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Ref: E32465BDlet-ASSMP

Health Infrastructure
ABN 89 600 377 397
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ACID SULFATE SOIL MANAGEMENT PLAN
PROPOSED MULTI-STOREY CAR PARK
LIVERPOOL HOSPITAL, MAIN CAMPUS, ELIZABETH STREET, LIVERPOOL, NSW

1 INTRODUCTION

Johnstaff Projects Pty Ltd on behalf of Health Infrastructure NSW ('the client') commissioned JK Environments (JKE) prepare an Acid Sulfate Soil Management Plan (ASSMP) for the proposed new multi-storey car park (MSCP) at Liverpool Health + Academic Precinct (Liverpool Hospital), Elizabeth Street, Liverpool, NSW ('the site'). The site location is shown on Figure 1 and the ASSMP applies to the land within the site boundaries as shown on Figure 2 attached in Appendix A.

This report has been prepared for the proposed MSCP development and supports the lodgement of the associated Sate Significant Development Application (SSDA).

JKE have previously investigated the site and prepared a Stage 2 Environmental Site Assessment (ESA)[1]. The JKE Stage 2 ESA incorporated data obtained during a separate JKE Stage 2 ESA[2]. A preliminary Acid Sulfate Soil (ASS) assessment was undertaken in conjunction with the Stage 2 ESA (2019), which included soil sampling from seven boreholes, three boreholes (JKE116, JKE122 and JKE 126) positioned within the MSCP site area. The applicable sampling locations for the site are shown on Figure 2 attached in Appendix A. The JKE Stage 2 ESA (2019) identified potential acid sulfate soils (PASS) at the site. Relevant information from the JKE Stage 2 ESA is summarised within this ASSMP.

The objective of the ASSMP is to reduce the potential on-site and off-site environmental impacts associated with disturbance of PASS.

[1] JKE, (2020). *Report to Health Infrastructure on Stage 2 Environmental Site Assessment for Proposed New Multi-Storey Car Park at Liverpool Health + Academic Precinct, Elizabeth Street, Liverpool, NSW*. Ref: E32465BDrpt5, dated 29 January 2020 (referred to as the 'JKE Stage 2 ESA')
[2] JKE, (2019). *Report to Health Infrastructure on Stage 2 Environmental Site Assessment (ESA) for Proposed Liverpool Hospital – Civil Infrastructure Works, Elizabeth Street, Liverpool, NSW.* Ref: E32465BDrpt4, dated 10 October 2019 (referred to as the 'JKE Stage 2 ESA (2019)')

General information on ASS is presented in Appendix B.

1.1 Proposed Development Details

Based on the supplied information, JKE understand the proposed MSCP development will include demolition of the existing P2 MSCP, associated on-grade car park to the east, and internal roads and landscaped areas in the north-eastern corner of the western campus. A new MSCP (seven levels) is to be constructed in the east section of the site, which will be oriented east-west. Extending off the eastern end of the southern side of the new MSCP will be a circular vehicle ramp structure. We understand that two additional floors may be provided to the structure at a later stage. The proposed car park structure will be supported on piles socketed into the underlying bedrock. An on-grade park associated with the new MSCP is proposed in the west section of the site.

The ground floor level will be constructed at approximately RL10.5m Australian Height Datum (AHD)and will require filling above existing grade to a maximum height of approximately 1m to achieve design subgrade level. Lifts are proposed towards the western end of the southern side of the new MSCP. We have assumed that the lift pit will require excavation to a maximum depth of approximately 2m below design subgrade level. New asphaltic concrete paved roadways and landscaping (including trees, shrubs, grass and synthetic grass) are proposed around the new MSCP. We have not been informed if surplus material will be generated as part of the proposed development.

JKE understand that civil infrastructure works are to occur prior to construction of the new MSCP. The civil infrastructure works are captured under a separate planning pathway.

1.2 Guidelines

The ASS assessment and preparation of this report were undertaken with reference to the Acid Sulfate Soil Management Advisory Committee (ASSMAC) Acid Sulfate Soil Manual (1998)[3] Queensland Acid Sulfate Soil Technical Manual v 3.8 (2002) and to the National Acid Sulfate Soils Guidance (2018) documents.

2 SITE INFORMATION

2.1 Site Identification

Table 2-1: Site Identification

Current Site Owner:	Health Infrastructure NSW
Site Address:	Part of 50 Goulburn Street, Liverpool, NSW (Liverpool Hospital). Address also known as Elizabeth Street, Liverpool, NSW.
Lot & Deposited Plan:	Part of Lot 501 DP 1165217

[3] Acid Sulfate Soils Management Advisory Committee (ASSMAC), (1998). *Acid Sulfate Soils Manual* (ASS Manual 1998)

Current Land Use:	Hospital
Proposed Land Use:	Hospital
Local Government Authority:	Liverpool City Council
Current Zoning:	SP2 Infrastructure (Health Services Facility and Education) – Liverpool LEP 2008 (Liverpool Hospital)
Site Area (m^2):	Approximately 15,000m^2
RL (AHD in m) (approx.):	10-14
Geographical Location (decimal degrees) (approx.):	Latitude: -33.919244 Longitude: 150.932669
Site Location Plan:	Figure 1
Sample Location Plan:	Figure 2

2.2 Site Description

The site is located in a predominantly residential and commercial area of Liverpool. The site is located on east side of Elizabeth Street, the south side of Northern Link Road and Liverpool Girls High School and in the east section of the Liverpool Hospital western campus. Georges River is located approximately 220m to the south-east of the site.

The regional topography is characterised by gentle slopes which generally fall to the east and north east at approximately 1-2°. The site itself is generally flat and appears to have been filled to accommodate the existing hospital buildings and features.

At the time of the inspections for the JKE Stage 2 ESA, the site was utilised by the hospital for predominantly as a MSCP. A disused multistorey residential building (Ron Dunbier Building) was located in the east section of the site. Internal road ways with stormwater drainage curb/gutter alignments were observed in central section of the site.

Sensitive environments such as wetlands, ponds, creeks or extensive areas of natural vegetation were not identified on or in the immediate vicinity of the site.

2.3 Summary of Geology, Soils and Hydrogeology

2.3.1 Regional Geology

Regional geological information presented in the JKE Stage 2 ESA indicated that the site is primarily underlain by Bringelly Shale of the Wianamatta Group, which typically consists of shale, carbonaceous claystone, claystone, laminite, fine to medium grained lithic sandstone, rare coal and tuff. The eastern and north-eastern section of the site are underlain by clayey quartzose sand and clay.

2.3.2 Acid Sulfate Soil (ASS) Risk and Planning

A review of the ASS risk map prepared by Department of Land and Water Conservation (1997)[4] at the time of the JKE Stage 2 ESA indicated that the site is not located within an ASS risk area.

Review of the Liverpool LEP 2008 indicated that the site is located within a Class 5 ASS risk area. Works in Class 5 areas that could pose an environmental risk in terms of ASS include works within 500m of adjacent Class 1,2,3,4 land which are likely to lower the water table below 1m AHD on the adjacent land.

The JKE Stage 2 ESA identified PASS at the site. Further details are discussed in Section 3.

2.3.3 Hydrogeology

Hydrogeological information presented in the JKE Stage 2 ESA indicated that the regional aquifer on-site and, in the areas immediately surrounding the site includes porous, extensive aquifers of low to moderate productivity. There were numerous registered bores within the report buffer of 1,000m. The nearest registered bore was located approximately 136m to the east of the site. There were no nearby, down gradient bores located to the east of the site.

The subsurface conditions at the site consist of relatively shallow imported fill low and moderate permeability (primarily alluvial) sandy soils and clays, overlying relatively deep bedrock.

Standing water levels (SWLs) measured in the monitoring wells JKEMW102, JKEMW122 and JKEMW135 installed at the site ranged from 7.85mBGL to 8.2mBGL. Groundwater monitoring well JKEMW108 reminded dry throughout the investigation. JKE engaged Geomat Engineering Pty Ltd to survey the surface levels (AHD) of the groundwater monitoring wells. Groundwater RLs calculated on these measurements ranged from RL 1.70m (MWJKE122) to RL 2.99m (JKEMW135). A groundwater contour plot was prepared for the groundwater levels using Surfer v11.0.642 (Surface Mapping Program) for the JKE Stage 2 ESA (2019) indicted that groundwater was likely to flow from the west to the north-east in this area of the hospital. Groundwater field measurements recorded during the JKE Stage 2 ESA (2019) were approximately as follows:

- pH ranged from 6.59 to 6.94;
- Electrical conductivity (EC) ranged from 10,224µS/cm to 11,208µS/cm. This indicated that the water was relatively fresh to brackish and supports the conclusion that groundwater is flowing towards the Georges River;
- Redox potential (Eh) ranged from 115.1mV to 194.3mV; and
- Dissolved oxygen (DO) ranged from 0.1ppm to 0.2ppm.

[4] Department of Land and Water Conservation, (1997). *1:25,000 Acid Sulfate Soil Risk Map (Series 9129N4, Ed 2)*

2.3.4 Receiving Water Bodies

The closest surface water body is Georges River which is located approximately 220m to the south-east of the site. Georges River is downgradient from site and is considered to be a potential receptor of excess surface water flows.

3 CONCEPTUAL SITE MODEL FOR PASS MATERIALS

The JKE Stage 2 ESA (2019) preliminary ASS assessment including soil sampling from three boreholes (JKE116, JKE122 and JKE126) within the site, the associated borehole logs are attached in Appendix C. Seven representative soils samples were analysed at the laboratory for Suspension Peroxide Oxidation Combined Acidity & Sulfur (sPOCAS). The laboratory results were compared to the 'coarse textured soils' action criteria presented in the Acid Sulfate Soil Manual (1998)[5] which are summarised below:

- pH - less than 5;
- Total Actual Acidity (TAA)/Total Sulfide Acidity (TSA)/ Total Potential Acidity (TPA) (pH5.5) – greater than 18mol H^+/tonne; and
- S_{pos} – greater than 0.03% sulfur oxidisable.

The results for Stage 2 ESA (2019) are presented in Table R attached in Appendix C. A summary of the result is provided in the following table:

Table 3-1: Summary of ASS Results

Analyte	Results Compared to ASS Guidelines
pH_{kcl} and pH_{ox}	The pH_{KCl} results ranged from 3.8 to 7.8. The pH_{KCl} results for JKE102 (4.7-4.95m), JKE108 (6.0-6.45m), JKE122 (9.0-9.45m), JKE135 (1.75-1.95m) and JKE140 (1.1-1.3m) exceeded (i.e. were below) the action criterion of pH 5. Following oxidation, the pH_{ox} results for the samples ranged from 3.5 to 7.4. The pH_{KCl} results for JKE108 (9.2-9.45m), JKE116 (9.2-9.45m), JKE116 (15.4-15.6m), JKE135 (1.7-1.95m), JKE140 (0.9-1.1m) and JKE140 (1.1-1.3m) exceeded (i.e. were below) the action criterion of pH 5. The pH of the samples typically dropped by one or more units following oxidation. The pH of the extremely weathered siltstone sample JKE116 (15.4-15.6m) dropped by 3.2 units following oxidation. Boreholes JKE116 and JKE122 are located within the proposed MSCP site.
Acid Trail	• TAA results ranged from less than the PQL to 49mol H^+/tonne. The result for the sample JKE140 (1.1-1.3m) was above the action criterion of 18mol H^+/tonne; • TPA results ranged from less than the PQL to 76mol H^+/tonne. The results for the samples JKE116 (15.4-15.6m) and JKE140 (1.1-1.3m) were above the action criterion of 18mol H^+/tonne; and • TSA results ranged from less than PQL to 60mol H^+/tonne. The results for the samples JKE116 (15.4-15.6m) and JKE140 (1.1-1.3m) were above the action criterion of 18mol H^+/tonne. Borehole JKE116 is located within the proposed MSCP site.

[5] Acid Sulfate Soils Management Advisory Committee (ASSMAC), (1998). *Acid Sulfate Soils Manual* (referred to as ASS Manual 1998)

Analyte	Results Compared to ASS Guidelines
Sulfur Trail	The S_{pos}% results ranged for PQL to 0.17%. The S_{pos}% result for the extremely weathered siltstone sample JKE116 (15.4-15.6m) exceeded the action criterion of 0.03%. Borehole JKE116 is located within the proposed MSCP site.
SCr	The extremely weathered siltstone sample JKE116 (15.4-15.6m) was analysed for chromium reducible sulfur (SCr), the result of 0.17% exceeded the action criterion of 0.03%. Borehole JKE116 is located within the proposed MSCP site.
Liming Rate	The liming rate required for neutralisation ranged from PQL to 5.6kg$CaCO_3$/tonne.

Significant S_{pos}% and chromium reducible sulfur (SCr) results were detected in the extremely weathered siltstone sample JKE116 (15.4-15.6m) obtained from JKE borehole JKE116 located with the proposed MSCP site.

The JKE Stage 2 ESA concluded that PASS or ASS conditions were not likely to be disturbed during any near surface earthworks within fill material or earthworks above groundwater undertaken for the MSCP development. However, an ASSMP will be required for any works (e.g. piling) which includes the disturbance of PASS beneath groundwater and/or the PASS detected in the extremely weathered siltstone sample JKE116 (15.4-15.6m).

Considering the above, for the purpose of management under this ASSMP, all natural soil (including extremely weathered bedrock) beneath groundwater is considered to be PASS. The fill material and natural soils is not considered to be PASS. However, separation of non-PASS and PASS during piling works required for the MSCP development are unlikely to be achievable, therefore all pile spoil is considered to be PASS.

4 MANAGEMENT PLAN

4.1 Application

Management requirements are triggered under this ASSMP for all soil disturbance that results in exposure of PASS to air. For this project, this includes all piling works at the site beneath the groundwater table estimated at approximately RL 1.70m AHD at JKE122. JKE understand that the proposed development does not include any other potential works beneath groundwater. Should this change, JKE should be advised as soon as possible and this ASSMP revised if required.

4.2 Roles and Responsibilities

The primary role and responsibility for implementing this ASSMP is the construction contractor. The construction contractor is responsible for obtaining a copy of this ASSMP and taking reasonable steps so that it is adequately implemented.

The construction contractor (or the client) is to engage a validation consultant to monitor the works and validate the implementation of the ASSMP. The validation must be suitably qualified and experienced in ASS assessment and management. This could include a 'Certified Environmental Practitioner' (CEnvP) under the Environment Institute of Australia and New Zealand scheme or a 'Certified Professional Soil Scientist' (CPSS CSAM) under the Soil Science Australia scheme.

4.3 Preferred Strategies for Management

The preferred strategy for managing environmental risks associated with PASS is to eliminate disturbance of the PASS. Where this cannot occur, disturbance is to be limited to the extent practicable and the disturbance is to be managed under this ASSMP. The strategy for excavated PASS will include ex-situ treatment of piling spoil, followed by waste classification and off-site disposal.

Based on the proposed development, disturbance of the PASS will largely be avoided. Disturbance of PASS is only likely to occur during piling works. JKE understand that piling methods for the proposed MSCP development include continuous flight auger (CFA) and or bored piles.

Once the design and construction methodologies (including piling methodologies) are finalised, the validation consultant is to undertake a review of these details in consultation with the client/construction contractor. If the scope of the ASSMP is not considered to be adequate to address the potential environmental risks associated with the disturbance of PASS during the development, an addendum or revised ASSMP is to be prepared and this must be submitted to the consent authority.

4.4 Management of PASS Piling Spoil

The PASS piling spoil will be managed by the addition of lime to neutralise acid that may be generated during and after the excavation works. The treated material is then assigned a waste classification in accordance with the NSW EPA Waste Classification Guidelines - Part 1: Classifying Waste (2014)[6] and NSW EPA Waste Classification Guidelines - Part 4: Acid Sulfate Soils (2014)[7], and disposed off-site to a facility licensed by the NSW EPA to receive the waste.

Reference is to be made to the following table for the ex-situ treatment and management procedure:

Table 4-1: Ex-situ Treatment/Management of PASS

Procedure	Details
Step 1: Lime Selection and Liming Rate Calculations	A suitable lime product is to be selected. A slightly alkaline, low solubility product such as agricultural lime should be used. This form of lime is chemically stable and any excess lime takes a significant period of time (years) to influence soil pH beyond the depth of application. The lime particles eventually become coated with an insoluble layer of ferrihydrite (Fe[OH]3) that inhibits further reaction. Long term alteration of groundwater conditions is not expected to occur as a result of the use of lime during the proposed development works. The construction contractor is to ensure that an appropriate Work Health and Safety Plan (WHSP) is prepared prior to the use of lime.

[6] NSW EPA, (2014). *Waste Classification Guidelines, Part 1: Classifying Waste.* (referred to as Part 1 of the Waste Classification Guidelines 2014)
[7] NSW EPA, (2014). *Waste Classification Guidelines, Part 4: Acid Sulfate Soils.* (referred to as Part 4 of the Waste Classification Guidelines 2014)

Procedure	Details
	A neutralising value (NV), effective neutralising value (ENV) and overall liming rate for ex-situ treatment of PASS is to be calculated based on the type of lime (and its properties) selected, the acid base accounting results presented in the Stage 2 ESA and in accordance with the ASS Manual 1998.
Step 2: Set up treatment area/s	A treatment area for the piling spoil with agricultural lime should be established. Where only small quantities of PASS require treatment, the treatment area could include a leak-proof skip bin. If treatment does not occur in a skip bin, the treatment area must include a relatively impermeable surface for treatment or alternatively be covered with a pad of lime to act as a guard layer. The pad of lime should be at least 100mm thick and this thickness should be maintained for the duration of treatment works. The purpose of this guard layer is to minimise the risk of acidic water leaching from the base of the treatment area into the groundwater. Dependent upon the rate of spoil generation, several bunded treatment areas may be necessary for stockpiling and treatment. An earthworks strategy should be prepared to ensure that sufficient space is available on-site to accommodate treatment of the PASS.
Step 3: Manage water run-off	The piling spoil will be generated from beneath the groundwater table and therefore the PASS being treated on this project are likely to be moist to wet. Installation of detention tanks or construction of ponds may not be viable on this site therefore all stockpiles created should be covered with builder's plastic or similar during rain to prevent the water coming into contact with the stockpiled material. Suitable bunding around the PASS stockpile area/s should be installed. If skip bins are used, bunding should not be necessary. However, the bins should be covered with builder's plastic or similar to prevent them from filling with rainwater. The application of neutralising agents into natural water bodies or water courses should be avoided unless carefully planned and approved by consent authority, council and other relevant authorities.
Step 4: Piling & handling of spoil	PASS disturbed during piling works should be immediately transferred to the designated treatment area and spread out in 150mm to 300mm thick layers. If possible, the layers should be allowed to dry in order to aid the mixing process. The layers should then be interspersed with the appropriate amount of lime to aid in the effective mixing of lime and soil. Lime should be applied to the excavated material within the treatment area as soon as possible. If circumstances prevent the spreading and treatment of the material, the surface area of the stockpile should be minimised by forming a relatively high coned shape and avoiding 'spreading-out' of the stockpile. This will limit the surface area exposed to oxidation. Water infiltration should be minimised by covering the stockpile during wet weather as noted in Step 3. This will limit the formation and transport of acid leachate due to rainfall. The stockpile should be bunded to prevent erosion of the PASS and any movement of potentially acid leachate. Upstream surface runoff water should also be diverted around the stockpile.

Procedure	Details
Step 5: Lime treatment & validation testing	An excavator or other suitable equipment (as deemed appropriate by the construction contractor) should be used to thoroughly mix the lime through the soil. Alternatively, use of a pug mill may be considered dependent upon the volume of soil to be treated in a timely fashion. Once treatment occurs, samples are to be collected from the treated soil at the rates required in the *National Acid Sulfate Soil Guidance: National acid sulfate soils sampling and identification methods manual* (2018). A minim of one sample is required per skip bin/batch of treated soil prior to off-site disposal, and the overall validation frequency must be as follows: • <250m^3, two samples; • 251-500m^3, three samples; • 1,000m^3, four samples; and • >1,000 m^3, four samples plus one sample per additional 500m^3. Field pH may be used as a preliminary indicator where deemed appropriate by the validation consultant. Validation testing is to occur at a NATA accredited laboratory and will include acid base accounting using the chromium reducible sulfur method described in the *National Acid Sulfate Soil Guidance: National acid sulfate soils identification and laboratory methods manual* (2018). The validation net acidity results should be less than the laboratory practical quantitation limits (PQL).
Step 6: Waste classification and off-site disposal	Following treatment, the material should be tested and assigned a waste classification in accordance with the Parts 1 and 4 of the Waste Classification Guidelines 2014. All neutralised material should be disposed of off-site to a facility licensed by the NSW EPA to accept treated PASS. Waste disposal is to be tracked by the construction contractor.

4.5 Groundwater Seepage and Dewatering

JKE understand that the proposed development will not require bulk excavations that extend to the water table and dewatering will not be required. In the event that the scope of the project changes and any bulk excavation extends to the water table and dewatering is required, an *Acid Sulfate Soil Dewatering Management Plan* is to be prepared by the validation consultant. This is to be designed with reference to the *National Acid Sulfate Soil Guidance: Guidance for the dewatering of acid sulfate soils in shallow groundwater environments* (2018).

The plan is to be submitted to the relevant consent authorities for approval prior to the commencement of works.

4.6 Contingency Plan

In the event the results of pile spoil neutralisation monitoring tests indicate a significant change in acidic conditions, the contingency plan should be implemented.

If pile spoil monitoring indicates the presence of significantly more acidic material than expected, all piling works should be placed on hold (where it is safe to do so) until further action is taken to limit the oxidation of PASS in the area of disturbance. Contingency works will be undertaken as follows:

- The pH of stockpiled piling spoil will be measured to establish the source area of the acidic conditions;
- Exposed piling spoil not transferred to the stockpiling area are to be immediately dust with lime and covered with builder's plastic;
- In the event unacceptable acidic levels continue to be recorded, a series of groundwater monitoring wells are to be installed around the boundary of the site and groundwater monitoring (of pH in groundwater) is to commence. Where groundwater pH is found to differ by more than 10-15% of the lower baseline reported for the JKE Stage 2 ESA (see Section 2.3.3 of this ASSMP), installation of a neutralisation trench (or similar) may be required to intercept and treat acidic groundwater. This could consist of an excavation filled with a sand/lime mixture designed to filter, intercept and treat groundwater flowing across the trench.

4.7 Documentation

On completion of the works requiring management under this ASSMP, a validation report is to be prepared by the validation consultant. The validation report is to document the works completed, present the validation testing results and comment on the adequacy of the overall compliance with the ASSMP. Any other specific conditions imposed by consent authority must also be adequately addressed.

5 LIMITATIONS

The report limitations are outlined below:

- JKE accepts no responsibility for any unidentified contamination, ASS or PASS issues at the site. Any unexpected problems/subsurface features that may be encountered during development works should be inspected by an environmental consultant as soon as possible;
- This report has been prepared based on site conditions which existed at the time of the investigation; scope of work and limitation outlined in the JKE proposal; and terms of contract between JKE and the client (as applicable);
- The conclusions presented in this report are based on investigation of conditions at specific locations, chosen to be as representative as possible under the given circumstances, visual observations of the site and immediate surrounds and documents reviewed as described in the report;
- Subsurface soil and rock conditions encountered between investigation locations may be found to be different from those expected. Groundwater conditions may also vary, especially after climatic changes;
- JKE has not undertaken any assessment of off-site areas that may be potential contamination sources or may have been impacted by site contamination, except where specifically stated in the report;
- The investigation and preparation of this report have been undertaken in accordance with accepted practice for environmental consultants, with reference to applicable environmental regulatory authority and industry standards, guidelines and the assessment criteria outlined in the report;

- Where information has been provided by third parties, JKE has not undertaken any verification process, except where specifically stated in the report;
- JKE accept no responsibility for potentially asbestos containing materials that may exist at the site. These materials may be associated with demolition of pre-1990 constructed buildings or fill material at the site;
- JKE have not and will not make any determination regarding finances associated with the site;
- Additional investigation work may be required in the event of changes to the proposed development or landuse. JKE should be contacted immediately in such circumstances;
- This report has been prepared for the particular project described and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose;
- Copyright in this report is the property of JKE. JKE has used a degree of care, skill and diligence normally exercised by consulting professionals in similar circumstances and locality. No other warranty expressed or implied is made or intended. Subject to payment of all fees due for the investigation, the client alone shall have a licence to use this report;
- If the client, or any person, provides a copy of this report to any third party, such third party must not rely on this report except with the express written consent of JKE; and
- Any third party who seeks to rely on this report without the express written consent of JKE does so entirely at their own risk and to the fullest extent permitted by law, JKE accepts no liability whatsoever, in respect of any loss or damage suffered by any such third party.

If you have any questions concerning the contents of this letter please do not hesitate to contact us.

Kind Regards

Mitch Delaney
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Vittal Boggaram
Principal Associate | Environmental Scientist

<u>**Appendices:**</u>

Appendix A: Figures
Appendix B: Information on Acid Sulfate Soils
Appendix C: JKE Stage 2 ESA ASS Table R and Borehole Logs JKE116, JKE122 and JKE126

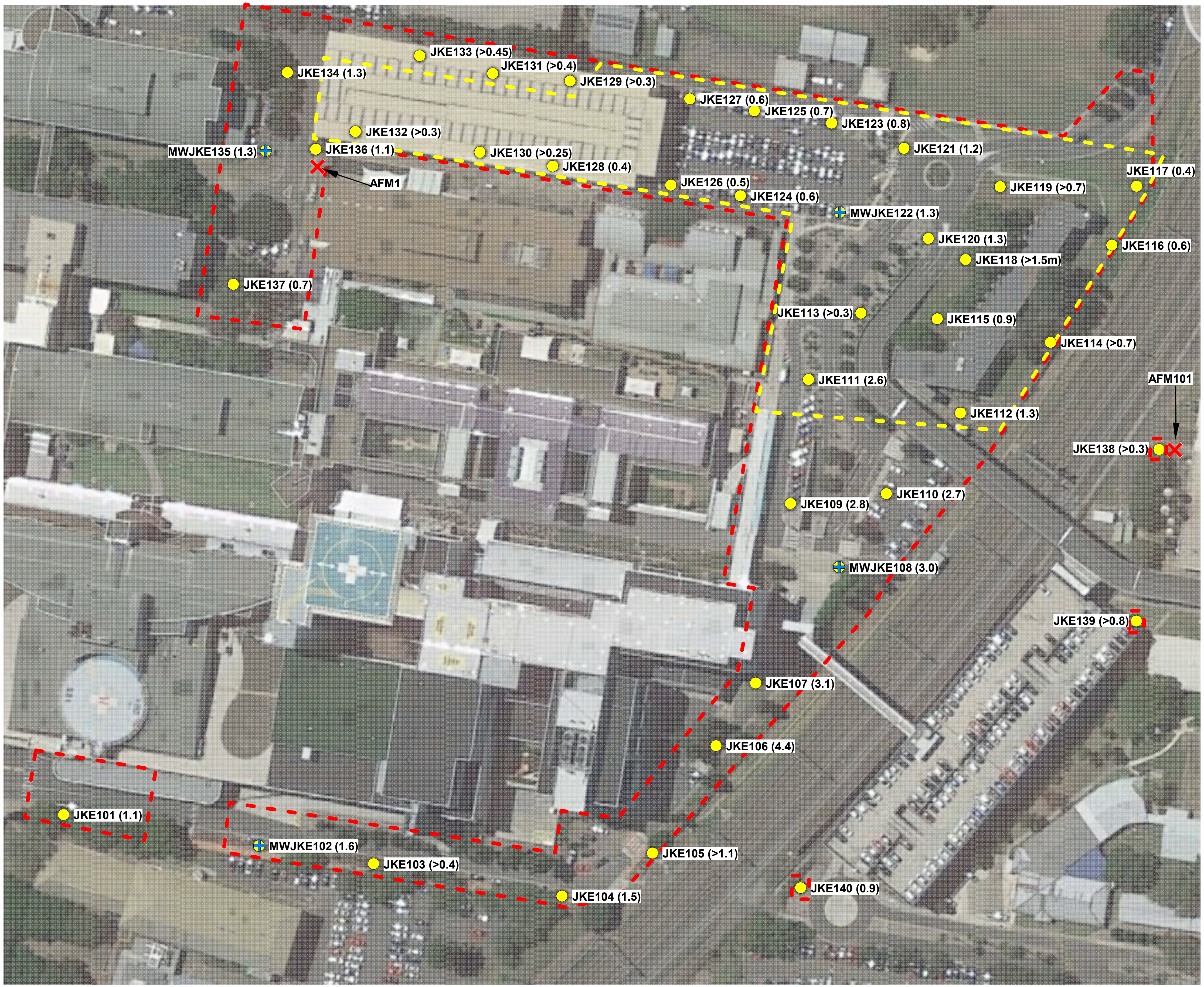
Appendix A: Figures

LEGEND:

APPROXIMATE SITE BOUNDARY AND EXTENT OF MULTI-STOREY CARPARK DEVELOPMENT

Notes: Reference should be made to the report text for a full understanding of this plan. Image Sources: https://maps.six.nsw.gov.au/ and wheris.com

Title:	SITE LOCATION PLAN
Location:	LIVERPOOL HOSPITAL ELIZABETH STREET, LIVERPOOL, NSW
Report No:	E32465BDlet-ASSMP
Figure No:	1
	JK ENVIRONMENTS



LEGEND:

- APPROXIMATE SITE BOUNDARY AND EXTENT OF MULTI-STOREY CARPARK DEVELOPMENT
- APPROXIMATE JKE STAGE 2 ESA (2019) SITE BOUNDARY
- **JKE (0.1)** JKE STAGE 2 ESA (2019) BOREHOLE LOCATION, NUMBER AND DEPTH OF FILL (m)
- **MWJKE (0.1)** JKE STAGE 2 ESA (2019) BOREHOLE AND GROUNDWATER MONITORING WELL LOCATION, NUMBER AND DEPTH OF FILL (m)
- **AMF** ASBESTOS SURFACE FRAGMENT LOCATION

Scale (m) @A3:

0 13 26 39 52 65

Notes: Reference should be made to the report text for a full understanding of this plan.

Image Source: Google Earth

Title:	**SAMPLING LOCATION PLAN**
Location:	LIVERPOOL HOSPITAL ELIZABETH STREET, LIVERPOOL, NSW
Report No: E32465BDlet-ASSMP	Figure No: 2
JK ENVIRONMENTS	

Appendix B: Information on Acid Sulfate Soils

A. Background

Acid Sulfate Soil (ASS) is formed from iron rich alluvial sediments and sulfate (found in seawater) in the presence of sulfate reducing bacteria and plentiful organic matter. These conditions are generally found in mangroves, salt marsh vegetation or tidal areas and at the bottom of coastal rivers and lakes. ASS materials are distinguished from other soil or sediment materials (referred to as 'soil materials' throughout the National Acid Sulfate Soils Guidance) by having properties and behaviour that have either:

1) Been affected considerably by the oxidation of Reduced Inorganic Sulfur (RIS), or
2) The capacity to be affected considerably by the oxidation of their RIS constituents.

Acid sulfate soil materials include Potential acid sulfate soils (PASS or sulfidic soil materials) and Actual acid sulfate soils (AASS or sulfuric soil materials). These are often found in the same profile, with AASS overlying PASS. PASS and AASS are defined further below:

- PASS are soil materials which contain RIS such as pyrite. The field pH of these soils in their undisturbed state is usually more than pH 4 and is commonly neutral to alkaline (pH 7–9). These soil materials are invariably saturated with water in their natural state. Their texture may be peat, clay, loam, silt or sand and is often dark grey in colour and soft in consistence, but these materials may also exhibit colours that are dark brown, or medium to pale grey to white; and
- AASS are soil materials which contained RIS such as pyrite that have undergone oxidation. This oxidation results in low pH (that is pH less than 4) and often a yellow (jarosite) and/or orange to red mottling (ferric iron oxides) in the soil profile. Actual ASS contains Actual Acidity, and commonly also contains RIS (the source of Potential Sulfuric Acidity) as well as Retained Acidity.

B. The ASS Planning Maps

The ASS planning maps provide an indication of the relative potential for disturbance of ASS to occur at locations within the council area. These maps do not provide an indication of the actual occurrence of ASS at a site or the likely severity of the conditions.

The maps are divided into five classes dependent upon the type of activities/works that if undertaken, may represent an environmental risk through the development of acidic conditions associated with ASS:

Table 1: Risk Classes

Risk Class	Description
Class 1	All works.
Class 2	All works below existing ground level and works by which the water table is likely to be lowered.
Class 3	Works at depths beyond 1m below existing ground level or works by which the water table is likely to be lowered beyond 1m below existing ground level.
Class 4	Works at depths beyond 2m below existing ground level or works by which the water table is likely to be lowered beyond 2m below existing ground level.
Class 5	Works within 500m of adjacent Class 1, 2, 3, 4 land which are likely to lower the water table below 1m AHD on the adjacent land.

C. The ASS Risk Maps

The ASS risk maps provide an indication of the probability of occurrence of PASS at a particular location based on interpretation from geological and soil landscape maps. The maps provide classes based on high probability, low probability, no known occurrence and areas of disturbed terrain (site specific assessment necessary) and the likely depth at which ASS are likely to be encountered.

D. Interpretation of ASS Field Tests

Tables A1 and A2 below provide some guidance on the interpretation of pH_F and pH_{FOX} test results, as detailed in the *National Acid Sulfate Soil Guidance: National acid sulfate soils sampling and identification methods manual* (2018):

Table A1: Interpretation of some pH_F test ranges

pH value	Result	Comments
$pH_F \leq 4$, jarosite not observed in the soil layer/horizon	May indicate an AASS indicating previous oxidation of RIS or may indicate naturally occurring, non ASS soils.	Generally not conclusive as naturally occurring, non ASS soils, such as many organic soils (for example peats) and heavily leached soils, often also return $pH_F \leq 4$.
$pH_F \leq 4$, jarosite observed in the soil layer/horizon	The soil material is an AASS.	Jarosite and other iron precipitate minerals in ASS such as schwertmannite require a pH < 4 to form and indicate prior oxidation of RIS.
$pH_F > 7$	Expected in waterlogged, unoxidised, or poorly drained soils.	Marine muds commonly have a pH > 7 which reflects a seawater (pH 8.2) influence. Oxidation of samples with H_2O_2 can help indicate if the soil materials contain RIS.

Source: Adapted from DER (2015a).

Table A2: Interpretation of pH_{FOX} test results

pH value and reaction	Result	Comments
Strong reaction of soil with H_2O_2 (that is X or V)	Useful indicator of the presence of RIS but cannot be used alone	Organic rich substrates such as peat and coffee rock, and soil constituents like manganese oxides, can also cause a reaction. Care must be exercised in interpreting these results. Laboratory analyses are required to confirm if appreciable RIS is present.
pH_{FOX} value at least one unit below field pH_F and strong reaction with H_2O_2 (that is X or V)	May indicate PASS	The difference between pH_F and pH_{FOX} is termed the ΔpH. Generally the larger the ΔpH the more indicative of PASS. The lower the final pH_{FOX} the better the likelihood of an appreciable RIS content. For example, a change from pH_F of 8 to pH_{FOX} of 7 (that is a ΔpH of 1) would not indicate PASS, however, a unit change from pH_F of 3.5 to pH_{FOX} of 2.5 would be indicative of PASS. Laboratory analyses are required to confirm if appreciable RIS is present.
$pH_{FOX} < 3$, large pH and a strong reaction with H_2O_2 (that is X or V)	Strongly indicates PASS	The lower the pH_{FOX} below 3, the greater the likelihood that appreciable RIS is present. A combination of all three parameters – pH_{FOX}, ΔpH and reaction strength –

		gives the best indication of PASS. Laboratory analyses are required to confirm that appreciable RIS is present.
A pH_{FOX} 3–4 and Low, Medium or Strong reaction with H_2O_2	Inconclusive	RIS may be present; however, organic matter may also be responsible for the decrease in pH. Laboratory analyses are required to confirm the presence of RIS.
pH_{FOX} 4–5	Inconclusive	RIS may be present in small quantities, or poorly reactive under rapid oxidation, or the sample may contain shell/ carbonate which neutralises some or all acid produced on oxidation. Equally, the pH_{FOX} value may be due to the production of organic acids with no RIS present. Laboratory analyses are required to confirm if appreciable RIS is present.
pH_{FOX} > 5, small or no pH, but Low, Medium or Strong reaction with H_2O_2	Inconclusive	For neutral to alkaline pHF with shell or white concretions, the fizz test with 1 M HCl can be used to identify the presence of carbonates. Laboratory analyses are required to confirm if appreciable RIS is present and further testing is required to confirm that effective self-neutralising materials are present.

Source: Adapted from DER (2015a).

Appendix C: JKE Stage 2 ESA ASS Table R and Borehole Logs JKE116, JKE122 and JKE126

TABLE R
SUMMARY OF LABORATORY RESULTS - ACID SULFATE SOIL ANALYSIS (sPOCAS)

		Analysis	**pH_{KCL}**	**TAA**	**pH_{ox}**	**TPA**	**TSA**	**S_{POS}**	**SCr**	**Liming Rate**
				pH 6.5		**pH 6.5**	**pH 6.5**	**%w/w**	**%w/w**	**kg $CaCO_3$/tonne**
Acid Sulfate Soil Manual (1998) - Action Criteria		Coarse Textured Soil	pH 5.0	18molH+/ tonne	pH 5.0	18molH+/ tonne	18molH+/ tonne	0.03% w/w	0.03% w/w	
Sample Reference	**Sample Depth (m)**	**Sample Description**								
JKE102	1.2-1.6	F: Silty clay	7.8	<5	5.8	<5	<5	0.03	NA	1.5
JKE102 (replicate)	1.2-1.6	F: Silty clay	7.8	<5	6.1	<5	<5	0.03	NA	1.5
JKE102	4.7-4.95	Silty clay	5.0	5	5.5	16	11	<0.005	NA	<0.75
JKE102	5.0-5.4	Silty clayey sand	5.3	<5	5.8	16	14	<0.005	NA	<0.75
JKE102	9.0-9.45	Silty clay	7.2	<5	6.5	<5	<5	<0.005	NA	<0.75
JKE102	9.8-10.0	Silty clay	7.4	<5	7.3	<5	<5	<0.005	NA	<0.75
JKE108	6.0-6.45	Silty clay	4.8	6	5.7	16	10	<0.005	NA	<0.75
JKE108	7.5-7.95	Sand	5.9	<5	6.6	<5	<5	<0.005	NA	<0.75
JKE108	8.4-8.8	Silty clay	7.1	<5	6.7	<5	<5	<0.005	NA	<0.75
JKE108	9.2-9.45	Silty sand	6.4	<5	5.0	<5	<5	<0.005	NA	<0.75
JKE116	7.6-7.95	Silty clay	6.7	<5	6.4	<5	<5	<0.005	NA	<0.75
JKE116 (replicate)	7.6-7.95	Silty clay	6.6	<5	6.3	<5	<5	<0.005	NA	<0.75
JKE116	8.3-8.6	Sandy clay	6.9	<5	6.4	<5	<5	<0.005	NA	<0.75
JKE116	15.4-15.6	Extremly weathered siltstone	6.7	<5	3.5	60	60	0.17	0.17	5.6
JKE122	8.5-8.8	Silty clay	6.6	<5	6.5	<5	<5	<0.005	NA	<0.75
JKE122	9.0-9.45	Silty clayey sand	4.9	5	5.5	<5	<5	<0.005	NA	<0.75
JKE126	12.5-13.0	Silty clay	7.5	<5	6.8	<5	<5	<0.005	NA	<0.75
JKE126	13.5-13.75	Extremly weathered siltstone	7.4	<5	7.2	<5	<5	0.01	NA	<0.75
JKE135	1.7-1.95	Silty clay	4.8	<5	4.3	5	<5	0.02	NA	1.2
JKE135	9.1-9.45	Silty sandy clay	7.1	<5	7.4	<5	<5	0.008	NA	<0.75
JKE140	0.9-1.1	Silty clay	5.7	5	4.6	<5	<5	0.009	NA	0.8
JKE140	1.1-1.3	Silty clay	3.8	49	4	76	28	<0.005	NA	4
Total Number of Samples			22	22	22	22	22	22	1	22
Minimum Value			3.8	5	3.5	5	5	0.008	0.17	0.8
Maximum Value			7.8	49	7.4	76	60	0.17	0.17	5.6

Values Exceeding Action Criteria **VALUE**

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ENVIRONMENTAL LOG

Log No. **JKE116**
1/3

Environmental logs are not to be used for geotechnical purposes

Client: JOHNSTAFF PROJECTS PTY LTD
Project: PROPOSED LIVERPOOL HOSPITAL - CIVIC & INFRSTUCTURE WORKS
Location: ELIZABETH STREET, LIVERPOOL, NSW

Job No.: E32465BD **Method:** SPIRAL AUGER **R.L. Surface:** ≈ 9.25m
Date: 5/8/2019 **Datum:** AHD
Plant Type: JK205 **Logged/Checked by:** A.M./M.D.

Groundwater Record	Samples (ES / ASS / ASB / SAL / DB)	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION			0			FILL: Sandy gravel, fine to coarse grained, grey, igneous, fine to medium grained sand, trace of organic material.	D			GRASS COVER 12.6kg BUCKET NO FCF NO SPT DUE TO LOOSE GRAVEL COLLAPSE
			1		CI-CH	Silty CLAY: medium to high plasticity, brown mottled grey, trace of root fibres.	w<PL			ALLUVIAL
		N = 21 8,9,12	2			as above, but orange brown mottled grey.				
			3		SP	SAND: fine to coarse grained, light brown.	D			
		N = 19 6,10,9			CL-CI	Sandy CLAY: low to medium plasticity, orange brown mottled grey, fine to medium grained sand.	w<PL			
			4							
		N = 24 7,12,12	5			Sandy CLAY: low to medium plasticity, grey mottled orange brown, fine to medium grained sand.				
						as above, but orange brown mottled grey with ironstone bands.				
		N = 19 6,8,11	6		CL-CI	Silty sandy CLAY: low to medium plasticity, grey with fine to coarse grained sand.	w>PL			
			7		CL-CI	Sandy CLAY: low to medium	w<PL			

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ENVIRONMENTAL LOG

Log No. **JKE116**

2/3

Environmental logs are not to be used for geotechnical purposes

Client: JOHNSTAFF PROJECTS PTY LTD

Project: PROPOSED LIVERPOOL HOSPITAL - CIVIC & INFRSTUCTURE WORKS

Location: ELIZABETH STREET, LIVERPOOL, NSW

Job No.: E32465BD **Method:** SPIRAL AUGER **R.L. Surface:** ≈ 9.25m

Date: 5/8/2019 **Datum:** AHD

Plant Type: JK205 **Logged/Checked by:** A.M./M.D.

Groundwater Record	Field Tests	Depth (m)	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
			CL-CI	plasticity, orange brown mottled grey, fine to coarse grained sand.	w<PL			
				Sandy CLAY: low to medium plasticity, orange brown mottled grey, fine to coarse grained sand.				
▶	N = 16 5,8,8	8	CL-CI	Silty CLAY: low to medium plasticity, grey.	w>PL			
▼			CL-CI	Sandy CLAY: low to medium plasticity orange brown, fine to coarse grained sand.	w>PL			
	N = 6 3,3,3	9	CL-CI	Silty CLAY: low to medium plasticity, grey, with fine to coarse grained sand and ironstone banding.	w>PL			
	N = 18 11,8,10	10 / 11 / 12	CI-CL	Sandy CLAY: low to medium plasticity, orange brown, with fine to coarse grained sand, siltstone and ironstone bands.	w>PL			
	N = 18 11,11,7	13 / 14		Sandy CLAY: low to medium plasticity, dark grey, trace of river and ironstone gravel.				

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ENVIRONMENTAL LOG

Log No. **JKE116**

Environmental logs are not to be used for geotechnical purposes

Client: JOHNSTAFF PROJECTS PTY LTD

Project: PROPOSED LIVERPOOL HOSPITAL - CIVIC & INFRSTUCTURE WORKS

Location: ELIZABETH STREET, LIVERPOOL, NSW

Job No.: E32465BD **Method:** SPIRAL AUGER **R.L. Surface:** ≈ 9.25m

Date: 5/8/2019 **Datum:** AHD

Plant Type: JK205 **Logged/Checked by:** A.M./M.D.

Groundwater Record	SAMPLES (ES, ASS, ASB, SAL, DB)	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
			15		CI-CL	Sandy CLAY: low to medium plasticity, dark grey, trace of river and ironstone gravel.	w>PL			
	ASS, SAL				-	Extremely Weathered siltstone: silty CLAY, medium to high plasticity, grey mottled brown.	XW			BRINGELLY SHALE
						END OF BOREHOLE AT 15.6m				
			16							
			17							
			18							
			19							
			20							

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ENVIRONMENTAL LOG

Log No. **JKE122** 1/2

Environmental logs are not to be used for geotechnical purposes

Client: JOHNSTAFF PROJECTS PTY LTD

Project: PROPOSED LIVERPOOL HOSPITAL - CIVIC & INFRSTUCTURE WORKS

Location: ELIZABETH STREET, LIVERPOOL, NSW

Job No.: E32465BD **Method:** SPIRAL AUGER **R.L. Surface:** ≈ 9.98m

Date: 6/8/2019 **Datum:** AHD

Plant Type: JK205 **Logged/Checked by:** A.M./M.D.

Groundwater Record	Field Tests	Depth (m)	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
		0	-	ASPHALTIC CONCRETE: 40mm.t				
				FILL: Gravelly sand, fine to medium grained, brown, fine to coarse grained igneous.	D			8.8kg BUCKET NO FCF
	N = 12 5,7,5			FILL: Silty clay, low to medium plasticity, brown, with fine to coarse grained sand, trace of igneous gravel and ash.	w>PL			4.2kg BUCKET NO FCF
		1		FILL: Silty clay, medium to high plasticity, dark grey, trace of sandstone, ironstone and igneous gravel, brick fragments and ash.	w≈PL			7.3kg BUCKET NO FCF
	N = 8 3,3,5		CI-CH	Silty CLAY: medium to high plasticity, brown mottled grey, trace of root fibres.	w>PL			ALLUVIAL
		2	CL-CI	Silty CLAY: low to medium plasticity, orange brown.				
	N = 20 6,10,10	3	CI-CH	Silty CLAY: medium to high plasticity, orange brown mottled grey, with ironstone gravel.	w<PL			
	N = 16 8,9,7	4, 5						
	N = 16 8,7,9	6	SC	Clayey SAND: fine to coarse grained, grey mottled orange brown.	D			
		7	CI-CH	Silty CLAY: medium to high plasticity, orange brown mottled grey, with ironstone banding.	w<PL			

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ENVIRONMENTAL LOG

Environmental logs are not to be used for geotechnical purposes

Log No. **JKE122** 2/2

Client: JOHNSTAFF PROJECTS PTY LTD

Project: PROPOSED LIVERPOOL HOSPITAL - CIVIC & INFRSTUCTURE WORKS

Location: ELIZABETH STREET, LIVERPOOL, NSW

Job No.: E32465BD **Method:** SPIRAL AUGER **R.L. Surface:** ≈ 9.98m

Date: 6/8/2019 **Datum:** AHD

Plant Type: JK205 **Logged/Checked by:** A.M./M.D.

Groundwater Record	SAMPLES (ES, ASS, ASB, SAL, DB)	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
ON 16/8/19		N = 20 6,9,11	8		CI_CH	Silty CLAY: medium to high plasticity, orange brown mottled grey, with ironstone banding.	w<PL			
ON COMPLE-TION OF AUGER-ING		N = 31 10,15,16	9		-	Silty clayey SAND: fine to coarse grained, red brown mottled grey.	M			
			10			END OF BOREHOLE AT 10.0m				Groundwater monitoring well installed to 10.0m. Class 18 machine slotted 50mm dia. PVC standpipe 10.0m to 2.0m. Casing 2.0m to 0.0m. 2mm sand filter pack 10.0m to 1.5m. Bentonite seal 1.5m to 1.0m. Backfilled with sand (and/or cuttings) to the surface. Completed with a concreted gatic cover.
			11							
			12							
			13							
			14							

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ENVIRONMENTAL LOG

Environmental logs are not to be used for geotechnical purposes

Log No. **JKE126** 1/2

Client: JOHNSTAFF PROJECTS PTY LTD

Project: PROPOSED LIVERPOOL HOSPITAL - CIVIC & INFRSTUCTURE WORKS

Location: ELIZABETH STREET, LIVERPOOL, NSW

Job No.: E32465BD **Method:** SPIRAL AUGER **R.L. Surface:** ≈ 9.76m

Date: 7/8/2019 **Datum:** AHD

Plant Type: JK305 **Logged/Checked by:** A.M./M.D.

Groundwater Record	Field Tests	Depth (m)	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
		0		ASPHALTIC CONCRETE: 80mm.t				
			-	FILL: Silty sand, fine to medium grained, brown, trace of igneous gravel.	D			5.4kg BUCKET NO FCF
					w>PL			3.1kg BUCKET NO FCF
	N = 13 5,6,7		CI-CH	FILL: Silty clay, low to medium plasticity, brown, trace of sandstone gravel.	w<PL			ALLUVIAL
		1		Silty CLAY: medium to high plasticity, brown mottled grey.				
	N = 29 6,10,19							
		2	CI-CH	Silty sandy CLAY: medium to high plasticity, red brown mottled orange brown, fine to coarse grained sand.	w>PL			
	N = 16 8,8,8	3						
		4	CI-CH	Silty CLAY: medium to high plasticity, red brown, trace of ironstone gravel.	w>PL			
	N = 20 5,8,12		CL-CI	Sandy CLAY: low to medium plasticity, grey, fine to coarse grained sand.	w>PL			
		5	SM	Silty SAND: fine to coarse grained, light brown.	D			
	N = 20 9,12,8	6		as above, but light brown mottled grey.				
		7	-	Silty clayey SAND: fine to coarse	M			

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ENVIRONMENTAL LOG

Log No. **JKE126**

Environmental logs are not to be used for geotechnical purposes

Client: JOHNSTAFF PROJECTS PTY LTD

Project: PROPOSED LIVERPOOL HOSPITAL - CIVIC & INFRSTUCTURE WORKS

Location: ELIZABETH STREET, LIVERPOOL, NSW

Job No.: E32465BD **Method:** SPIRAL AUGER **R.L. Surface:** ≈ 9.76m

Date: 7/8/2019 **Datum:** AHD

Plant Type: JK305 **Logged/Checked by:** A.M./M.D.

Groundwater Record	SAMPLES (ES, ASS, ASB, SAL, DB)	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
		N = 18 11,10,8	8			grained, orange brown, trace of igneous gravel.	M			
▶ ▼ ON COMPLETION OF AUGERING		N = 24 10,12,12	9		SM	Silty SAND: fine to coarse grained, brown, trace of clay fines.	M			
			10		CL-CI	Silty CLAY: low to medium plasticity, grey with siltstone and sand banding.	w<PL			
		N = 15 5,7,8	11			as above, but grey mottled brown.	w>PL			
			12			Silty CLAY: low to medium plasticity, brown, with siltstone banding.				RESIDUAL
		N > 20 20,20/ 100mm REFUSAL	13		-	Extremely Weathered siltstone: silty CLAY, medium plasticity, dark grey.	XW			BRINGELLY SHALE
			14			END OF BOREHOLE AT 13.75m				

ENVIRONMENTAL LOGS EXPLANATION NOTES

INTRODUCTION

These notes have been provided to amplify the environmental report in regard to classification methods, field procedures and certain matters relating to the logging of soil and rock. Not all notes are necessarily relevant to all reports.

Where geotechnical borehole logs are utilised for environmental purpose, reference should also be made to the explanatory notes included in the geotechnical report. Environmental logs are not suitable for geotechnical purposes.

The ground is a product of continuing natural and man-made processes and therefore exhibits a variety of characteristics and properties which vary from place to place and can change with time. Environmental studies include gathering and assimilating limited facts about these characteristics and properties in order to understand or predict the behaviour of the ground on a particular site under certain conditions. This report may contain such facts obtained by inspection, excavation, probing, sampling, testing or other means of investigation. If so, they are directly relevant only to the ground at the place where and time when the investigation was carried out.

DESCRIPTION AND CLASSIFICATION METHODS

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726:2017 *'Geotechnical Site Investigations'*. In general, descriptions cover the following properties – soil or rock type, colour, structure, strength or density, and inclusions. Identification and classification of soil and rock involves judgement and the Company infers accuracy only to the extent that is common in current geoenvironmental practice.

Soil types are described according to the predominating particle size and behaviour as set out in the attached soil classification table qualified by the grading of other particles present (eg. sandy clay) as set out below:

Soil Classification	Particle Size
Clay	< 0.002mm
Silt	0.002 to 0.075mm
Sand	0.075 to 2.36mm
Gravel	2.36 to 63mm
Cobbles	63 to 200mm
Boulders	> 200mm

Non-cohesive soils are classified on the basis of relative density, generally from the results of Standard Penetration Test (SPT) as below:

Relative Density	SPT 'N' Value (blows/300mm)
Very loose (VL)	< 4
Loose (L)	4 to 10
Medium dense (MD)	10 to 30
Dense (D)	30 to 50
Very Dense (VD)	> 50

Cohesive soils are classified on the basis of strength (consistency) either by use of a hand penetrometer, vane shear, laboratory testing and/or tactile engineering examination. The strength terms are defined as follows.

Classification	Unconfined Compressive Strength (kPa)	Indicative Undrained Shear Strength (kPa)
Very Soft (VS)	≤ 25	≤ 12
Soft (S)	> 25 and ≤ 50	> 12 and ≤ 25
Firm (F)	> 50 and ≤ 100	> 25 and ≤ 50
Stiff (St)	> 100 and ≤ 200	> 50 and ≤ 100
Very Stiff (VSt)	> 200 and ≤ 400	> 100 and ≤ 200
Hard (Hd)	> 400	> 200
Friable (Fr)	Strength not attainable – soil crumbles	

Rock types are classified by their geological names, together with descriptive terms regarding weathering, strength, defects, etc. Where relevant, further information regarding rock classification is given in the text of the report. In the Sydney Basin, 'shale' is used to describe fissile mudstone, with a weakness parallel to bedding. Rocks with alternating inter-laminations of different grain size (eg. siltstone/claystone and siltstone/fine grained sandstone) are referred to as 'laminite'.

INVESTIGATION METHODS

The following is a brief summary of investigation methods currently adopted by the Company and some comments on their use and application. All methods except test pits, hand auger drilling and portable Dynamic Cone Penetrometers require the use of a mechanical rig which is commonly mounted on a truck chassis or track base.

Test Pits: These are normally excavated with a backhoe or a tracked excavator, allowing close examination of the insitu soils and 'weaker' bedrock if it is safe to descend into the pit. The depth of penetration is limited to about 3m for a backhoe and up to 6m for a large excavator. Limitations of test pits are the problems associated with disturbance and difficulty of reinstatement and the consequent effects on close-by structures. Care must be taken if construction is to be carried out near test pit locations to either properly recompact the backfill during construction or to design and construct the structure so as not to be adversely affected by poorly compacted backfill at the test pit location.

Hand Auger Drilling: A borehole of 50mm to 100mm diameter is advanced by manually operated equipment. Refusal of the hand auger can occur on a variety of materials such as obstructions within any fill, tree roots, hard clay, gravel or ironstone, cobbles and boulders, and does not necessarily indicate rock level.

Continuous Spiral Flight Augers: The borehole is advanced using 75mm to 115mm diameter continuous spiral flight augers, which are withdrawn at intervals to allow sampling and insitu testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface by the flights or may be collected after withdrawal of the auger flights, but they can be very disturbed and layers may become mixed. Information from the auger sampling (as distinct from specific sampling by SPTs or undisturbed samples) is of limited reliability due to mixing or softening of samples by groundwater, or uncertainties as to the original depth of the samples. Augering below the groundwater table is of even lesser reliability than augering above the water table.

Rock Augering: Use can be made of a Tungsten Carbide (TC) bit for auger drilling into rock to indicate rock quality and continuity by variation in drilling resistance and from examination of recovered rock cuttings. This method of investigation is quick and relatively inexpensive but provides only an indication of the likely rock strength and predicted values may be in error by a strength order. Where rock strengths may have a significant impact on construction feasibility or costs, then further investigation by means of cored boreholes may be warranted.

Wash Boring: The borehole is usually advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be assessed from the cuttings, together with some information from "feel" and rate of penetration.

Mud Stabilised Drilling: Either Wash Boring or Continuous Core Drilling can use drilling mud as a circulating fluid to stabilise the borehole. The term 'mud' encompasses a range of products ranging from bentonite to polymers. The mud tends to mask the cuttings and reliable identification is only possible from intermittent intact sampling (eg. from SPT and U50 samples) or from rock coring, etc.

Continuous Core Drilling: A continuous core sample is obtained using a diamond tipped core barrel. Provided full core recovery is achieved (which is not always possible in very low strength rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation. In rocks, NMLC or HQ triple tube core barrels, which give a core of about 50mm and 61mm diameter, respectively, is usually used with water flush. The length of core recovered is compared to the length drilled and any length not recovered is shown as NO CORE. The location of NO CORE recovery is determined on site by the supervising engineer; where the location is uncertain, the loss is placed at the bottom of the drill run.

Standard Penetration Tests: Standard Penetration Tests (SPT) are used mainly in non-cohesive soils, but can also be used in cohesive soils, as a means of indicating density or strength and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289.6.3.1–2004 (R2016) *'Methods of Testing Soils for Engineering Purposes, Soil Strength and Consolidation Tests – Determination of the Penetration Resistance of a Soil – Standard Penetration Test (SPT)'*.

The test is carried out in a borehole by driving a 50mm diameter split sample tube with a tapered shoe, under the impact of a 63.5kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm 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 150mm of, say, 4, 6 and 7 blows, as

  N = 13
  4, 6, 7

- In a case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm, as

  N > 30
  15, 30/40mm

The results of the test can be related empirically to the engineering properties of the soil.

A modification to the SPT is where the same driving system is used with a solid 60° tipped steel cone of the same diameter as the SPT hollow sampler. The solid cone can be continuously driven for some distance in soft clays or loose sands, or may be used where damage would otherwise occur to the SPT. The results of this Solid Cone Penetration Test (SCPT) are shown as 'N_c' on the borehole logs, together with the number of blows per 150mm penetration.

LOGS

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

The terms and symbols used in preparation of the logs are defined in the following pages.

Interpretation of the information shown on the logs, and its application to design and construction, should therefore take into account the spacing of boreholes or test pits, the method of drilling or excavation, the frequency of sampling and testing and the possibility of other than 'straight line' variations between the boreholes or test pits. Subsurface conditions between boreholes or test pits may vary significantly from conditions encountered at the borehole or test pit locations.

GROUNDWATER

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

- Although groundwater may be present, in low permeability soils it may enter the hole slowly or perhaps not at all during the time it 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 and may not be the same at the time of construction.
- 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 be washed out of the hole or 'reverted' chemically if reliable water observations are to be made.

More reliable measurements can be made by installing standpipes which are read after the groundwater level has stabilised at intervals ranging from several days to 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 perched water tables or surface water.

FILL

The presence of fill materials can often be determined only by the inclusion of foreign objects (eg. bricks, steel, etc) or by distinctly unusual colour, texture or fabric. Identification of the extent of fill materials will also depend on investigation methods and frequency. Where natural soils similar to those at the site are used for fill, it may be difficult with limited testing and sampling to reliably assess the extent of the fill.

The presence of fill materials is usually regarded with caution as the possible variation in density and material type is much greater than with natural soil deposits. Consequently, there is an increased risk of adverse environmental characteristics or behaviour. If the volume and nature of fill is of importance to a project, then frequent test pit excavations are preferable to boreholes.

LABORATORY TESTING

Laboratory testing has not been undertaken to confirm the soil classification and rock strengths indicated on the environmental logs unless noted in the report.

SYMBOL LEGENDS

SOIL

FILL

TOPSOIL

CLAY (CL, CI, CH)

SILT (ML, MH)

SAND (SP, SW)

GRAVEL (GP, GW)

SANDY CLAY (CL, CI, CH)

SILTY CLAY (CL, CI, CH)

CLAYEY SAND (SC)

SILTY SAND (SM)

GRAVELLY CLAY (CL, CI, CH)

CLAYEY GRAVEL (GC)

SANDY SILT (ML, MH)

PEAT AND HIGHLY ORGANIC SOILS (Pt)

ROCK

CONGLOMERATE

SANDSTONE

SHALE/MUDSTONE

SILTSTONE

CLAYSTONE

COAL

LAMINITE

LIMESTONE

PHYLLITE, SCHIST

TUFF

GRANITE, GABBRO

DOLERITE, DIORITE

BASALT, ANDESITE

QUARTZITE

OTHER MATERIALS

BRICKS OR PAVERS

CONCRETE

ASPHALTIC CONCRETE

CLASSIFICATION OF COARSE AND FINE GRAINED SOILS

Major Divisions		Group Symbol	Typical Names	Field Classification of Sand and Gravel	Laboratory Classification	
Coarse grained soil (more than 65% of soil excluding oversize fraction is greater than 0.075mm)	GRAVEL (more than half of coarse fraction is larger than 2.36mm	GW	Gravel and gravel-sand mixtures, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength	≤ 5% fines	$C_u > 4$ $1 < C_c < 3$
		GP	Gravel and gravel-sand mixtures, little or no fines, uniform gravels	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength	≤ 5% fines	Fails to comply with above
		GM	Gravel-silt mixtures and gravel-sand-silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength	≥ 12% fines, fines are silty	Fines behave as silt
		GC	Gravel-clay mixtures and gravel-sand-clay mixtures	'Dirty' materials with excess of plastic fines, medium to high dry strength	≥ 12% fines, fines are clayey	Fines behave as clay
	SAND (more than half of coarse fraction is smaller than 2.36mm)	SW	Sand and gravel-sand mixtures, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength	≤ 5% fines	$C_u > 6$ $1 < C_c < 3$
		SP	Sand and gravel-sand mixtures, little or no fines	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength	≤ 5% fines	Fails to comply with above
		SM	Sand-silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength	≥ 12% fines, fines are silty	N/A
		SC	Sand-clay mixtures	'Dirty' materials with excess of plastic fines, medium to high dry strength	≥ 12% fines, fines are clayey	

Major Divisions		Group Symbol	Typical Names	Field Classification of Silt and Clay			Laboratory Classification
				Dry Strength	Dilatancy	Toughness	% < 0.075mm
ine grained soils (more than 35% of soil excluding oversize fraction is less than 0.075mm)	SILT and CLAY (low to medium plasticity)	ML	Inorganic silt and very fine sand, rock flour, silty or clayey fine sand or silt with low plasticity	None to low	Slow to rapid	Low	Below A line
		CL, CI	Inorganic clay of low to medium plasticity, gravelly clay, sandy clay	Medium to high	None to slow	Medium	Above A line
		OL	Organic silt	Low to medium	Slow	Low	Below A line
	SILT and CLAY (high plasticity)	MH	Inorganic silt	Low to medium	None to slow	Low to medium	Below A line
		CH	Inorganic clay of high plasticity	High to very high	None	High	Above A line
		OH	Organic clay of medium to high plasticity, organic silt	Medium to high	None to very slow	Low to medium	Below A line
	Highly organic soil	Pt	Peat, highly organic soil	–	–	–	–

Laboratory Classification Criteria

A well graded coarse grained soil is one for which the coefficient of uniformity $Cu > 4$ and the coefficient of curvature $1 < C_c < 3$. Otherwise, the soil is poorly graded. These coefficients are given by:

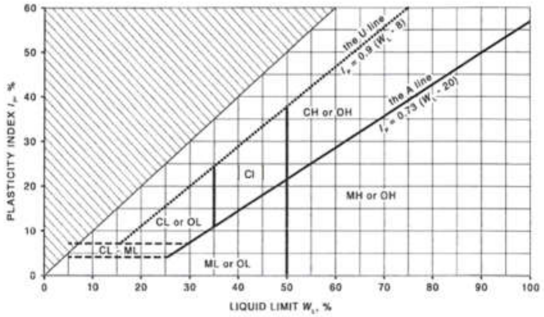
$$C_U = \frac{D_{60}}{D_{10}} \quad \text{and} \quad C_C = \frac{(D_{30})^2}{D_{10}\,D_{60}}$$

Where D_{10}, D_{30} and D_{60} are those grain sizes for which 10%, 30% and 60% of the soil grains, respectively, are smaller.

NOTES:

1. For a coarse grained soil with a fines content between 5% and 12%, the soil is given a dual classification comprising the two group symbols separated by a dash; for example, for a poorly graded gravel with between 5% and 12% silt fines, the classification is GP-GM.
2. Where the grading is determined from laboratory tests, it is defined by coefficients of curvature (C_c) and uniformity (C_u) derived from the particle size distribution curve.
3. Clay soils with liquid limits > 35% and ≤ 50% may be classified as being of medium plasticity.
4. The U line on the Modified Casagrande Chart is an approximate upper bound for most natural soils.

Modified Casagrande Chart for Classifying Silts and Clays according to their Behaviour



LOG SYMBOLS

Log Column	Symbol	Definition
Groundwater Record	▼	Standing water level. Time delay following completion of drilling/excavation may be shown.
	C	Extent of borehole/test pit collapse shortly after drilling/excavation.
	▶	Groundwater seepage into borehole or test pit noted during drilling or excavation.
Samples	ES	Sample taken over depth indicated, for environmental analysis.
	U50	Undisturbed 50mm diameter tube sample taken over depth indicated.
	DB	Bulk disturbed sample taken over depth indicated.
	DS	Small disturbed bag sample taken over depth indicated.
	ASB	Soil sample taken over depth indicated, for asbestos analysis.
	ASS	Soil sample taken over depth indicated, for acid sulfate soil analysis.
	SAL	Soil sample taken over depth indicated, for salinity analysis.
Field Tests	N = 17 4, 7, 10	Standard Penetration Test (SPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration. 'Refusal' refers to apparent hammer refusal within the corresponding 150mm depth increment.
	N_c = 5 7 3R	Solid Cone Penetration Test (SCPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration for 60° solid cone driven by SPT hammer. 'R' refers to apparent hammer refusal within the corresponding 150mm depth increment.
	VNS = 25	Vane shear reading in kPa of undrained shear strength.
	PID = 100	Photoionisation detector reading in ppm (soil sample headspace test).
Moisture Condition (Fine Grained Soils)	w > PL	Moisture content estimated to be greater than plastic limit.
	w ≈ PL	Moisture content estimated to be approximately equal to plastic limit.
	w < PL	Moisture content estimated to be less than plastic limit.
	w ≈ LL	Moisture content estimated to be near liquid limit.
	w > LL	Moisture content estimated to be wet of liquid limit.
(Coarse Grained Soils)	D	DRY – runs freely through fingers.
	M	MOIST – does not run freely but no free water visible on soil surface.
	W	WET – free water visible on soil surface.
Strength (Consistency) Cohesive Soils	VS	VERY SOFT – unconfined compressive strength ≤ 25kPa.
	S	SOFT – unconfined compressive strength > 25kPa and ≤ 50kPa.
	F	FIRM – unconfined compressive strength > 50kPa and ≤ 100kPa.
	St	STIFF – unconfined compressive strength > 100kPa and ≤ 200kPa.
	VSt	VERY STIFF – unconfined compressive strength > 200kPa and ≤ 400kPa.
	Hd	HARD – unconfined compressive strength > 400kPa.
	Fr	FRIABLE – strength not attainable, soil crumbles.
	( )	Bracketed symbol indicates estimated consistency based on tactile examination or other assessment.
Density Index/ Relative Density (Cohesionless Soils)		**Density Index (I_D) Range (%)** / **SPT 'N' Value Range (Blows/300mm)**
	VL	VERY LOOSE ≤ 15 / 0 – 4
	L	LOOSE > 15 and ≤ 35 / 4 – 10
	MD	MEDIUM DENSE > 35 and ≤ 65 / 10 – 30
	D	DENSE > 65 and ≤ 85 / 30 – 50
	VD	VERY DENSE > 85 / > 50
	( )	Bracketed symbol indicates estimated density based on ease of drilling or other assessment.
Hand Penetrometer Readings	300 250	Measures reading in kPa of unconfined compressive strength. Numbers indicate individual test results on representative undisturbed material unless noted otherwise.

Log Column	Symbol	Definition
Remarks	'V' bit	Hardened steel 'V' shaped bit.
	'TC' bit	Twin pronged tungsten carbide bit.
	T_{60}	Penetration of auger string in mm under static load of rig applied by drill head hydraulics without rotation of augers.
	Soil Origin	The geological origin of the soil can generally be described as:
		RESIDUAL – soil formed directly from insitu weathering of the underlying rock. No visible structure or fabric of the parent rock.
		EXTREMELY WEATHERED – soil formed directly from insitu weathering of the underlying rock. Material is of soil strength but retains the structure and/or fabric of the parent rock.
		ALLUVIAL – soil deposited by creeks and rivers.
		ESTUARINE – soil deposited in coastal estuaries, including sediments caused by inflowing creeks and rivers, and tidal currents.
		MARINE – soil deposited in a marine environment.
		AEOLIAN – soil carried and deposited by wind.
		COLLUVIAL – soil and rock debris transported downslope by gravity, with or without the assistance of flowing water. Colluvium is usually a thick deposit formed from a landslide. The description 'slopewash' is used for thinner surficial deposits.
		LITTORAL – beach deposited soil.

Classification of Material Weathering

<table>
<tr><th colspan="2">Term</th><th colspan="2">Abbreviation</th><th>Definition</th></tr>
<tr><td colspan="2">Residual Soil</td><td colspan="2">RS</td><td>Material is weathered to such an extent that it has soil properties. Mass structure and material texture and fabric of original rock are no longer visible, but the soil has not been significantly transported.</td></tr>
<tr><td colspan="2">Extremely Weathered</td><td colspan="2">XW</td><td>Material is weathered to such an extent that it has soil properties. Mass structure and material texture and fabric of original rock are still visible.</td></tr>
<tr><td>Highly Weathered</td><td rowspan="2">Distinctly Weathered (Note 1)</td><td>HW</td><td rowspan="2">DW</td><td>The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable. Rock strength is significantly changed by weathering. Some primary minerals have weathered to clay minerals. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.</td></tr>
<tr><td>Moderately Weathered</td><td>MW</td><td>The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable, but shows little or no change of strength from fresh rock.</td></tr>
<tr><td colspan="2">Slightly Weathered</td><td colspan="2">SW</td><td>Rock is partially discoloured with staining or bleaching along joints but shows little or no change of strength from fresh rock.</td></tr>
<tr><td colspan="2">Fresh</td><td colspan="2">FR</td><td>Rock shows no sign of decomposition of individual minerals or colour changes.</td></tr>
</table>

NOTE 1: The term 'Distinctly Weathered' is used where it is not practicable to distinguish between 'Highly Weathered' and 'Moderately Weathered' rock. 'Distinctly Weathered' is defined as follows: *'Rock strength usually changed by weathering. The rock may be highly discoloured, usually by iron staining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores'*. There is some change in rock strength.

Rock Material Strength Classification

			Guide to Strength	
Term	**Abbreviation**	**Uniaxial Compressive Strength (MPa)**	**Point Load Strength Index $I_{s(50)}$ (MPa)**	**Field Assessment**
Very Low Strength	VL	0.6 to 2	0.03 to 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 30mm thick can be broken by finger pressure.
Low Strength	L	2 to 6	0.1 to 0.3	Easily scored with a knife; indentations 1mm to 3mm show in the specimen with firm blows of the pick point; has dull sound under hammer. A piece of core 150mm long by 50mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.
Medium Strength	M	6 to 20	0.3 to 1	Scored with a knife; a piece of core 150mm long by 50mm diameter can be broken by hand with difficulty.
High Strength	H	20 to 60	1 to 3	A piece of core 150mm long by 50mm diameter cannot be broken by hand but can be broken by a pick with a single firm blow; rock rings under hammer.
Very High Strength	VH	60 to 200	3 to 10	Hand specimen breaks with pick after more than one blow; rock rings under hammer.
Extremely High Strength	EH	> 200	> 10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer.