked CBR 80%	Minimum 95% Modified Compaction (AS 1289 5.2.1)
Select Filling (where required)	Minimum soaked CBR 15%	Minimum 100% Standard dry density (AS 1289.5.1.1)
Subgrade	Minimum Soaked CBR of 2%	Minimum 100% Standard dry density (AS 1289.5.1.1)

The pavement thickness designs presented above are dependent on the provision and maintenance of adequate surface and subsurface drainage.

9.8.5 Subgrade Preparation

Pavement subgrade preparation for the north-western and north-eastern development areas should be carried out in general accordance with the following methodology:

- Excavate to formation level;
- Remove any additional deleterious materials;
- Remove any areas of additional filling to expose natural material;
- Undertake geotechnical inspection of the exposed surface to assess the suitability of any existing filling to remain in place. This may require proof rolling of the exposed surface;
- Proof roll the subgrade using a smooth drum roller to assess the presence of any soft / heaving areas. If such areas are identified, the soft / wet material should be removed and replaced with select material (CBR>15%) compacted to a dry density ratio of 100% Standard;

- It should be noted that a number of existing in-ground services run through Area 3. The exact alignment, depth and protection provision of the services should be determined prior to construction of the pavement;
- Bedrock subgrades should be ripped to destroy any rock structure to a depth of 100 mm to 150 mm and then re-compacted to 100% density ratio (Standard);
- Where open jointing within the bedrock is encountered at subgrade level, additional drainage measures may be required;
- If filling is required, place approved filling in layers not exceeding 300 mm loose thickness and compact to a density ratio of at least 100% Standard;
- The moisture content of the subgrade and fill for materials other than sand and non-plastic granular materials should be within -4% (dry) to -1% (dry) of optimum moisture content (OMC); and
- Protect the area after subgrade preparation to maintain moisture contents as far as practicable. Previous experience suggests that shrinkage of clay soils may result if they are allowed to dry and then subsequently swell as they return to their equilibrium moisture content following completion of pavement construction. Therefore excessive surface drying should be avoided in pavement subgrade areas.

Geotechnical inspections and testing should be undertaken during construction in accordance with AS 3798-2007.

9.8.6 Soil Aggressivity

Previous investigations detailed in DP "Report on Geotechnical Investigation, Proposed Upgrade of Cessnock Correctional Facility, Project 39632-1, February 2007" indicated a non-aggressive exposure classification when compared to the requirements for steel/concrete piles presented in AS 2159-1995 (Ref 8).

9.9 Earthquake Classification

Using the results of the geotechnical investigation and the procedures described in AS1170.4 – 2007 (Ref 9) an earthquake hazard factor of 0.10 was estimated for the site. Ref 9 indicates a site sub-soil classification of Class C_e (shallow soil site) for evaluation of earthquake loads.

10. Recommended Additional Investigation

Further investigation will be required as conceptual design/planning progresses together with additional work during the construction phase. Specific investigation would include (but not limited to):

- Detailed geotechnical investigation, particularly in the areas of proposed excavation, to assess the strength and structure of the bedrock and assist with design of bulk earthworks and assessment of rippability;
- Detailed investigation in the area of proposed major retaining walls;
- Assessment of all material to be removed from site for appropriate classification for disposal at a licensed landfill or beneficial reuse in accordance with the NSW EPA Waste Classification guidelines (Ref 10) or appropriate EPA Resource Recovery Orders; and

- Routine inspections and earthworks monitoring during construction.

Additional assessment has also been recommended as a result of the concurrent Preliminary Site Investigation (Contamination) [Ref 1].

11. References

1. Douglas Partners Pty Ltd "Report on Preliminary Site Investigation (Contamination), Proposed Upgrade of Cessnock Correctional Centre", Project 81986 dated July 2016.
2. Douglas Partners Pty Ltd "Report on Geotechnical Investigation, Proposed Upgrade of Cessnock Correctional Facility" Prepared for Department of Commerce dated February 2007, Project 39632-1.
3. Australian Standard AS2870-2011, 'Residential Slabs and Footings', April 2011, Standards Australia.
4. Australian Standard AS3798-2007 "Guidelines on Earthworks for Commercial and Residential Developments", Standards Australia.
5. "A Guide to Pavement Technology, Part 2: Pavement Structural Design", Austroads, AGPT02-12 February 2012.
6. TN 61 "Articulated Walling", Cement & Concrete Association of Australia.
7. ARRB Special Report 41, "A Structural Design Guide for Flexible Residential Street Pavements", Australian Road Research Board, April 1989.
8. Australian Standard AS 2159-2009 "Piling - Design and Installation", Standards Australia.
9. Australian Standards AS 1170.4-2007, Structural design actions, Part 4: Earthquake actions in Australia, October 2007, Standards Australia.
10. NSW EPA, "Waste Classification Guidelines – Part 1: Classifying Waste, November 2014".

12. Limitations

Douglas Partners (DP) has prepared this report for this project at Cessnock Correctional Centre in accordance with DP's proposal NCL160276 dated 11 April 2016 and acceptance received from NBRS and Partners Pty Ltd dated 12 July 2016. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of NBRS and Partners Pty Ltd and the NSW Department of Justice for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. 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 on the site only at the specific sampling and/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 human 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 affected by undetected variations in ground conditions across the site between and beyond the sampling and/or testing 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 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 stated 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 instructions for construction.

The scope for work for this investigation/report did not include the assessment of surface or sub-surface materials or groundwater for contaminants, within or adjacent to the site. Should evidence of filling of unknown origin be noted in the report, and in particular the presence of building demolition materials, it should be recognised that there may be some risk that such filling may contain contaminants and hazardous building materials.

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. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to DP. Any such risk assessment would, however, be necessarily restricted to the geotechnical components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

Douglas Partners Pty Ltd

Appendix A

CSIRO BTF18
About This Report
Sampling Methods
Soil Descriptions
Rock Descriptions
Symbols and Abbreviations

Foundation Maintenance and Footing Performance:
A Homeowner's Guide

CSIRO
PUBLISHING
BTF 18-2011
replaces
Information
Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870-2011, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction

There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion

All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation

This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume, particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil

All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure

This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.

In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites, which may experience only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes

Note

1. Where controlled fill has been used, the site may be classified A to E according to the type of fill used.
2. Filled sites. Class P is used for sites which include soft fills, such as clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise.
3. Where deep-seated moisture changes exist on sites at depths of 3 m or greater, further classification is needed for Classes M to E (M-D, H1-D, H2-D and E-D).

Tree root growth
Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation
Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

Seasonal swelling/shrinkage in clay
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Trees can cause shrinkage and damage

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots
In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself
Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures
Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention. However, there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures

Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation causes a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures

Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem. Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870-2011.

AS 2870-2011 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing

Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage

In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

Protection of the building perimeter

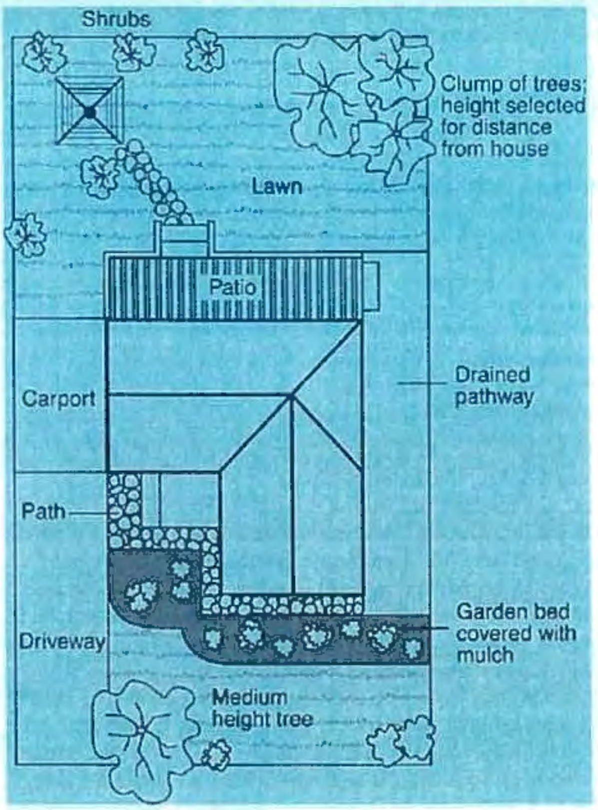
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving should

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly.	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired.	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted.	15–25 mm but also depends on number of cracks	4

Gardens for a reactive site



extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

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About this Report

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.

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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.

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 geotechnicel 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.

Sampling Methods

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

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.

Soil Descriptions

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 Descriptions

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 loner 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

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

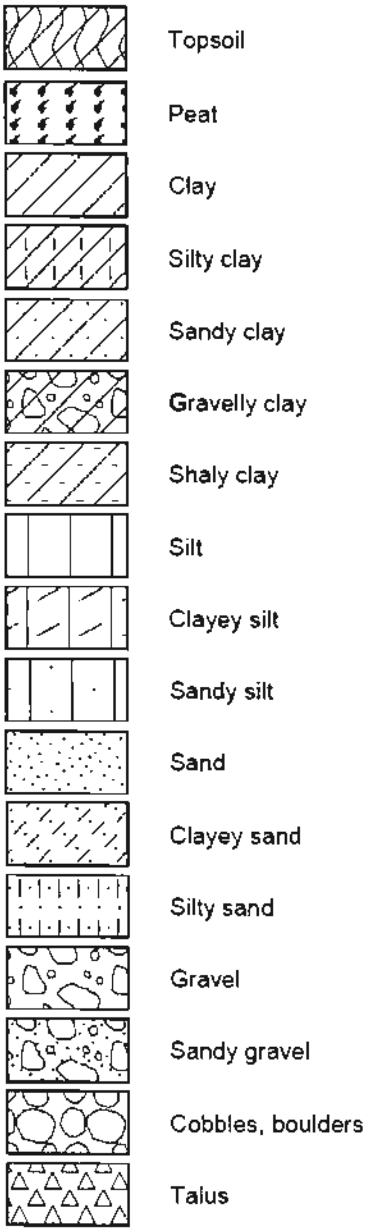
fg	fragmented
bnd	band
qtz	quartz

Symbols & Abbreviations

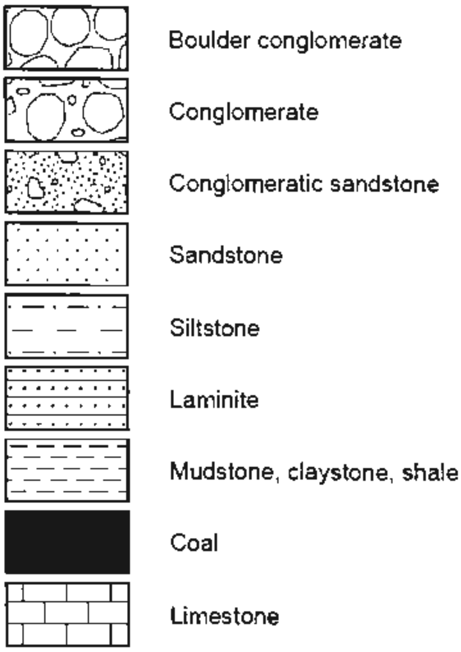
Graphic Symbols for Soil and Rock

General

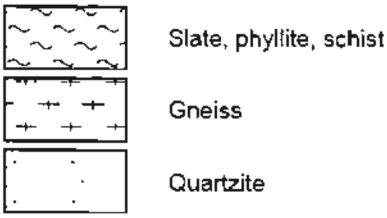
Soils



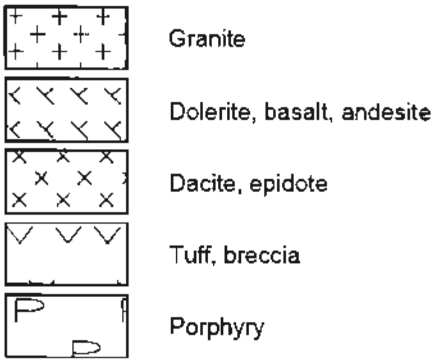
Sedimentary Rocks



Metamorphic Rocks



Igneous Rocks



Appendix B

Borehole Logs (present and relevant past investigations)
Photoplates 1 to 3
Results of Dynamic Penetrometer Testing

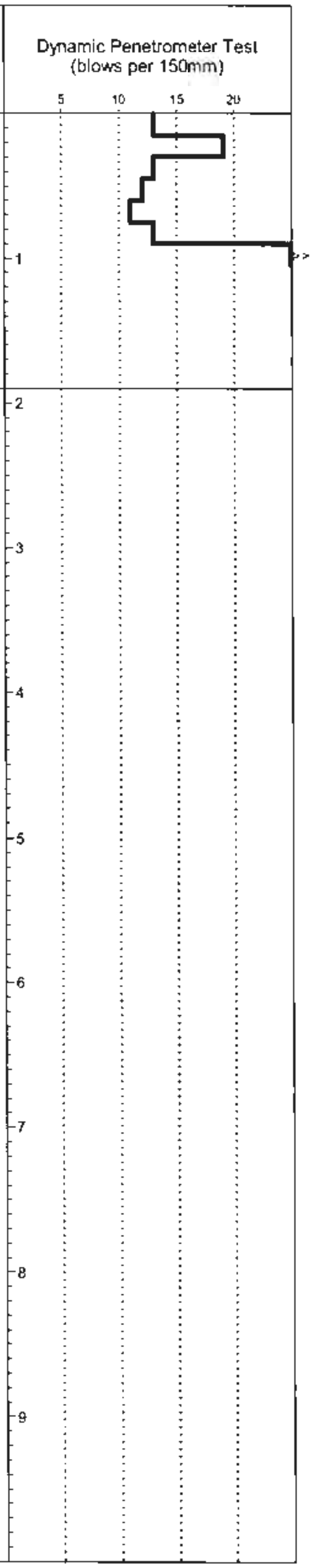
BOREHOLE LOG

CLIENT: NBRS & Partners Pty Ltd
PROJECT: Redevelopment of Correctional Facility
LOCATION: Lindsay Street, Cessnock

SURFACE LEVEL: RL106m AHD*
EASTING: 344068
NORTHING: 6367749
DIP/AZIMUTH: 90°/--

BORE No: 301
PROJECT No: 81986.00
DATE: 25/5/2016
SHEET 1 **OF** 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		TOPSOIL / FILLING - Generally comprising brown clay filling, trace silt and trace rootlets, M<<Wp		A	0.0 0.1			
	0.6	CLAY - Very stiff to hard, red-brown clay, with trace fine to medium grained sand, M<<Wp		S	0.5 0.6 0.82 0.95		pp >600 8,14,14 N = 28	
	0.82	SANDSTONE - Extremely low strength, extremely weathered, red, medium to coarse grained sandstone From 1.5m, yellow with occassional ironstaining		S	1.5 1.64		25/140,-,- refusal double bounce	
	1.9	Bore discontinued at 1.9m, limit of investigation, v-bit refusal						



RIG: FG102, 4WD Rig **DRILLER:** FICO **LOGGED:** Goodall **CASING:** Uncased

TYPE OF BORING: 150mm v-bit auger

WATER OBSERVATIONS: No free groundwater observed

REMARKS: * Surface level interpolated from 2m digital contour mapping and are approximate only

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

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
Geotechnics / Environment / Groundwater

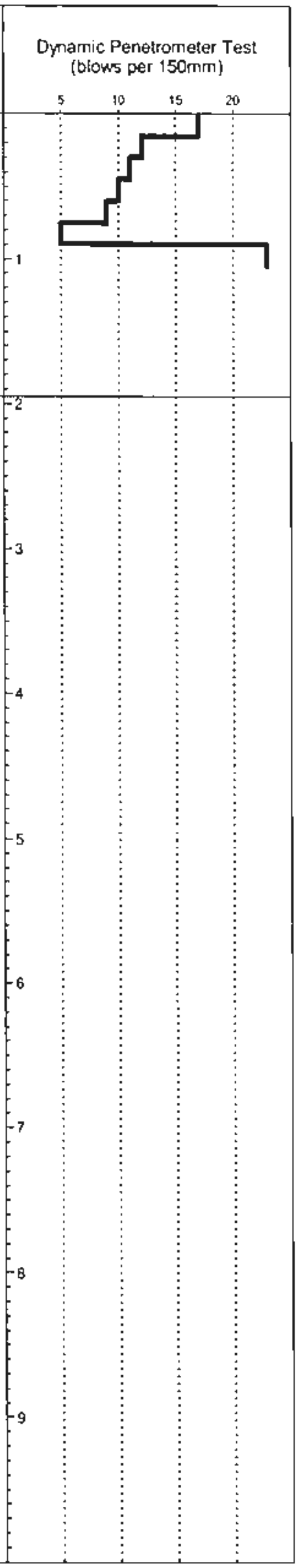
BOREHOLE LOG

CLIENT: NBRS & Partners Pty Ltd
PROJECT: Redevelopment of Correctional Facility
LOCATION: Lindsay Street, Cessnock

SURFACE LEVEL: RL102m AHD*
EASTING: 344013
NORTHING: 6367759
DIP/AZIMUTH: 90°/--

BORE No: 302
PROJECT No: 81986.00
DATE: 25/5/2016
SHEET 1 **OF** 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
	0.1	FILLING - Generally comprising brown-red clay filling, trace silt and trace rootlets, M<Wp		E A	0.0 0.08 0.1			
		CLAY - Hard, red-brown clay, trace fine to medium grained sand, M<Wp		S	0.5		pp >600 6,10,21/110 refusal	
	0.78	SANDSTONE - Extremely low strength, extremely weathered, yellow, fine grained sandstone From 1.0m, brown-red			0.91			
		From 1.5m, grey with occassional ironstaining		S	1.5		6,9,18 N = 27	
	1.95	Bore discontinued at 1.95m, limit of investigation, v-bit refusal			1.95			



RIG: FG102, 4WD Rig **DRILLER:** FICO **LOGGED:** Goodall **CASING:** Uncased

TYPE OF BORING: 150mm v-bit auger

WATER OBSERVATIONS: No free groundwater observed

REMARKS: * Surface level interpolated from 2m digital contour mapping and are approximate only

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SAMPLING & IN SITU TESTING LEGEND

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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
Geotechnics | Environment | Groundwater

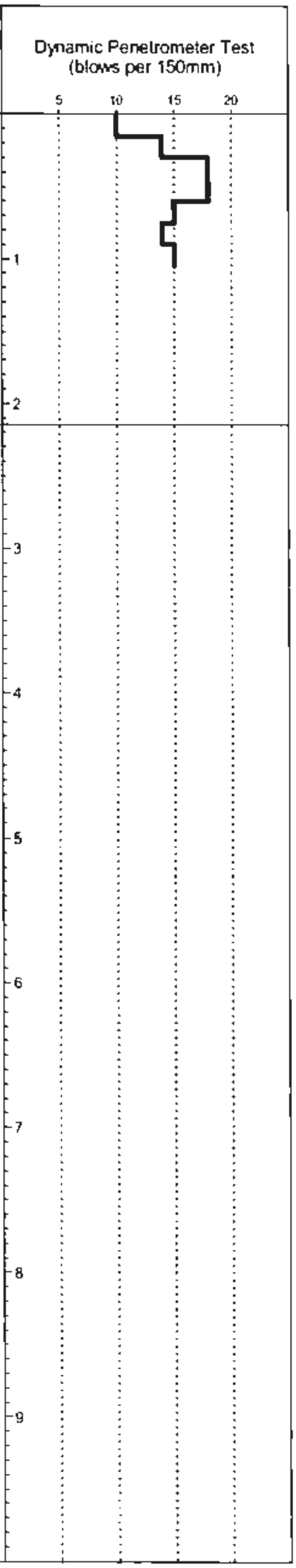
BOREHOLE LOG

CLIENT: NBRS & Partners Pty Ltd
PROJECT: Redevelopment of Correctional Facility
LOCATION: Lindsay Street, Cessnock

SURFACE LEVEL: RL98m AHD*
EASTING: 344044
NORTHING: 6367916
DIP/AZIMUTH: 90°/--

BORE No: 303
PROJECT No: 81986.00
DATE: 25/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water
				Type	Depth	Sample	Results & Comments	
	0.1	TOPSOIL / FILLING - Generally comprising brown clay filling, trace silt and trace rootlets, M<<Wp		A	0.0 0.1			
	1.46	SANDY CLAY - Very stiff to hard, brown mottled red-orange sandy clay, trace subrounded gravel up to 5mm in size, M<<Wp		S	0.5 0.95		pp >600 9,12,16 N = 28	
	2.15	SANDSTONE - Extremely low strength, extremely weathered, grey, fine grained sandstone with occasional ironstaining		S	1.5 1.94		8,17,25/140 refusal	
		Bore discontinued at 2.15m, limit of investigation, v-bit refusal						



RIG: FG102, 4WD Rig **DRILLER:** FICO **LOGGED:** Goodall **CASING:** Uncased

TYPE OF BORING: 150mm v-bit auger

WATER OBSERVATIONS: No free groundwater observed

REMARKS: * Surface level interpolated from 2m digital contour mapping and are approximate only

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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(O)	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
Geotechnics / Environment / Groundwater

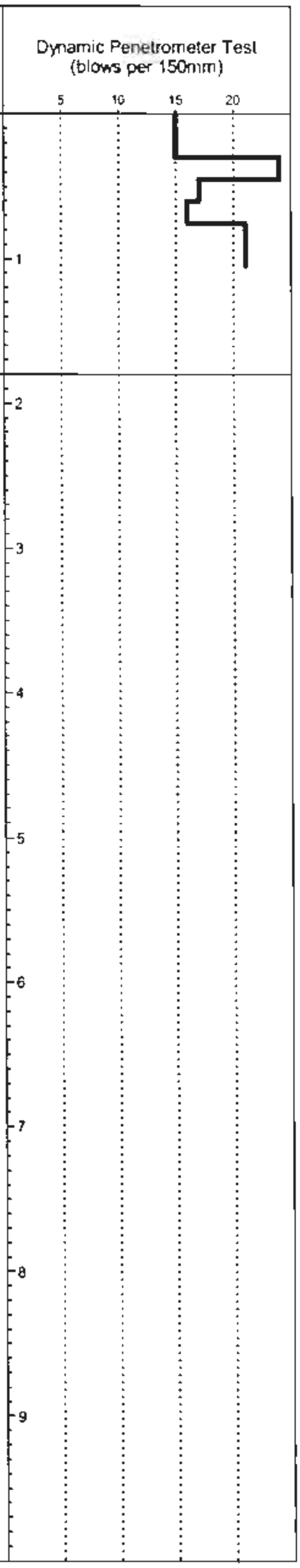
BOREHOLE LOG

CLIENT: NBRS & Partners Pty Ltd
PROJECT: Redevelopment of Correctional Facility
LOCATION: Lindsay Street, Cessnock

SURFACE LEVEL: RL96m AHD*
EASTING: 344122
NORTHING: 6367931
DIP/AZIMUTH: 90°/--

BORE No: 304
PROJECT No: 81986.00
DATE: 25/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
	0.1	TOPSOIL / FILLING - Generally comprising brown-red clay filling, M<<Wp			0.1			
		CLAY - Very stiff to hard, brown clay, trace sand, trace silt, M<<Wp From 0.4m, trace subangular to subrounded gravel up to 5mm in size		B	0.5			
				U_x	0.7		pp >600	
	1							
	1.6	CLAYSTONE - Extremely low strength, extremely weathered, grey claystone, trace subangular to subrounded pebbles up to 8mm in size		S	1.5 1.75		20,14/100,- refusal	
	1.8	Bore discontinued at 1.8m, limit of investigation, v-bit refusal						
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							



RIG: FG102, 4WD Rig **DRILLER:** FICO **LOGGED:** Goodall **CASING:** Uncased

TYPE OF BORING: 150mm v-bit auger

WATER OBSERVATIONS: No free groundwater observed

REMARKS: * Surface level interpolated from 2m digital contour mapping and are approximate only

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

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_x	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
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NBRS & Partners Pty Ltd
PROJECT: Redevelopment of Correctional Facility
LOCATION: Lindsay Street, Cessnock

SURFACE LEVEL: RL107m AHD*
EASTING: 344114
NORTHING: 6367781
DIP/AZIMUTH: 90°/--

BORE No: 305
PROJECT No: 81986.00
DATE: 25/5/2016
SHEET 1 OF 1

Depth (m)	Description of Strata	Discontinuities B - Bedding J - Joint S - Shear F - Fault	Type	Core Rec. %	RQD %	Test Results & Comments
0.05	TOPSOIL - Generally comprising silty sandy topsoil, trace subangular gravel up to 10mm in size, dry					
	CLAY - Very stiff to hard, red brown clay, M<Wp					
0.6	CLAYSTONE - Extremely low strength, extremely weathered, grey mottled red claystone		S			pp >600 5,8,15 N = 23
1						
			S			5,11,23 N = 34
2						
	From 2.3m to 2.4m, possible clay (drilled 0.1m under own weight in less than 10 seconds)					
2.7	SANDSTONE - Extremely low strength, extremely weathered, grey, fine grained sandstone					
3	At 3.0m, start coring From 3.01m, medium strength, slightly weathered with some subangular to subrounded pebbles up to 10mm in size					PL(A) = 0.41 PL(D) = 0.45
	From 3.6m, high strength	3.48m: P, pl, ro, fe 3.52m: P, pl, ro				PL(A) = 0.97 PL(D) = 1
	From 3.78m, fresh		C	100	97	
4						
	From 4.5m, medium strength, slightly weathered	4.54m: P, pl, ro				
	From 4.78m, fresh	4.73m: P, pl, ro				PL(A) = 0.88
5	From 5.0m, high strength					PL(A) = 0.21 PL(D) = 1.38
	From 5.32m, slightly weathered	5.31m: P, pl, ro	C	100	100	
	From 5.36m, fresh					
	From 5.45m, slightly weathered					PL(D) = 0.85
	From 5.5m, medium strength					
	From 5.61m, fresh					PL(A) = 0.76 PL(D) = 0.91
6 6.0	From 5.7m, slightly weathered From 5.78m, fresh and yellow Bore discontinued at 6.0m, limit of investigation					

RIG: FG102 4WD **DRILLER:** FICO **LOGGED:** Goodall **CASING:** HQ at 3.0m
TYPE OF BORING: V-bit to 3.0m, NMLC from 3.0m
WATER OBSERVATIONS: No free groundwater observed
REMARKS: * Surface level interpolated from 2m digital contour mapping and are approximate only

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)

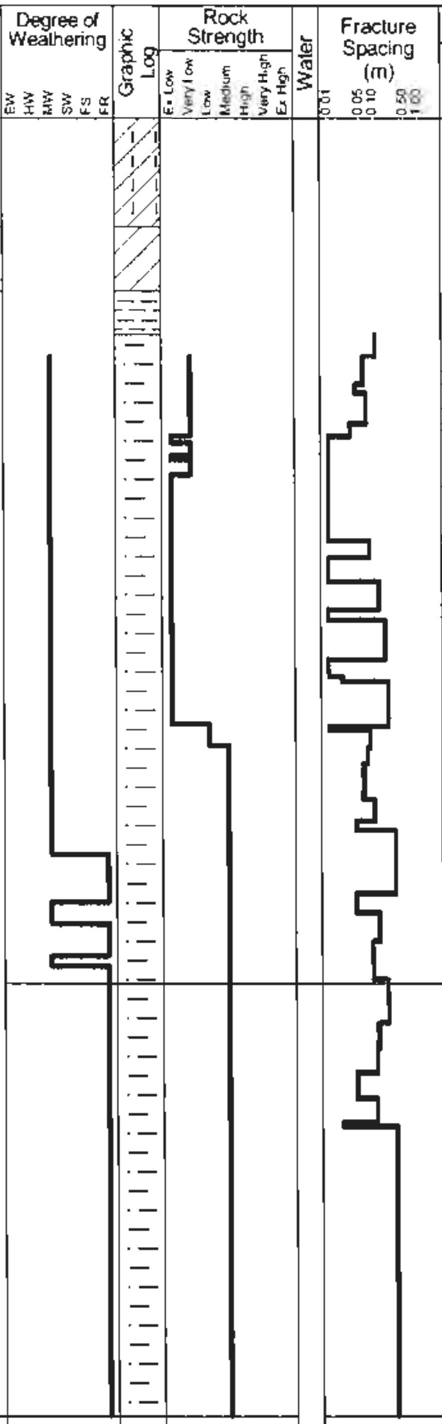
Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NBRS & Partners Pty Ltd
PROJECT: Redevelopment of Correctional Facility
LOCATION: Lindsay Street, Cessnock

SURFACE LEVEL: RL93m AHD*
EASTING: 344480
NORTHING: 6367529
DIP/AZIMUTH: 90°/--

BORE No: 306
PROJECT No: 81986.00
DATE: 26/5/2016
SHEET 1 OF 1



RL	Depth (m)	Description of Strata	Discontinuities B - Bedding J - Joint S - Shear F - Fault	Sampling & In Situ Testing: Type	Core Rec. %	RQD %	Test Results & Comments
		SILTY CLAY - (Very stiff), brown silty clay, trace rootlets, trace subangular gravel up to 5mm in size, M<Wp		A			
	0.5	CLAY - Hard, red brown clay, M<Wp		A U_{50}			pp >600
	0.8	CLAYSTONE - Extremely low strength, extremely weathered, red brown claystone					
1 2 3	1.0	SILTSTONE - Very low strength, moderately weathered, grey siltstone, with extremely low strength bands At 1.0m, start coring From 1.47m to 1.5m, extremely low strength From 1.56m to 1.58m, extremely low strength From 1.65m, extremely low strength From 2.8m, low strength From 2.9m, medium strength From 3.4m, fresh From 3.62m, moderately weathered From 3.72m, fresh From 3.87m, moderately weathered From 3.92m, fresh	1.1m: P, pl, sm 1.17m: J, 5°, pl, ro, 30mm clay infill 1.23m: J, 30°, pl, ro 1.27m: J, 10°, pl, ro, 30mm clay infill 1.34m: J, 10°, pl, ro 1.41m: P, pl, ro 1.44m: P, pl, ro From 1.70m to 1.95m, fg 1.95m: J, 70°, pl, ro, fe From 2.03m to 2.14m, fg From 2.27m to 2.32m, fg From 2.5m to 2.58m, fg 2.68m: P, pl, ro, 3mm clay infill From 2.81m to 2.83m, fg 2.91m: P, pl, ro 2.98m: J, 20°, pl, ro 3.04m: J, 5°, pl, ro 3.15m: J, 20°, pl, ro 3.25m: J, 60°, pl, ro, fe 3 29m: J, 60°, pl, ro 3.58m: J, 20°, pl, ro 3.67m: J, 49, pl, ro 3.8m: J, 20°, pl, ro 3.89m: P, pl, ro				PL(D) = 0.02 PL(A) = 0.1 PL(A) = 0.27 PL(A) = 0.08 PL(A) = 0.38 PL(D) = 0.17 PL(A) = 0.58 PL(A) = 0.87 PL(D) = 0.46 PL(A) = 0.76 PL(D) = 0.75
4 5			3.98m: J, 20°, pl, ro 4.18m: J, 5°, pl, ro, fe 4.3m: J, 20°, pl, ro, fe 4.41m: J, 10°, pl, ro, fe 4.45m: P, pl, ro, fe 4.49m: J, 5°, pl, ro, fe 4.53m: P, pl, ro, fe 4.64m: J, 30°, pl, ro 4.66m: J, 30°, pl, ro 4.96m: P, pl, ro, fe	C	100	91	PL(A) = 0.41 PL(A) = 0.42
				C	100	100	PL(A) = 0.72 PL(D) = 0.7
6	6.0	Bore discontinued at 6.0m, limit of investigation					

RIG: FG102 4WD **DRILLER:** FICO **LOGGED:** Goodall **CASING:** HQ at 1.0m

TYPE OF BORING: V-bit to 0.8m, TC-bit to 1.0m, NMLC from 1.0m

WATER OBSERVATIONS: No free groundwater observed

REMARKS: * Surface level interpolated from 2m digital contour mapping and are approximate only

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)

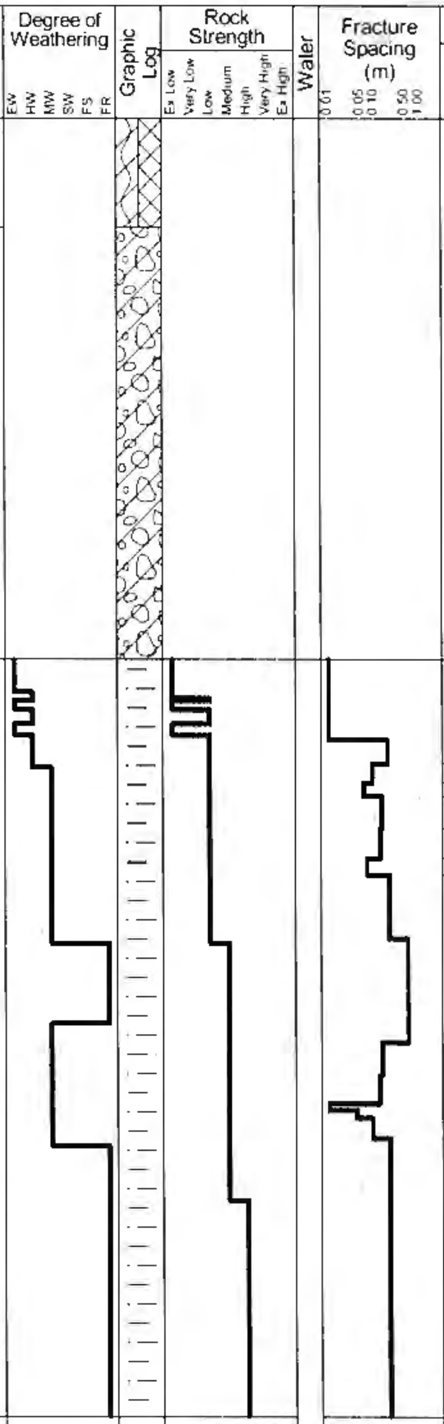
Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NBRS & Partners Pty Ltd
PROJECT: Redevelopment of Correctional Facility
LOCATION: Lindsay Street, Cessnock

SURFACE LEVEL: RL90m AHD*
EASTING: 344496
NORTHING: 6367449
DIP/AZIMUTH: 90°/--

BORE No: 307
PROJECT No: 81986.00
DATE: 26/5/2016
SHEET 1 OF 1



RL	Depth (m)	Description of Strata	Discontinuities B - Bedding J - Joint S - Shear F - Fault	Type	Core Rec. %	RQD %	Test Results & Comments
		TOPSOIL/FILLING - Generally comprising brown, silty sand filling, fine grained sand, trace rootlets, humid		A			
	0.5	GRAVELLY CLAY - Hard, brown red gravelly clay, with subangular to subrounded gravel up to 8mm in size, M<<Wp From 0.85m, trace gravel		S			21,20,14 N = 34 pp >600
	2.5	SILTSTONE - Extremely low strength, extremely weathered, grey siltstone At 2.5m, start coring From 2.65m, low strength, highly weathered From 2.69m, extremely low strength, extremely weathered From 2.73m, low strength, highly weathered From 2.80m, extremely low strength, extremely weathered From 2.8m, low strength, moderately weathered From 2.85m, low strength, highly weathered From 3.81m, medium strength, fractured From 4.18m, moderately weathered From 4.75m, medium strength, fractured From 5.0m, high strength	2.87m: J, 10°, pl, ro, fe, 20mm clay infill 2.98m: P, pl, ro, fe 3.07m: J, 5°, pl, ro, fe 3.13m: J, 10°, pl, ro 3.28m: J, 20°, pl, ro 3.42m: J, 20°, pl, ro 3.49m: J, 10°, pl, ro, fe 3.71m: J, 5°, pl, ro, fe 4.27m: P, pl, sm, fe 4.42m: P, pl, ro, fe From 4.55m to 4.58m, fg 4.62m: P, pl, su, fe 4.71m: J, 5°, ro, fe 4.93m: P, pl, ro, fe	C C C	100 100 100	67 88 100	PL(A) = 0.13 PL(A) = 0.23 PL(A) = 0.11 PL(D) = 0.24 PL(A) = 0.37 PL(D) = 0.27 PL(A) = 1.1 PL(D) = 0.64 PL(A) = 0.62 PL(D) = 0.35 PL(A) = 0.97 PL(A) = 1.25 PL(D) = 0.85
	6.0	Bore discontinued at 6.0m, limit of investigation					

RIG: FG102 4WD **DRILLER:** FICO **LOGGED:** Goodall **CASING:** HQ at 2.5m

TYPE OF BORING: V-bit to 2.5m, NMLC from 2.5m

WATER OBSERVATIONS: No free groundwater observed

REMARKS: * Surface level interpolated from 2m digital contour mapping and are approximate only

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
Geotechnics / Environment / Groundwater

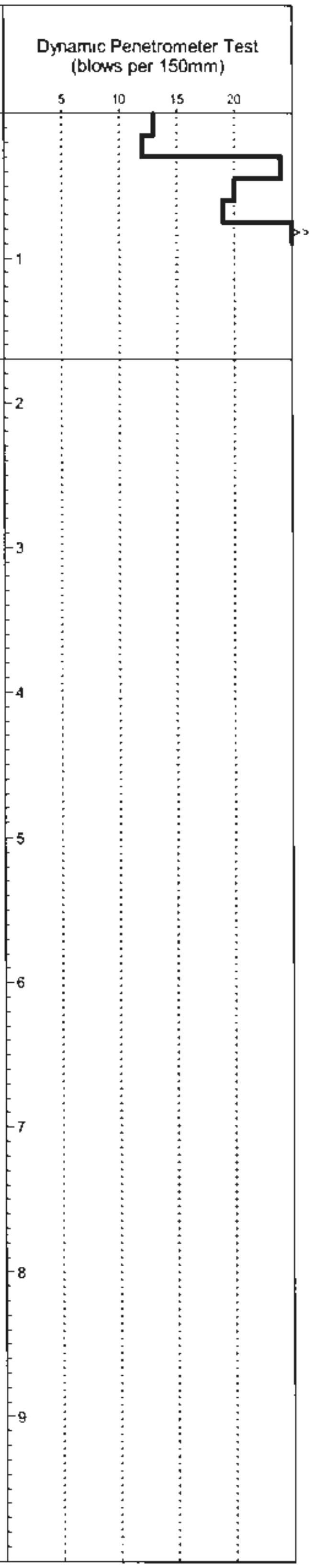
BOREHOLE LOG

CLIENT: NBRS & Partners Pty Ltd
PROJECT: Redevelopment of Correctional Facility
LOCATION: Lindsay Street, Cessnock

SURFACE LEVEL: RL102m AHD*
EASTING: 344287
NORTHING: 6367590
DIP/AZIMUTH: 90°/--

BORE No: 308
PROJECT No: 81986.00
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Type	Depth	Sample	Results & Comments	Water
		TOPSOIL / FILLING - Generally comprising brown silty gravel filling with subangular to subrounded gravel up to 20mm in size, humid	A	0.0 0.1			
	0.4	CLAY - Hard, brown-red clay, trace fine to medium grained sand, M<<Wp	A	0.5			
	1.2	SANDSTONE - Extremely low strength, extremely weathered, grey, fine to medium grained sandstone					
	1.7	Bore discontinued at 1.7m, limit of investigation, v-bit refusal					



RIG: FG102, 4WD Rig **DRILLER:** FICO **LOGGED:** Goodall **CASING:** Uncased

TYPE OF BORING: 150mm v-bit auger

WATER OBSERVATIONS: No free groundwater observed

REMARKS: * Surface level interpolated from 2m digital contour mapping and are approximate only

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

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
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NBRS & Partners Pty Ltd
PROJECT: Redevelopment of Correctional Facility
LOCATION: Lindsay Street, Cessnock

SURFACE LEVEL: RL101m AHD*
EASTING: 344310
NORTHING: 6367604
DIP/AZIMUTH: 90°/--

BORE No: 309
PROJECT No: 81986.00
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm) 5 10 15 20
	0.15	TOPSOIL / FILLING - Generally comprising brown silty sand filling with subangular to subrounded up to 20mm in size		A	0.0 0.1				>>
	0.25	CLAY - Hard, brown-red clay, trace fine to medium grained sand, trace subangular gravel up to 5mm in size, M<<Wp							>>
	0.4	SANDSTONE - Extremely low strength, extremely weathered, grey, fine to medium grained sandstone							>>
		Bore discontinued at 0.4m, limit of investigation, auger refusal							
	1								1
	2								2
	3								3
	4								4
	5								5
	6								6
	7								7
	8								8
	9								9

RIG: FG102, 4WD Rig **DRILLER:** FICO **LOGGED:** Goodall **CASING:** Uncased

TYPE OF BORING: 300mm auger

WATER OBSERVATIONS: No free groundwater observed

REMARKS: * Surface level interpolated from 2m digital contour mapping and are approximate only

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

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
Geotechnics / Environment / Groundwater

BOREHOLE LOG

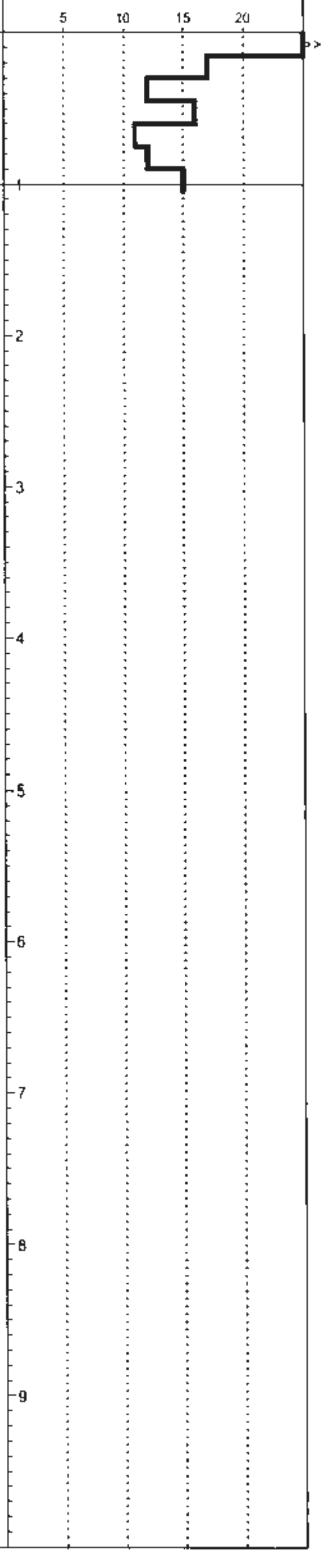
CLIENT: NBRS & Partners Pty Ltd
PROJECT: Redevelopment of Correctional Facility
LOCATION: Lindsay Street, Cessnock

SURFACE LEVEL: RL107m AHD*
EASTING: 344319
NORTHING: 6367587
DIP/AZIMUTH: 90°/--

BORE No: 310
PROJECT No: 81986.00
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
	0.25	TOPSOIL / FILLING - Generally comprising brown silty sand filling with some subangular to subrounded gravel up to 20mm in size, trace rootlets, humid		A	0.0 0.1			
	1.0	CLAY - Hard, orange-brown clay with some subangular to subrounded gravel up to 5mm in size, M<Wp		B	0.25 0.6			
1		Bore discontinued at 1.0m, limit of investigation, v-bit refusal						

Dynamic Penetrometer Test (blows per 150mm)



RIG: FG102, 4WD Rig **DRILLER:** FICO **LOGGED:** Goodall **CASING:** Uncased

TYPE OF BORING: 150mm v-bit auger

WATER OBSERVATIONS: No free groundwater observed

REMARKS: * Surface level interpolated from 2m digital contour mapping and are approximate only

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

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_x	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
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NBRS & Partners Pty Ltd
PROJECT: Redevelopment of Correctional Facility
LOCATION: Lindsay Street, Cessnock

SURFACE LEVEL: RL100m AHD* **BORE No:** 311
EASTING: 344340 **PROJECT No:** 81986.00
NORTHING: 6367604 **DATE:** 27/5/2016
DIP/AZIMUTH: 90°/-- **SHEET** 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Dynamic Penetrometer Test (blows per 150mm) 5 10 15 20
				Type	Depth	Sample	Results & Comments		
	0.4	TOPSOIL / FILLING - Generally comprising brown silty sand filling, trace subangular gravel up to 8mm in size, trace rootlets, humid		A	0.1				>> >>
1	1.0	GRAVELLY CLAY - Hard, red-brown gravelly clay with subangular to subrounded gravel up to 10mm in size, M<Wp From 0.54m, trace gravel		U_{50}	0.4 0.54		pp >600		
	1.2	SILTSTONE - Extremely low strength, extremely weathered, grey siltstone							
		Bore discontinued at 1.2m, limit of investigation, v-bit refusal							

RIG: FG102, 4WD Rig **DRILLER:** FICO **LOGGED:** Goodall **CASING:** Uncased

TYPE OF BORING: 150mm v-bit auger

WATER OBSERVATIONS: No free groundwater observed

REMARKS: * Surface level interpolated from 2m digital contour mapping and are approximate only

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

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
Geotechnics / Environment / Groundwater

BOREHOLE LOG

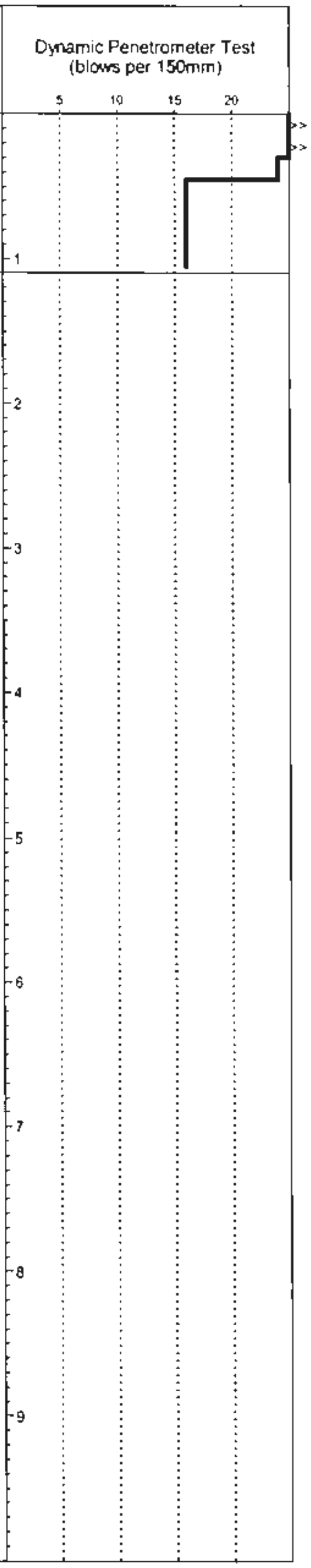
CLIENT: NBRS & Partners Pty Ltd
PROJECT: Redevelopment of Correctional Facility
LOCATION: Lindsay Street, Cessnock

SURFACE LEVEL: RL100m AHD*
EASTING: 344354
NORTHING: 6367587
DIP/AZIMUTH: 90°/--

BORE No: 312
PROJECT No: 81986.00
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water
				Type	Depth	Sample	Results & Comments	
	0 25	TOPSOIL / FILLING - Generally comprising brown silty sand filling, fine to medium grained sand with trace subangular to subrounded gravel up to 15mm in size, humid						
	0 9	CLAY - Hard, red-brown clay, M=Wp						
	1 1.1	SILTSTONE - Extremely low strength, extremely weathered, grey siltstone						
		Bore discontinued at 1.1m, limit of investigation, v-bit refusal						
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							

Dynamic Penetrometer Test (blows per 150mm)



RIG: FG102, 4WD Rig **DRILLER:** FICO **LOGGED:** Goodall **CASING:** Uncased

TYPE OF BORING: 150mm v-bit auger

WATER OBSERVATIONS: No free groundwater observed

REMARKS: * Surface level interpolated from 2m digital contour mapping and are approximate only

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

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
Geotechnics / Environment / Groundwater

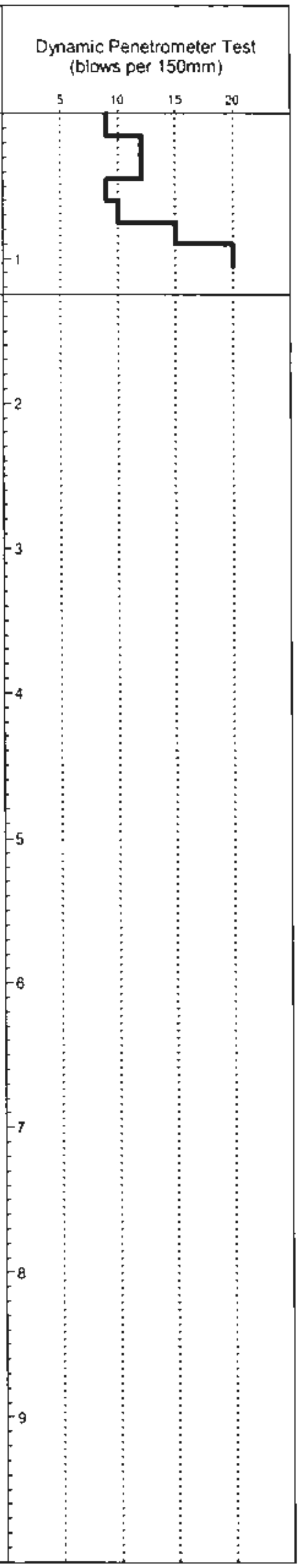
BOREHOLE LOG

CLIENT: NBRS & Partners Pty Ltd
PROJECT: Redevelopment of Correctional Facility
LOCATION: Lindsay Street, Cessnock

SURFACE LEVEL: RL99m AHD*
EASTING: 344373
NORTHING: 6367620
DIP/AZIMUTH: 90°/--

BORE No: 313
PROJECT No: 81986.00
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
	0.15	TOPSOIL / FILLING - Generally comprising brown silty sand, fine to medium grained sand, trace subangular to subrounded gravel up to 20mm in size, trace rootlets, humid			0.15			
		CLAY - Very stiff, red-brown clay, trace subangular to subrounded gravel up to 5mm in size, M<WP From 0.75m, hard		B	0.45			
	1.15							
	1.25	SILTSTONE - Extremely low strength, extremely weathered, grey siltstone						
		Bore discontinued at 1.25m, limit of investigation, v-bit refusal						



RIG: FG102, 4WD Rig **DRILLER:** FICO **LOGGED:** Goodall **CASING:** Uncased

TYPE OF BORING: 300mm auger

WATER OBSERVATIONS: No free groundwater observed

REMARKS: * Surface level interpolated from 2m digital contour mapping and are approximate only

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

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
Geotechnics / Environment / Groundwater

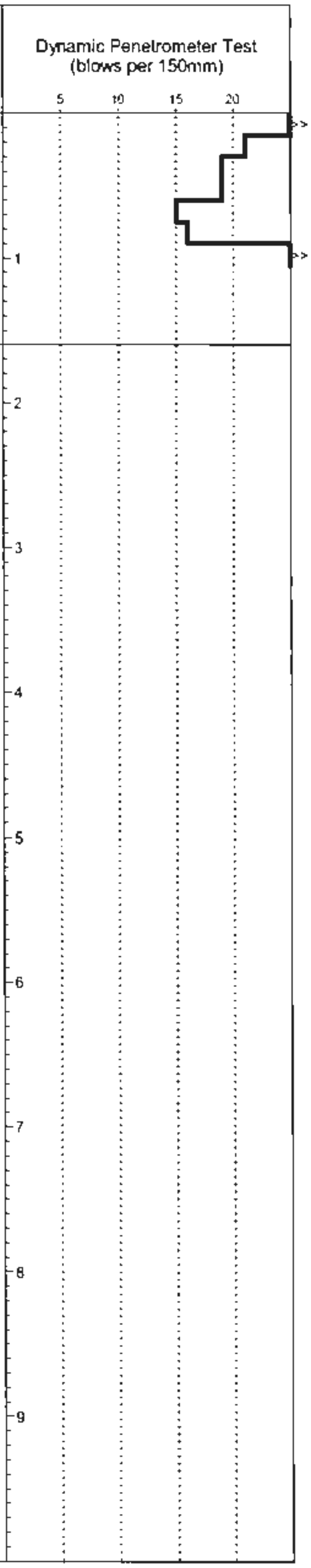
BOREHOLE LOG

CLIENT: NBRS & Partners Pty Ltd
PROJECT: Redevelopment of Correctional Facility
LOCATION: Lindsay Street, Cessnock

SURFACE LEVEL: RL98m AHD*
EASTING: 344381
NORTHING: 6367630
DIP/AZIMUTH: 90°/--

BORE No: 314
PROJECT No: 81986.00
DATE: 27/5/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		TOPSOIL / FILLING - Generally comprising brown silty sand filling, fine to medium grained sand, trace subangular to subrounded gravel, up to 5mm in size, humid						
	0.35	CLAY - Hard, red-brown clay, trace subangular to subrounded gravel up to 5mm in size, M<Wp		U_{50}	0.35 0.55		pp >600	
	1.4	SILTSTONE - Extremely low strength, extremely weathered, grey siltstone						
	1.6	Bore discontinued at 1.6m, limit of investigation, v-bit refusal						



RIG: FG102, 4WD Rig **DRILLER:** FICO **LOGGED:** Goodall **CASING:** Uncased

TYPE OF BORING: 150mm v-bit auger

WATER OBSERVATIONS: No free groundwater observed

REMARKS: * Surface level interpolated from 2m digital contour mapping and are approximate only

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

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_x	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)

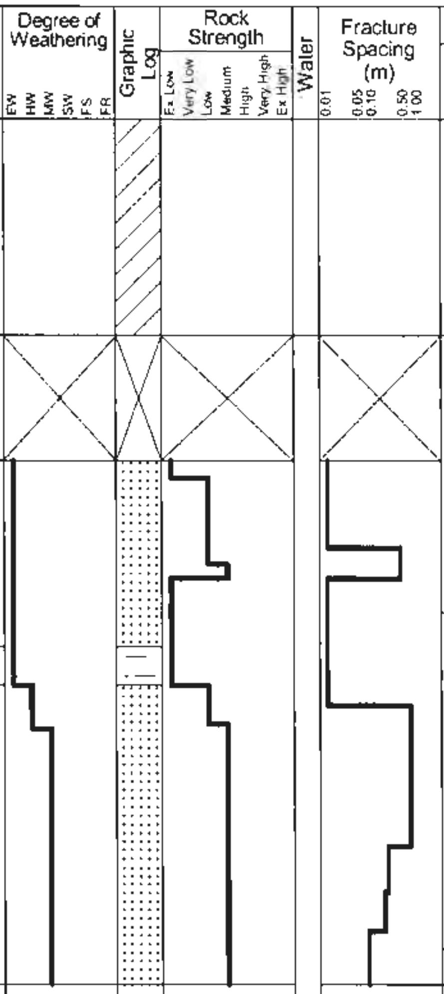
Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NBRS & Partners Pty Ltd
PROJECT: Redevelopment of Correctional Facility
LOCATION: Lindsay Street, Cessnock

SURFACE LEVEL: RL103m AHD*
EASTING: 344061
NORTHING: 6367802
DIP/AZIMUTH: 90°/--

BORE No: 315
PROJECT No: 81986.00
DATE: 27/5/2016
SHEET 1 OF 1



Discontinuities: B - Bedding J - Joint S - Shear F - Fault

RL	Depth (m)	Description of Strata	Discontinuities	Type	Core Rec. %	RQD %	Test Results & Comments
		CLAY - Hard, red brown clay, trace subangular to subrounded gravel up to 10mm in size, M<Wp					
1	1.0	CORE LOSS - 0.58m	1m: CORE LOSS: 580mm				
2	1.58	SANDSTONE - Extremely low strength, extremely weathered, yellow, fine grained sandstone From 1.66m, low strength From 2.06m, medium strength From 2.12m to 2.17m, extremely low strength clay	1.98m: J, pl, ro 2.2m: P, pl, sm, 3mm clay infill From 2.28m to 2.44m, fg	C	61	27	PL(A) = 0.1 PL(D) = 0.36
	2.44	SILTSTONE - Extremely low strength, extremely weathered, dark grey siltstone					
3	2.62	SANDSTONE - Low strength, highly weathered, dark grey, medium grained sandstone From 2.8m, fine grained, medium strength, moderately weathered	2.71m: P, pl, ro 3.36m: P, sl, ro, fe 3.57m: J, 30°, pl, ro, fe 3.75m: P, pl, ro, fe 3.83m: P, pl, ro, fe	C	100	51	PL(A) = 0.13 PL(D) = 0.07 PL(A) = 0.42 PL(D) = 0.35 PL(D) = 0.42
4	4.0	Bore discontinued at 4.0m, limit of investigation					
5							
6							

RIG: FG102 4WD **DRILLER:** FICO **LOGGED:** Goodall **CASING:** HQ at 1.0m

TYPE OF BORING: V-bit to 1.0m, NMLC from 1.0m

WATER OBSERVATIONS: No free groundwater observed

REMARKS: * Surface level interpolated from 2m digital contour mapping and are approximate only

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)

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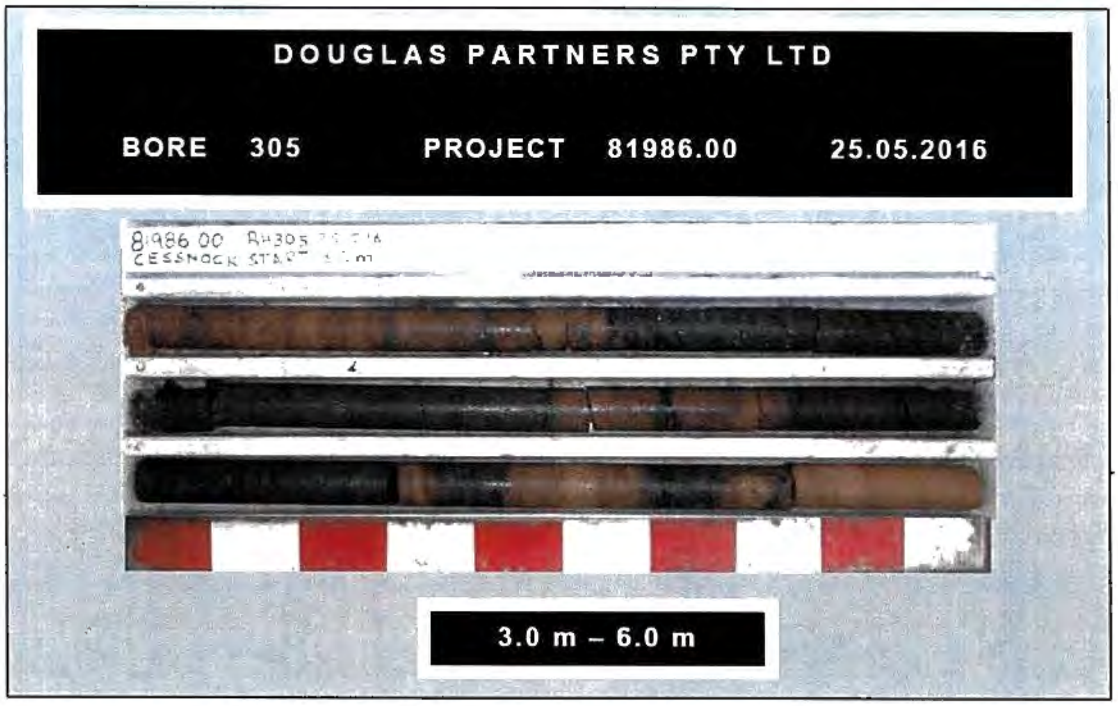

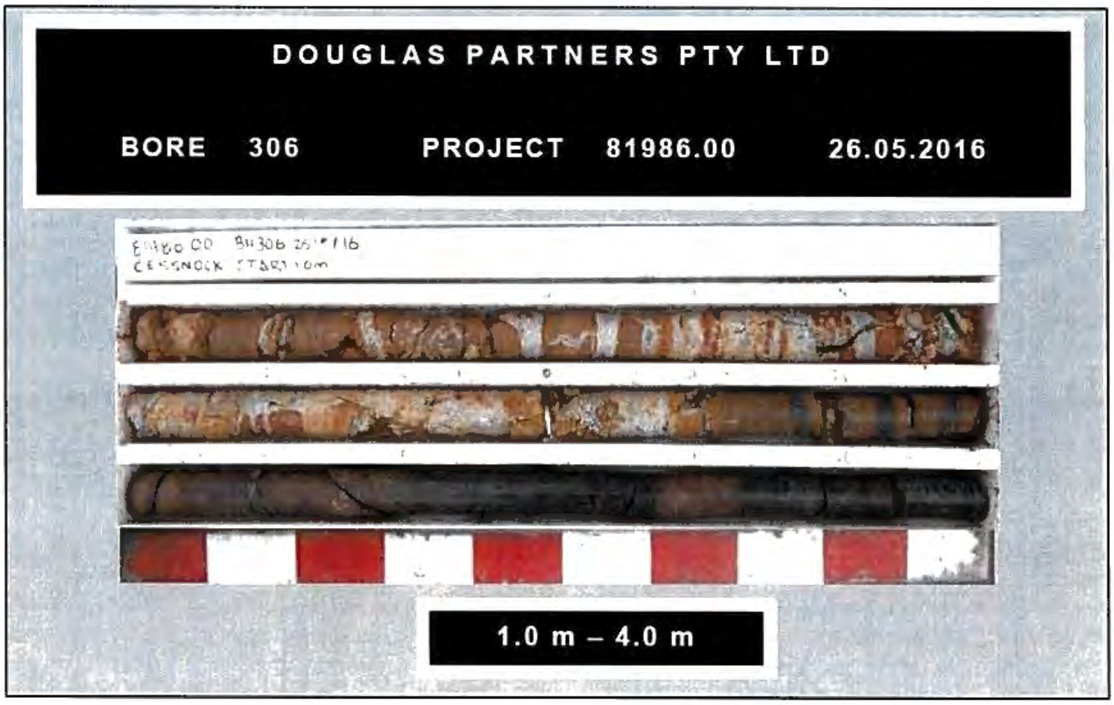

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Core Photoplate

Redevelopment of Correctional Facility

Lindsay Street, Cessnock

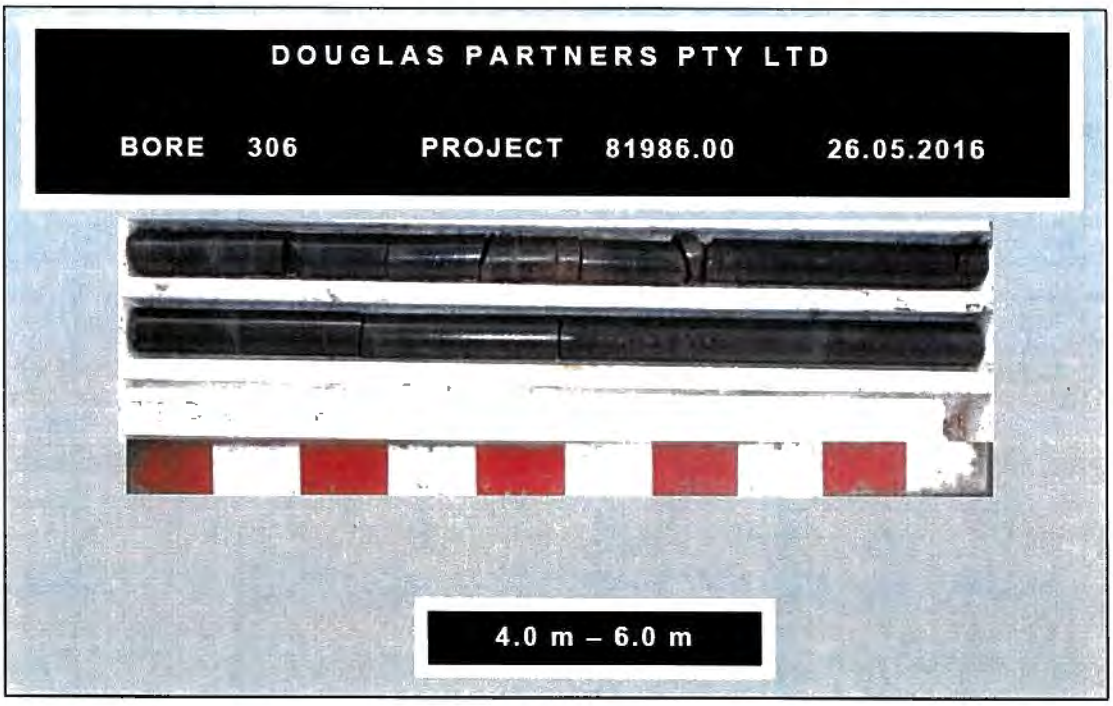
CLIENT NBRS & Partners Pty Ltd

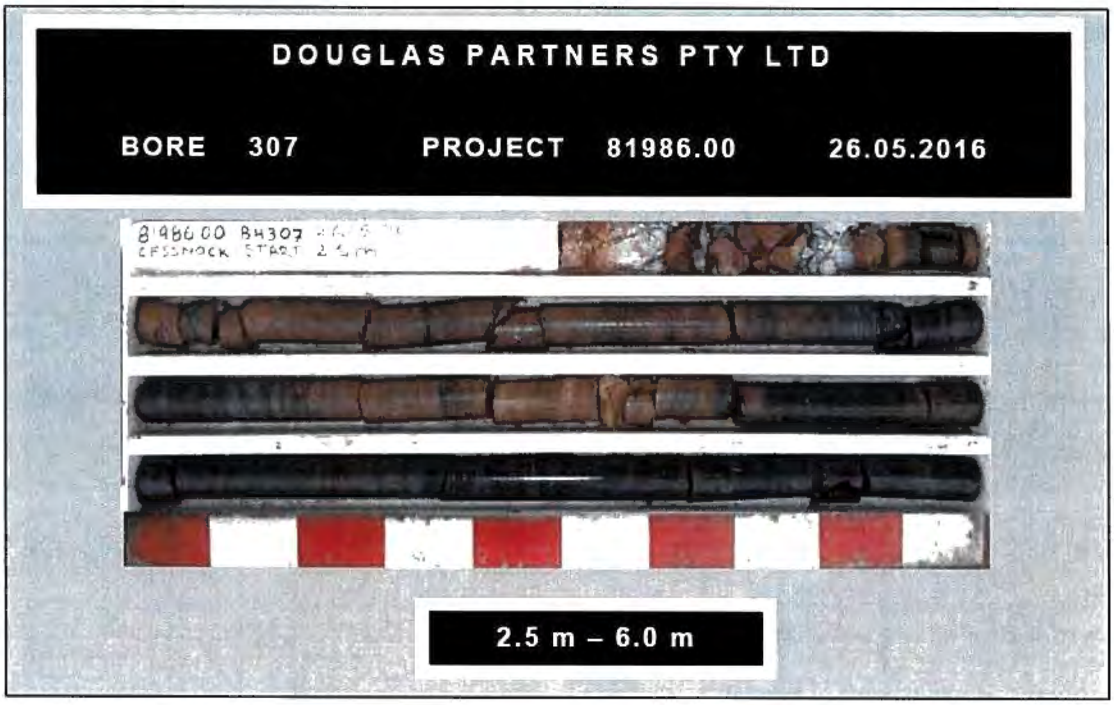
PROJECT 81986.00

PLATE No 1

REV 0

DATE 28.06.16





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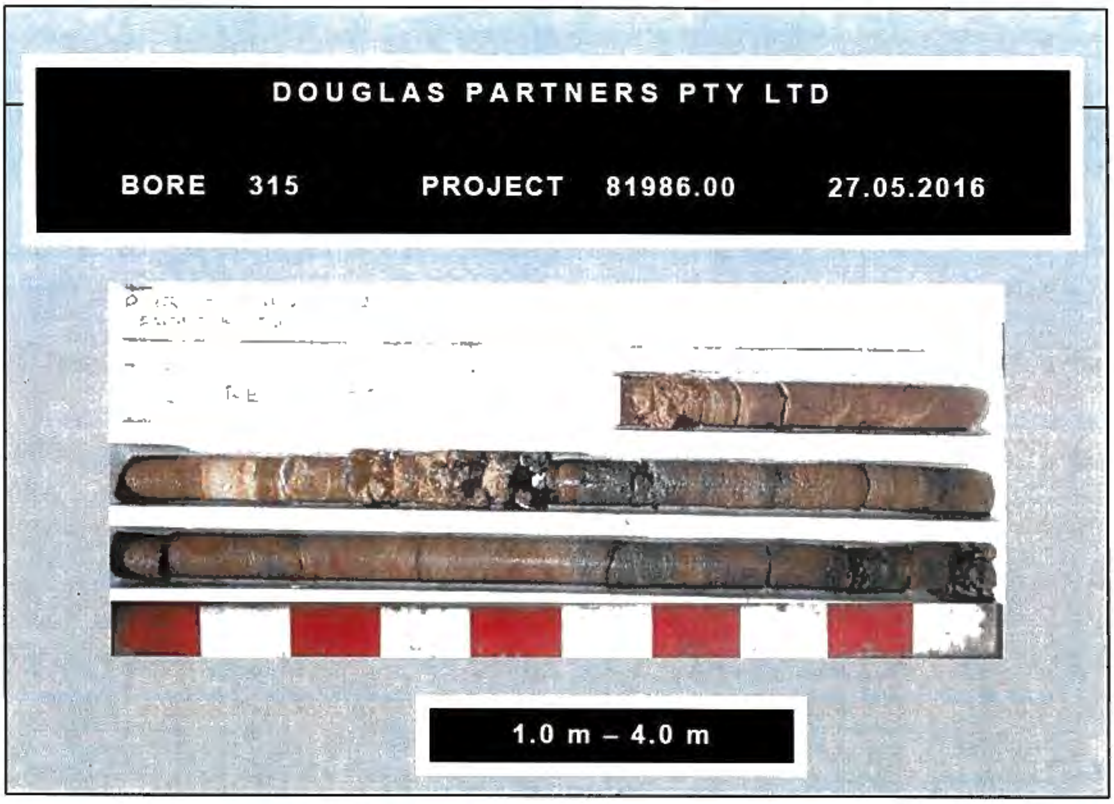
Core Photoplate		PROJECT	81986.00
Redevelopment of Correctional Facility		PLATE No:	2
Lindsay Street, Cessnock		REV	0
CLIENT:	NBRS & Partners Pty Ltd	DATE	28.06.16



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Core Photoplate

Redevelopment of Correctional Facility

Lindsay Street, Cessnock

PROJECT:	81986.00
PLATE No	3
REV	0
CLIENT	NBRS & Partners Pty Ltd
DATE	28.06.16

Douglas Partners
Geotechnics / Environment / Groundwater

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Hunter Region Mail Centre NSW 2310
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Fax (02) 4960 9601

Results of Dynamic Penetrometer Tests

Client NBRS & Partners Pty Ltd
Project Redevelopment of Correctional Facility
Location Lindsay Street, Cessnock

Project No. 81986.00
Date 25/5-27/5/16
Page No. 1 of 2

Test Location	301	302	303	304	305	306	307	308	309	310
RL of Test (AHD)										
Depth (m)	**Penetration Resistance** Blows/150 mm									
0 - 0.15	13	17	10	15	31	13	18	13	36	31
0.15 - 0.30	19	12	14	15	16	10	34	12	35	17
0.30 - 0.45	13	11	18	24	18	16	50	24	46/140mm ref	12
0.45 - 0.60	12	10	18	17	9	21	20/40mm ref	20		16
0.60 - 0.75	11	9	15	16	23	36/100mm ref		19		11
0.75 - 0.90	13	5	14	21	12			23/140mm ref		12
0.90 - 1.05	33	23	15	21	12/100mm ref					15
1.05 - 1.20										
1.20 - 1.35										
1.35 - 1.50										
1.50 - 1.65										
1.65 - 1.80										
1.80 - 1.95										
1.95 - 2.10										
2.10 - 2.25										
2.25 - 2.40										
2.40 - 2.55										
2.55 - 2.70										
2.70 - 2.85										
2.85 - 3.00										
3.00 - 3.15										
3.15 - 3.30										
3.30 - 3.45										
3.45 - 3.60										

Test Method AS 1289.6.3.2, Cone Penetrometer ☑
AS 1289.6.3.3, Sand Penetrometer ☐

Tested By SG
Checked By MPG

Remarks Ref = Refusal, 24/110 indicates 25 blows for 110 mm penetration

Douglas Partners
Geotechnics / Environment / Groundwater

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Results of Dynamic Penetrometer Tests

Client NBRS & Partners Pty Ltd
Project Redevelopment of Correctional Facility
Location Lindsay Street, Cessnock

Project No. 81986.00
Date 25/5-27/5/16
Page No. 2 of 2

Test Location	311	312	313	314	315					
RL of Test (AHD)										
Depth (m)	**Penetration Resistance** Blows/150 mm									
0 - 0.15	26/100mm	37	9	40	12					
0.15 - 0.30	ref	28	12	21	8					
0.30 - 0.45		24	12	19	6					
0.45 - 0.60		16	9	19	11					
0.60 - 0.75		16	10	15	15					
0.75 - 0.90		16	15	16	25					
0.90 - 1.05		16	20	30	22/50mm ref					
1.05 - 1.20										
1.20 - 1.35										
1.35 - 1.50										
1.50 - 1.65										
1.65 - 1.80										
1.80 - 1.95										
1.95 - 2.10										
2.10 - 2.25										
2.25 - 2.40										
2.40 - 2.55										
2.55 - 2.70										
2.70 - 2.85										
2.85 - 3.00										
3.00 - 3.15										
3.15 - 3.30										
3.30 - 3.45										
3.45 - 3.60										

Test Method AS 1289.6.3.2, Cone Penetrometer ☑
AS 1289.6.3.3, Sand Penetrometer ☐

Tested By SG
Checked By MPG

Remarks Ref = Refusal, 24/110 indicates 25 blows for 110 mm penetration

BOREHOLE LOG

CLIENT: Department of Commerce
PROJECT: Upgrade of Cessnock Correctional Facility
LOCATION: Cessnock

SURFACE LEVEL: --
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 214
PROJECT No: 39632
DATE: 20 Dec 06
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		
		TOPSOIL - Dark brown silt topsoil with some clay and some organics, humid	▨						
	0.1	CLAY - Very stiff to hard brown-red clay, with some silt, M<Wp	▨						
				U_{50}	0.5				
				pp	0.8		>450 kPa		
	1				1.0				1
	1.1	SANDSTONE - Extremely low strength, extremely weathered, brown fine to medium grained sandstone	░	S			7,20 refusal		
	1.3	Bore discontinued at 1.3m, refusal			1.3				
	2								2

RIG: Drillcat 4WD **DRILLER:** Foody **LOGGED:** Harris **CASING:**

TYPE OF BORING: Solid flight auger (v-bit) to1.3m (refusal)

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	PID	Photo ionisation detector
B	Bulk sample	S	Standard penetration test
U_x	Tube sample (x mm dia.)	PL	Point load strength Is(50) MPa
W	Water sample	V	Shear Vane (kPa)
C	Core drilling	▷	Water seep ▼ Water level

CHECKED
Initials:
Date:

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Geotechnics · Environment · Groundwater

BOREHOLE LOG

CLIENT: Department of Commerce
PROJECT: Upgrade of Cessnock Correctional Facility
LOCATION: Cessnock

SURFACE LEVEL: –
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 217
PROJECT No: 39632
DATE: 20 Dec 06
SHEET 1 **OF** 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water	Well Construction Details
	0.2	**TOPSOIL** - Dark brown silt topsoil with some clay and some organics, humid	▨						
	0.8	CLAY - Very stiff to hard brown-red clay, with some silt, M<Wp	▨						
	0.9	CLAYSTONE - (Extremely low strength), extremely weathered light grey-white mottled red brown claystone	▤						
		Bore discontinued at 0.9m, refusal							
	1								1
	2								2

RIG: Drillcat 4WD **DRILLER:** Foody **LOGGED:** Harris **CASING:**
TYPE OF BORING: Solid flight auger (v-bit) to 0.9m (refusal)
WATER OBSERVATIONS: No free groundwater observed
REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	PID	Photo ionisation detector
B	Bulk sample	S	Standard penetration test
U_x	Tube sample (x mm dia.)	PL	Point load strength Is(50) MPa
W	Water sample	V	Shear Vane (kPa)
C	Core drilling	▷	Water seep ▼ Water level

CHECKED
Initials:
Date:

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BOREHOLE LOG

CLIENT: Department of Commerce
PROJECT: Upgrade of Cessnock Correctional Facility
LOCATION: Cessnock

SURFACE LEVEL: --
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 218
PROJECT No: 39632
DATE: 20 Dec 06
SHEET 1 **OF** 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
		TOPSOIL - Dark brown silt topsoil with some clay and some organics, humid							
	0.3	SILTY CLAY - Very stiff to hard brown-red mottled grey silty clay, with trace to some fine sized subrounded gravel, M<Wp							
1	1.0	CLAYSTONE - (Extremely low strength), extremely weathered light grey-white mottled red brown claystone		S	1.0 1.45		5,10,14 N = 24		1
	1.45	Bore discontinued at 1.45m, refusal							
2									2

RIG: Drillcat 4WD **DRILLER:** Foody **LOGGED:** Harris **CASING:**
TYPE OF BORING: Solid flight auger (v-bit) to 1.35m (refusal)
WATER OBSERVATIONS: No free groundwater observed
REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	PID	Photo ionisation detector
B	Bulk sample	S	Standard penetration test
U_x	Tube sample (x mm dia.)	PL	Point load strength Is(50) MPa
W	Water sample	V	Shear Vane (kPa)
C	Core drilling	▷	Water seep ▼ Water level

CHECKED
Initials:
Date:

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BOREHOLE LOG

CLIENT: Department of Commerce	**SURFACE LEVEL:** –	**BORE No:** 219
PROJECT: Upgrade of Cessnock Correctional Facility	**EASTING:**	**PROJECT No:** 39632
LOCATION: Cessnock	**NORTHING:**	**DATE:** 20 Dec 06
	DIP/AZIMUTH: 90°/--	**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		
		TOPSOIL - Dark brown silt topsoil with some clay and some organics, humid		A	0.1				
	0.15	CLAY - Very stiff to hard brown-red clay, with some silt, M<Wp							
				U_{50}	0.5				
				pp	0.8		>450 kPa		
1		From 1.0m - grading into extremely weathered claystone		S	1.0 1.45		7,12,15 N = 27		1
	1.8	CLAYSTONE - (Extremely low strength), extremely weathered light grey-white mottled red brown claystone							
	1.9	Bore discontinued at 1.9m, refusal							
2									2

RIG: Drillcat 4WD **DRILLER:** Foody **LOGGED:** Harris **CASING:**

TYPE OF BORING: Solid flight auger (v-bit) to 1.9m (refusal)

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	PID	Photo ionisation detector
B	Bulk sample	S	Standard penetration test
U_x	Tube sample (x mm dia.)	PL	Point load strength Is(50) MPa
W	Water sample	V	Shear Vane (kPa)
C	Core drilling	▷	Water seep ▼ Water level

CHECKED
Initials:
Date:

Douglas Partners
Geotechnics · Environment · Groundwater

BOREHOLE LOG

CLIENT:	Department of Commerce	**SURFACE LEVEL:** –		**BORE No:**	220
PROJECT:	Upgrade of Cessnock Correctional Facility	**EASTING:**		**PROJECT No:**	39632
LOCATION:	Cessnock	**NORTHING:**		**DATE:**	20 Dec 06
		DIP/AZIMUTH:	90°/--	**SHEET**	1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
		TOPSOIL - Dark brown silt topsoil with some clay and some organics, humid	▨	A	0.2				
	0.4	**CLAY** - Very stiff to hard brown-red clay, with some silt, M<Wp	▨						
	0.5	**CLAYEY SILT** - Hard brown clayey silt, humid	▨	U_{50}	0.5				
				pp	0.65		>450 kPa		
1	1.0	**CLAYEY SILT/SILTY CLAY** - Hard grey-brown clayey silt/silty clay with trace to some fine sized subrounded gravel and with trace to some fine to medium grained sand (extremely weathered siltstone), M<Wp	▨	SPT pp	1.0 1.45		6,10,15 N = 25 >450 kPa		1
	1.5	Bore discontinued at 1.5m, refusal							
2									2

RIG: Drillcat 4WD DRILLER:Foody LOGGED: Harris CASING:

TYPE OF BORING:Solid flight auger (v-bit) to 1.5m (refusal)

WATER OBSERVATIONS:No free groundwater observed

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	PID	Photo ionisation detector
B	Bulk sample	S	Standard penetration test
U_x	Tube sample (x mm dia.)	PL	Point load strength Is(50) MPa
W	Water sample	V	Shear Vane (kPa)
C	Core drilling	▷	Water seep ▼ Water level

CHECKED
Initials:
Date:

Douglas Partners
Geotechnics - Environment - Groundwater

BOREHOLE LOG

CLIENT: Department of Commerce
PROJECT: Upgrade of Cessnock Correctional Facility
LOCATION: Cessnock

SURFACE LEVEL: --
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 221
PROJECT No: 39632
DATE: 20 Dec 06
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		
		TOPSOIL - Dark brown silt topsoil with some clay and some organics, humid		A	0.1				
	0.12	CLAY - Very stiff to hard brown-red clay, with some silt, M<Wp							
1	1.0	CLAYSTONE - (Extremely low strength), extremely weathered light grey-white mottled red brown claystone		SPT, pp	1.0 1.3		9,15 refusal >450 kPa		1
	1.5	Bore discontinued at 1.5m, refusal							
2									2

RIG: Drillcat 4WD DRILLER:Foody LOGGED: Harris CASING:

TYPE OF BORING:Solid flight auger (v-bit) to 1.5m (refusal)

WATER OBSERVATIONS:No free groundwater observed

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	PID	Photo ionisation detector
B	Bulk sample	S	Standard penetration test
U_x	Tube sample (x mm dia.)	PL	Point load strength Is(50) MPa
W	Water sample	V	Shear Vane (kPa)
C	Core drilling	▷	Water seep ▼ Water level

CHECKED
Initials:
Date:

Douglas Partners
Geotechnics · Environment · Groundwater

BOREHOLE LOG

CLIENT: Department of Commerce
PROJECT: Upgrade of Cessnock Correctional Facility
LOCATION: Cessnock

SURFACE LEVEL: --
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 223
PROJECT No: 39632
DATE: 20 Dec 06
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
		TOPSOIL - Dark brown silt topsoil with some clay and some organics, humid							
	0.1	CLAYEY SILT - Very stiff brown clayey silt, M<Wp							
	0.3	CLAY - Very stiff to hard brown-red clay, with some silt, M<Wp							
				U_{50}	0.5				
				pp	0.8		>450 kPa		
	1			SPT, pp	1.0		3,7,10 N = 17 >450 kPa		1
					1.45				
	1.9	CLAYSTONE - (Extremely low strength), extremely weathered light grey-white mottled red brown claystone							
	2								2
	2.2	Bore discontinued at 2.2m, refusal							

RIG: Drillcat 4WD
DRILLER: Foody
LOGGED: Harris
CASING:
TYPE OF BORING: Solid flight auger (v-bit) to 2.2m (refusal)
WATER OBSERVATIONS: No free groundwater observed
REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	PID	Photo ionisation detector
B	Bulk sample	S	Standard penetration test
U_x	Tube sample (x mm dia.)	PL	Point load strength Is(50) MPa
W	Water sample	V	Shear Vane (kPa)
C	Core drilling	▷	Water seep ⯆ Water level

CHECKED
Initials:
Date:

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Appendix C

Results of Laboratory Testing

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[illegible]

[illegible]
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Envirolab Services Pty Ltd – Sydney ABN 37 112 535 645

CERTIFICATE OF ANALYSIS 147956

Client:
Douglas Partners Newcastle
Box 324 Hunter Region Mail Centre
Newcastle
NSW 2310

Attention: Michael Gawn

Sample log in details:

Your Reference:	**81986.00, Geotechnical Assessment**
No. of samples:	8 Soils
Date samples received / completed instructions received	06/06/16 / 06/06/16

Analysis Details:

Please refer to the following pages for results, methodology summary and quality control data.
Samples were analysed as received from the client. Results relate specifically to the samples as received.
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.
Please refer to the last page of this report for any comments relating to the results.

Report Details:

Date results requested by: / Issue Date:	14/06/16 / 9/06/16
Date of Preliminary Report:	Not Issued

NATA accreditation number 2901. This document shall not be reproduced except in full.
Accredited for compliance with ISO/IEC 17025. **Tests not covered by NATA are denoted with *.**

Results Approved By:

Jacinta Hurst
Laboratory Manager

Asbestos ID - soils						
Our Reference	UNITS	147956-1	147956-2	147956-3	147956-4	147956-5
Your Reference	------------	BH301	BH302	BH303	BH306	BH307
Type of sample	------------	Soil	Soil	Soil	Soil	Soil
Date analysed	-	9/06/2016	9/06/2016	9/06/2016	9/06/2016	9/06/2016
Sample mass tested	g	Approx. 70g	Approx. 65g	Approx. 65g	Approx. 55g	Approx. 55g
Sample Description	-	Brown fine-grained soil & rocks	Brown fine-grained soil & rocks	Brown fine-grained soil & rocks	Brown fine-grained soil & rocks	Brown fine-grained soil & rocks
Asbestos ID in soil	-	No asbestos detected at reporting limit of 0.1g/kg Organic fibres detected	No asbestos detected at reporting limit of 0.1g/kg Organic fibres detected	No asbestos detected at reporting limit of 0.1g/kg Organic fibres detected	No asbestos detected at reporting limit of 0.1g/kg Organic fibres detected	No asbestos detected at reporting limit of 0.1g/kg Organic fibres detected
Trace Analysis	-	No asbestos detected	No asbestos detected	No asbestos detected	No asbestos detected	No asbestos detected

Asbestos ID - soils				
Our Reference	UNITS	147956-6	147956-7	147956-8
Your Reference	------------	BH308	BH309	BH310
Type of sample	------------	Soil	Soil	Soil
Date analysed	-	9/06/2016	9/06/2016	9/06/2016
Sample mass tested	g	Approx. 95g	Approx. 75g	Approx. 70g
Sample Description	-	Brown fine-grained soil & rocks	Brown fine-grained soil & rocks	Brown fine-grained soil & rocks
Asbestos ID in soil	-	No asbestos detected at reporting limit of 0.1g/kg Organic fibres detected	No asbestos detected at reporting limit of 0.1g/kg Organic fibres detected	No asbestos detected at reporting limit of 0.1g/kg Organic fibres detected
Trace Analysis	-	No asbestos detected	No asbestos detected	No asbestos detected

Method ID	Methodology Summary
ASB-001	Asbestos ID - Qualitative identification of asbestos in bulk samples using Polarised Light Microscopy and Dispersion Staining Techniques including Synthetic Mineral Fibre and Organic Fibre as per Australian Standard 4964-2004

Report Comments:

Asbestos ID was analysed by Approved Identifier: Paul Ching
Asbestos ID was authorised by Approved Signatory: Paul Ching

INS: Insufficient sample for this test
NR: Test not required
<: Less than

PQL: Practical Quantitation Limit
RPD: Relative Percent Difference
>: Greater than

NT: Not tested
NA: Test not required
LCS: Laboratory Control Sample

Quality Control Definitions

Blank: This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.

Duplicate: This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.

Matrix Spike : A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.

LCS (Laboratory Control Sample) : This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.

Surrogate Spike: Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.
Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.
Spikes for Physical and Aggregate Tests are not applicable.
For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.
Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

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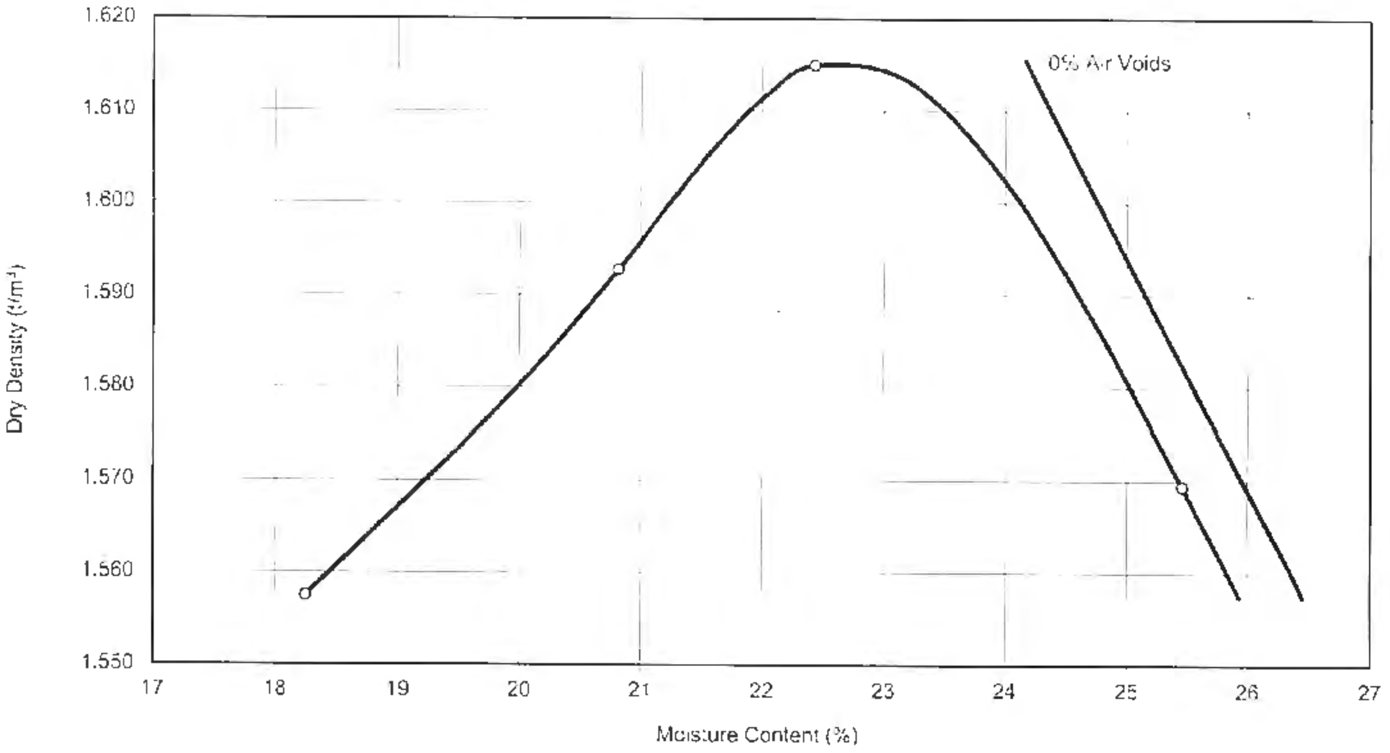
Results of Compaction Test

Client :	NBRS & Partners Pty Ltd	**Project No. :**	81986
		Report No. :	N16-138_1
Project :	Cessnock Correctional Facility	**Report Date :**	29.06.2016
Location :	Cessnock	**Date of Test:**	07.06.2016
		Page:	1 of 1



Sample Details: **Location:** Pit 310
Depth: 0.25 - 0.60m

Particles > 19mm: 0%

Description: CLAY - Orange brown

Maximum Dry Density:	1.62 t/m^3
Optimum Moisture Content:	22.5 %

Remarks:

Test Methods: AS 1289 5.1.1, AS 1289.2.1.1

Sampling Methods: Sampled by DP Engineering Department

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 AV
Checked DM

Dave Millard
Laboratory Manager

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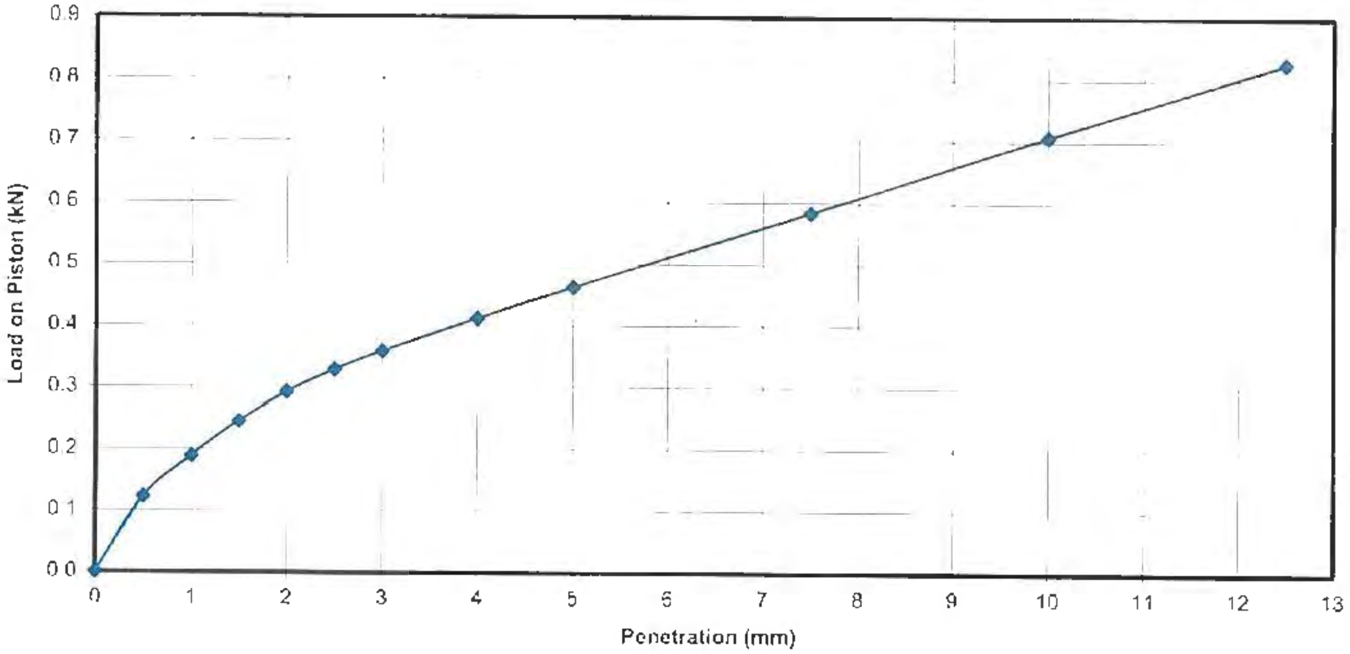
Result of California Bearing Ratio Test

Client :	NBRS & Partners Pty Ltd	**Project No. :**	81986
		Report No. :	N16-138_2
Project :	Cessnock Correctional Facility	**Report Date :**	29.06.2016
		Date Sampled :	25-27.05.16
Location :	Cessnock	**Date of Test:**	14.06.2016
Test Location :	Pit 310		
Depth / Layer :	0.25 -0.60m	**Page:**	1 of 1



Description: CLAY - Orange brown

Sampling Method(s): Sampled by DP Engineering Department
Test Method(s): AS 1289.6.1.1, AS 1289.2.1.1

Remarks:

Percentage > 19mm: 0.0%

LEVEL OF COMPACTION: 99.5% of STD MDD
MOISTURE RATIO: 100% of STD OMC
SURCHARGE: 4.5 kg
SOAKING PERIOD: 4 days
SWELL: 2.7%

CONDITION		MOISTURE CONTENT %	DRY DENSITY t/m^3
At compaction		22.5	1.61
After soaking		26.3	1.57
After test	Top 30mm of sample	31.0	-
	Remainder of sample	22.9	-
Field values		18.2	-
Standard Compaction	(OMC/MDD)	22.5	1.62

RESULTS		
TYPE	PENETRATION	CBR (%)
TOP	2.5mm	2.5

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Checked:	DM

Dave Millard
Laboratory Manager

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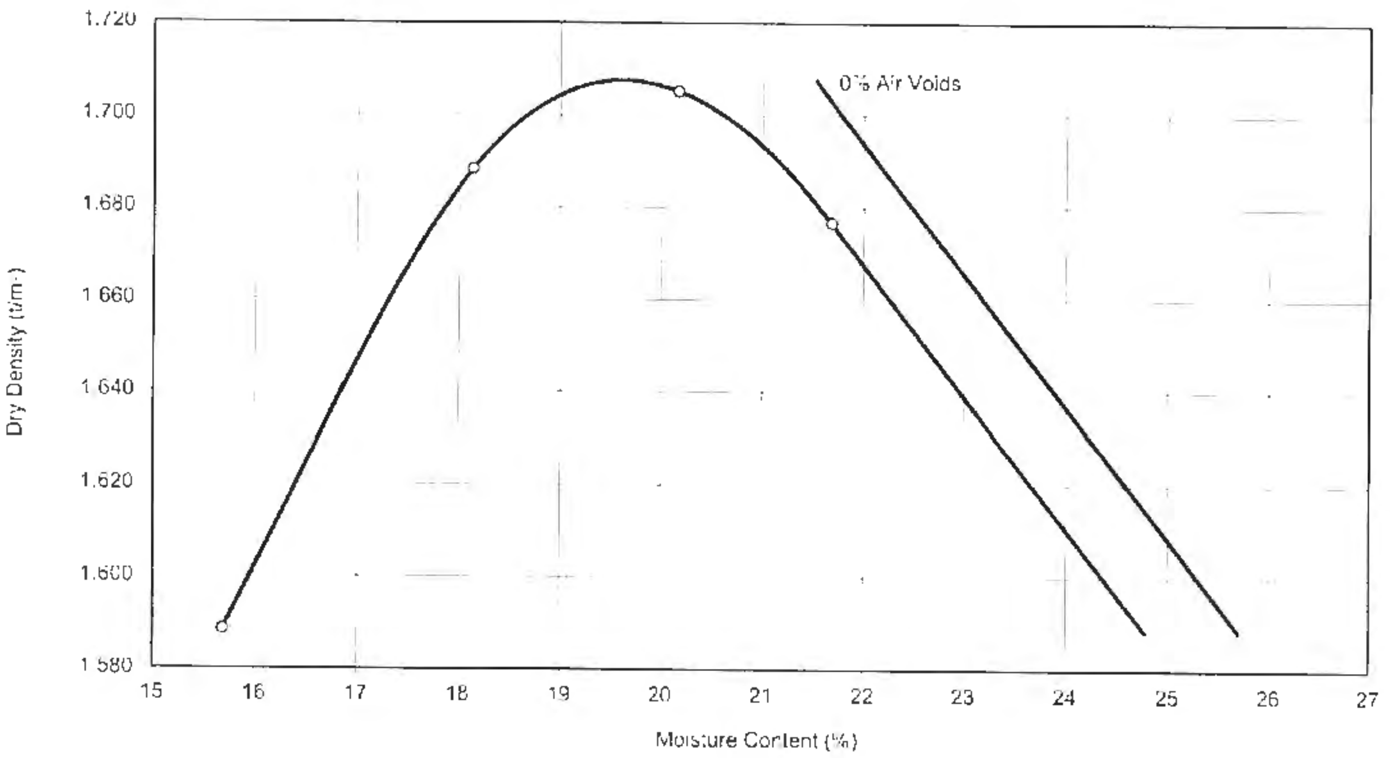
Results of Compaction Test

Client :	NBRS & Partners Pty Ltd	**Project No. :**	81986
		Report No. :	N16-138_3
Project :	Cessnock Correctional Facility	**Report Date :**	29.06.2016
Location :	Cessnock	**Date of Test:**	07.06.2016
		Page:	1 of 1



Sample Details: **Location:** Pit 313

Depth: 0.15 - 0.45m

Particles > 19mm: 0%

Description: CLAY - Red brown

Maximum Dry Density:	1.71 t/m^3
Optimum Moisture Content:	19.5 %

Remarks:

Test Methods: AS 1289.5.1.1, AS 1289.2 1 1

Sampling Methods: Sampled by DP Engineering Department

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Tester AV
Checked DM

Dave Millard
Laboratory Manager

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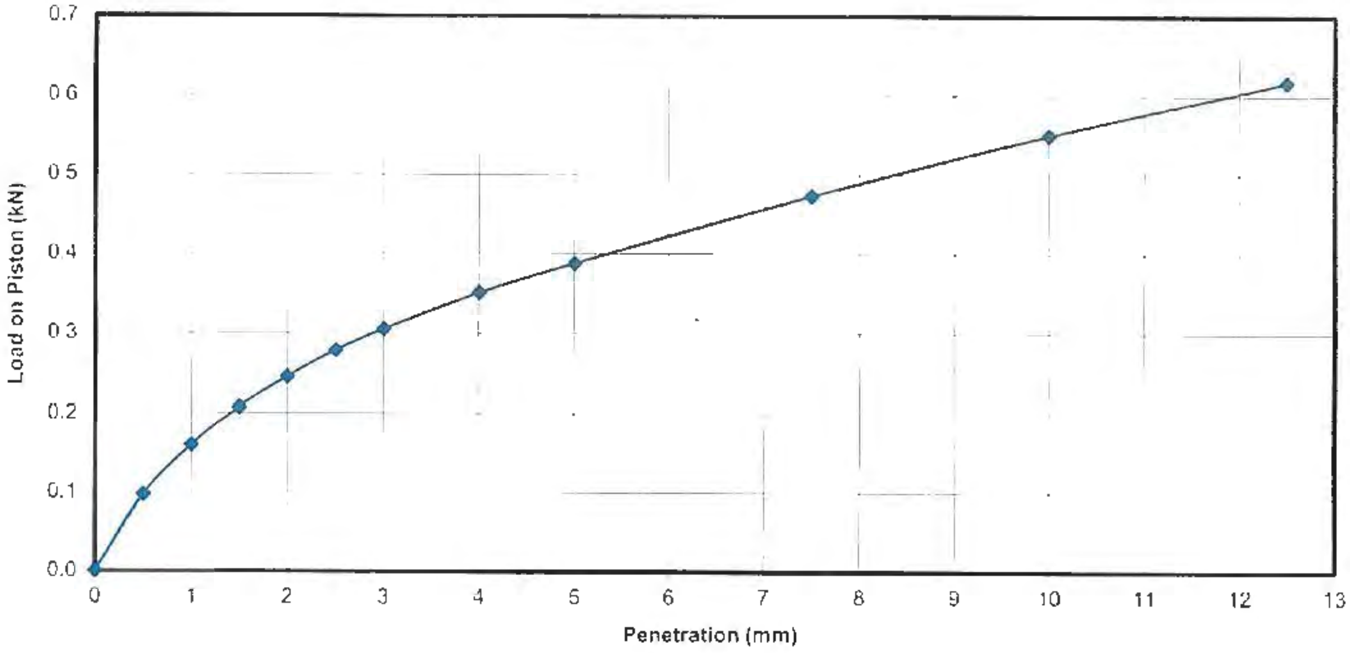
Result of California Bearing Ratio Test

Client :	NBRS & Partners Pty Ltd	**Project No. :**	81986
		Report No. :	N16-138_4
Project :	Cessnock Correctional Facility	**Report Date :**	29.06.2016
		Date Sampled :	25-27.05.16
Location :	Cessnock	**Date of Test:**	14.06.2016
Test Location :	Pit 313		
Depth / Layer :	0.15 - 0.45m	**Page:**	1 of 1



Description:	CLAY - Red brown
Sampling Method(s):	Sampled by DP Engineering Department
Test Method(s):	AS 1289.6.1.1, AS 1289.2.1.1
Remarks:	

Percentage > 19mm: 0.0%

LEVEL OF COMPACTION: 100% of STD MDD
MOISTURE RATIO: 99.5% of STD OMC

SURCHARGE: 4.5 kg
SOAKING PERIOD: 4 days

SWELL: 3.4%

CONDITION		MOISTURE CONTENT %	DRY DENSITY t/m^3
At compaction		19.4	1.71
After soaking		24.1	1.65
After test	Top 30mm of sample	27.6	-
	Remainder of sample	21.2	-
Field values		15.7	-
Standard Compaction	(OMC/MDD)	19.5	1.71

RESULTS		
TYPE	PENETRATION	CBR (%)
TOP	2.5mm	2.0

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Checked:	DM

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Result of Shrink-Swell Index Determination

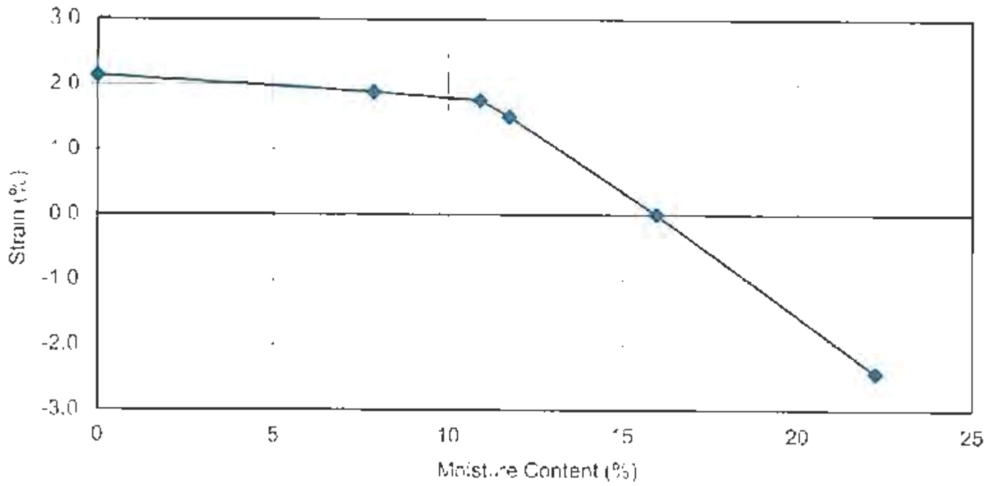
Client :	NBRS & Partners Pty Ltd	**Project No. :**	81986.00
		Report No. :	N16-138_5
Project :	Cessnock Correctional Facility	**Report Date :**	29.06.2016
		Date Sampled :	25-27.05.16
Location :	Cessnock	**Date of Test:**	06.06.2016
Test Location :	Pit 304		
Depth / Layer :	0.5 - 0.7m	**Page:**	1 of 1

CORE SHRINKAGE TEST

Shrinkage - air dried	1.9 %
Shrinkage - oven dried	2.1 %
Significant inert inclusions	0.0 %
Extent of cracking	MC
Extent of soil crumbling	<5 %
Moisture content of core	16.0 %

SWELL TEST

Pocket penetrometer reading at initial moisture content	>600 kPa
Pocket penetrometer reading at final moisture content	320 kPa
Initial Moisture Content	15.0 %
Final Moisture Content	22.3 %
Swell under 25kPa	2.4 %



SHRINK-SWELL INDEX Iss 1.9% per Δ pF

Description: CLAY - Brown

Test Method(s): AS 1289.7.1.1, AS 1289.2.1.1

Sampling Method(s): Sampled by Newcastle Engineering Department

Extent of Cracking:

UC - Uncracked
SC - Slightly cracked
MC - Moderately cracked
HC - Highly cracked
FR - Fractured

Remarks:

Note that NATA accreditation does not cover the performance of pocket penetrometer readings.

NATA Accredited Laboratory Number: 828

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Tested:	PG
Checked:	DM

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Result of Shrink-Swell Index Determination

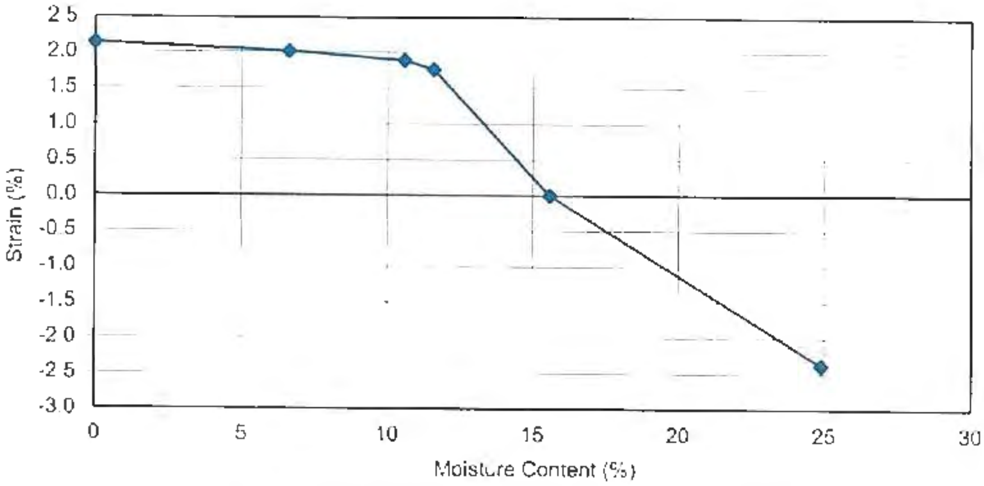
Client :	NBRS & Partners Pty Ltd	**Project No. :**	81986.00
		Report No. :	N16-138_6
Project :	Cessnock Correctional Facility	**Report Date :**	29.06.2016
		Date Sampled :	25-27.05.16
Location :	Cessnock	**Date of Test:**	06.06.2016
Test Location :	Pit 314		
Depth / Layer :	0.35 - 0.55m	**Page:**	1 of 1

CORE SHRINKAGE TEST

Shrinkage - air dried	2.0 %
Shrinkage - oven dried	2.1 %
Significant inert inclusions	<5 %
Extent of cracking	SC
Extent of soil crumbling	5.0 %
Moisture content of core	15.6 %

SWELL TEST

Pocket penetrometer reading at initial moisture content	>600 kPa
Pocket penetrometer reading at final moisture content	280 kPa
Initial Moisture Content	16.1 %
Final Moisture Content	24.9 %
Swell under 25kPa	2.4 %



SHRINK-SWELL INDEX Iss 1.8% per Δ pF

Description:	CLAY - Red brown	
Test Method(s):	AS 1289.7.1.1, AS 1289.2.1.1	
Sampling Method(s):	Sampled by Newcastle Engineering Department	
Extent of Cracking:	**UC** - Uncracked	**HC** - Highly cracked
	SC - Slightly cracked	**FR** - Fractured
	MC - Moderately cracked	

Remarks:

Note that NATA accreditation does not cover
the performance of pocket penetrometer readings

NATA Accredited Laboratory Number 828

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Tested	PG
Checked	DM

Dave Millard
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Results of Moisture Content, Plasticity and Linear Shrinkage Tests

Client:	NBRS & Partners Pty Ltd	**Project No:**	81986
		Report No:	N16-138 7
Project:	Cessnock Correctional Facility	**Report Date:**	29.06.2016
		Date Sampled:	25-27.05.16
Location:	Cessnock	**Date of Test:**	08.06.2016
		Page:	1 of 1

Test Location	Depth (m)	Description	Code	W_F %	W_L %	W_P %	PI %	*LS %
Pit 307	0.50-0.95	Gravelly CLAY - Brown Red	2,5	-	31	12	19	8.5 (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 DP Engineering Department

Remarks:

NATA

TECHNICAL COMPETENCE

NATA Accredited Laboratory Number: 828

[illegible]
[illegible]
traceable to Australian [illegible] standards [illegible]
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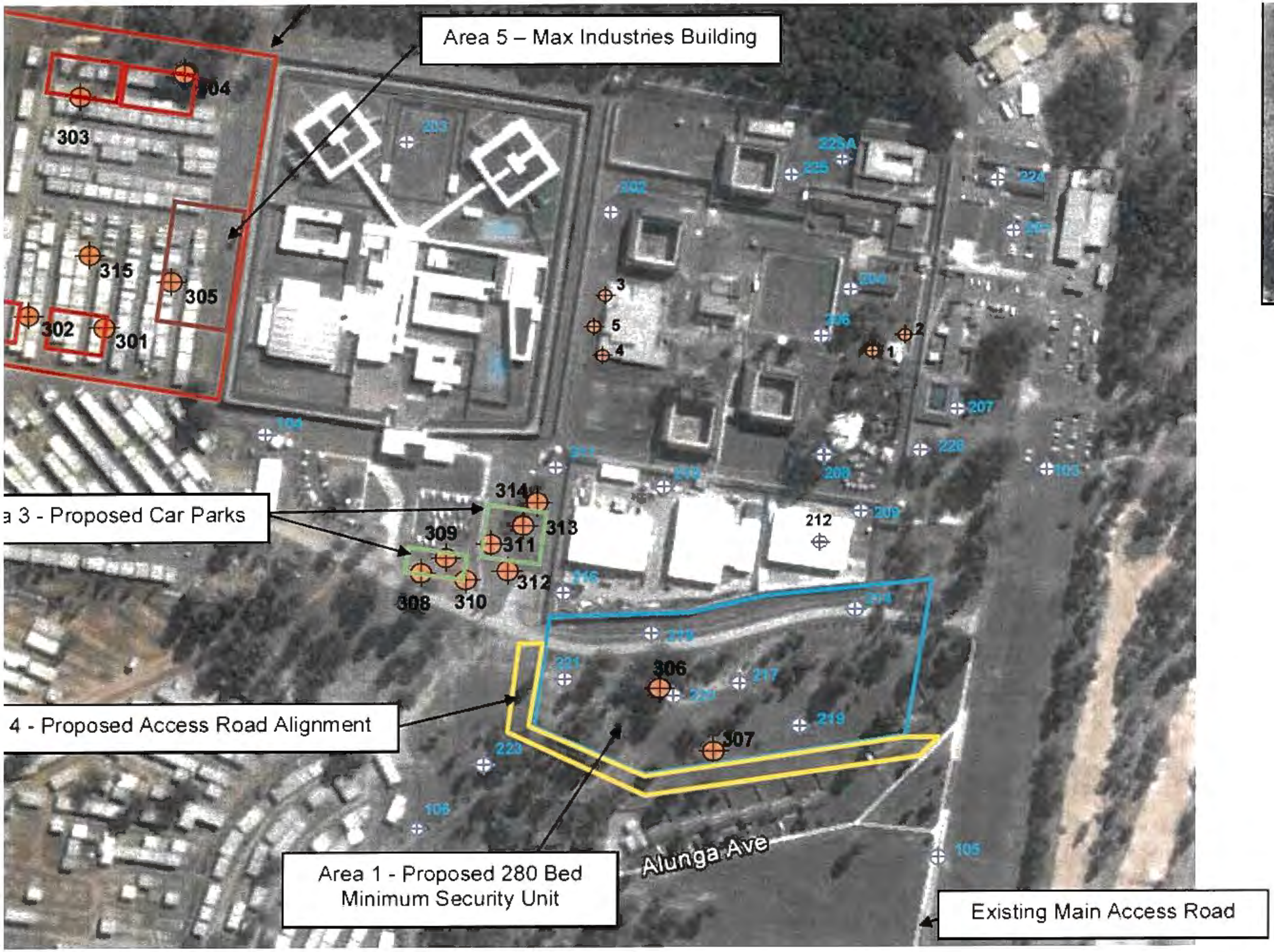
[illegible]
[illegible]

Dave Millard
Laboratory Manager

Appendix D

Drawing 1 – Test Location Plan



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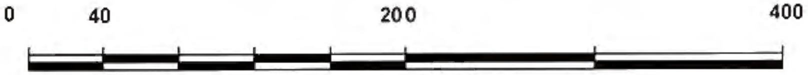
plan provided by the client



Legend:

⊕ Approximate Test Bore Locati

⊕ Approximate Test Bore Locati