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28 June 2023
Our ref: SA/AP/UK/C14315

Bega Valley Shire Council
Via email: Jcrawford@begavalley.nsw.gov.au

**Attention: Jessica Crawford**

# MERIMBULA FORESHORE BOARDWALK - MERIMBULA, NSW

## *Geotechnical Investigation Report*

We are pleased to present our geotechnical investigation report, assessing the geotechnical conditions for the proposed upgrade of Merimbula Foreshore Boardwalk, in Merimbula, NSW.

The report outlines the methods and results of exploration, describes site subsurface conditions, provides site classification and recommendations for footing design.

Should you require any further information regarding this report, please do not hesitate to contact our office.

Yours faithfully,
***ACT Geotechnical Engineers Pty Ltd***

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# BEGA VALLEY SHIRE COUNCIL

# MERIMBULA FORESHORE BOARDWALK, MERIMBULA, NSW

# GEOTECHNICAL INVESTIGATION REPORT

# JUNE 2023

# BEGA VALLEY SHIRE COUNCIL

# MERIMBULA FORESHORE BOARDWALK, MERIMBULA, NSW

# GEOTECHNICAL INVESTIGATION REPORT

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# MERIMBULA FORESHORE BOARDWALK, MERIMBULA, NSW

# GEOTECHNICAL INVESTIGATION REPORT

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## 1 INTRODUCTION

At the request of Bega Valley Shire Council, ACT Geotechnical Engineers Pty Ltd carried out a geotechnical investigation for the proposed Merimbula Foreshore Boardwalk, in Merimbula, NSW.

It has been indicated that the project involved the construction of a ~2500m long boardwalk along the Boggy Creek foreshore, between Market Street and Lakewood Drive, which will be founded on timber driven piles or steel screw piles. The proposed boardwalk is intended to replace the existing boardwalk, which is deteriorating.

The scope of this report is:

(i) Identify subsurface conditions including the extent and nature of any fill materials, soil strata, bedrock type and depth, and groundwater presence.

(ii) Advise on excavation conditions and suitability of excavated material for use as structural fill.

(iii) Provide site classification to AS2870 "Residential Slabs & Footings".

(iv) Advise on suitable footings systems, founding depths, allowable bearing pressures and design parameters for ground slabs.

(v) Provide guidelines for construction of controlled fill platforms.

(vi) Provide subgrade CBR value(s).

(vii) Soil aggressivity lab testing and exposure classification for concrete and steel structures.

The recommendations contained within this report are based on the available investigation data.

## 2 SITE DESCRIPTION & GEOLOGY

The investigation site is located along the northern coastline of the Boggy Creek Foreshore, in Merimbula, NSW. The boardwalk links Market Street to the east and Lakewood Drive to the west.

The Bega-Mallacoota 1:250,000 geological map (geological series sheet SJ/55-4) indicates that the site is covered by Holocene age estuarine tidal delta flat deposits of Fine- to medium-grained lithic-carbonate-quartz sand (marine-deposited), silt, clay, shell material, polymictic gravel, underlain by Late Devonian Merimbula group bedrock of undifferentiated sandstone and conglomerate. Plate 1 shows the geological map extract of the site.


*Plate 1. Geological map extract*

## 3 GROUND INVESTIGATION

The field investigation was carried out on 05 and 06 June 2023. The field investigation comprised of ten (10) boreholes drilled to 2m depth, and twenty-five (25) Dynamic Cone Penetrometer (DCP) tests to refusal at depths ranging from 0m to 4.6m.

The approximate borehole and DCP locations are show in Figure 1. The subsurface profiles were visually logged in accordance with the Unified Soil Classification System (USCS). Log of the borehole, including subgrade DCP test results, are presented in Appendix A.

Definitions of geotechnical engineering terms used on the borehole logs and in this report, including a copy of the USCS chart, are provided in Appendix C.

## 4 RESULTS OF GEOTECHNICAL INVESTIGIATON

### 4.1 Subsurface Conditions

Table 1 outlines the subsurface conditions found during our investigation and Table 2 outlines the depth of different geological profiles encountered in ten (10) investigation boreholes.

*Table 1 –Subsurface Conditions*

| Geological Profile | Unit | Description |
|---|---|---|
| TOPSOIL | Unit 1: Sandy SILT | Sandy SILT; low plasticity silt, fine to coarse sand, pale brown, with fine to coarse sub-angular to angular gravel, moist, loose. |
| FILL | Unit 2: Clayey GRAVEL | FILL; Clayey GRAVEL; fine to coarse gravel, low to medium plasticity, red-brown, brown, dry to wet. |

| | | |
|---|---|---|
| MARINE SOIL | Unit 3: Very Loose to Loose SAND/Silty SAND/Sandy SILT | SAND; fine to medium sand, pale brown, pale grey, with/trace of low plasticity silt, moist to wet, very loose to loose.<br>OR<br>SAND; fine to coarse sand, pale grey, orange-white, moist to wet, very loose.<br>OR<br>Silty SAND; fine to medium sand, dark grey, pale grey, grey, low plasticity silt, with/trace of organic content and shells, wet, very loose to loose.<br>OR<br>Sandy SILT; low plasticity, dark grey, fine to coarse sand, with/trace organic materials and shells, wet, very loose. |
| RESIDUAL SOIL | Unit 4: Clayey SAND | Clayey SAND; fine to medium sand, pale brown, low to medium plasticity clay, trace of fine to sub-angular to angular gravel, wet, moisture greater than plastic limit, medium dense. |
| COLLUVIAL SOIL | Unit 5: Gravelly Clayey SAND | Gravelly Clayey SAND; fine to coarse sand, red-brown, fine to coarse sub-angular to angular gravel, low to medium plasticity clay, moist, medium dense. |
| Bedrock | Unit 6: HW to MW SANDSTONE | Highly Weathered (HW) to Moderately Weathered (MW) SANDSTONE; fine to medium grained, red-brown, red-grey, inferred low to medium strength. |

*Table 2 – Geological profiles encountered in investigation boreholes*

| Unit | Depth below ground level (m) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | BH01 | BH02 | BH03 | BH04 | BH05 | BH06 | BH07 | BH08 | BH09 | BH10 |
| Unit 1 | - | - | - | - | - | - | 0.15 | - | - | - |
| Unit 2 | - | - | - | - | - | 0.2 | - | - | - | - |
| Unit 3 | 2.0 | 1.8 | 2.0 | 2.0 | 2.0 | 2.0 | - | 0.1 | 2.0 | - |
| Unit 4 | - | 2.0 | - | - | - | - | - | - | - | - |
| Unit 5 | - | - | - | - | - | - | - | - | - | 0.4 |
| Unit 6 | - | - | - | - | - | - | - | >0.1 | - | >0.4 |

Permanent groundwater is expected at shallow depth and will correspond to the water level in the adjacent Boggy Creek/Lake Merimbula. The boardwalk will be located within the tidal/splash zone of Boggy Creek/Lake Merimbula.

## 4.2 DCP Testing

DCP test results are presented in Table 3. Note that the numbers in red indicate soils that have a low bearing capacity and are unsuitable for founding structure footings in.

*Table 3a - DCP Test Results for DCP01 to DCP10*

| Depth from ground surface (mm) | Blows per 100mm Penetration from Ground Surface | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DCP01 | DCP02 @BH01 | DCP03 @BH02 | DCP04 | DCP05 | DCP06 @BH03 | DCP07 | DCP08 @BH04 | DCP09 | DCP10 |
| 100 | 5 | 0 | 0 | 0 | 0 | 2 | 8 | 0 | 0 | 0 |
| 200 | 8 | 0 | 0 | 0 | 0 | 4 | Refusal | 0 | 0 | 0 |
| 300 | 20 | 0 | 3 | 0 | 0 | 3 | | 0 | 0 | 0 |
| 400 | Refusal | 0 | 3 | 0 | 0 | 0 | | 0 | 0 | 0 |
| 500 | | 0 | 0 | 0 | 2 | 0 | | 1 | 0 | 0 |
| 600 | | 0 | 0 | 0 | 1 | 1 | | 0 | 0 | 0 |
| 700 | | 0 | 0 | 0 | 1 | 1 | | 0 | 0 | 0 |
| 800 | | 0 | 2 | 0 | 2 | 2 | | 0 | 0 | 0 |
| 900 | | 0 | 2 | 0 | 3 | 2 | | 0 | 1 | 0 |
| 1000 | | 0 | 0 | 1 | 2 | 2 | | 0 | 0 | 0 |
| 1100 | | 0 | 0 | 0 | 2 | 1 | | 0 | 0 | 0 |
| 1200 | | 0 | 0 | 0 | 1 | 1 | | 0 | 0 | 0 |
| 1300 | | 0 | 1 | 1 | 2 | 0 | | 0 | 0 | 0 |
| 1400 | | 1 | 1 | 0 | 2 | 0 | | 1 | 0 | 0 |
| 1500 | | 2 | 0 | 0 | 0 | 1 | | 1 | 0 | 0 |
| 1600 | | 2 | 2 | 0 | 0 | 1 | | 0 | 0 | 0 |
| 1700 | | 0 | 2 | 1 | 0 | 2 | | 0 | 0 | 0 |
| 1800 | | 0 | 5 | 0 | 0 | 2 | | 0 | 0 | 0 |
| 1900 | | 0 | 5 | 0 | 0 | 2 | | 1 | 0 | 0 |
| 2000 | | 0 | 8 | 0 | 0 | 2 | | 1 | 0 | 0 |
| 2100 | | 0 | 8 | 0 | 0 | 2 | | 0 | 0 | 0 |
| 2200 | | 0 | 9 | 1 | 0 | 1 | | 0 | 0 | 0 |
| 2300 | | 0 | 18 | 2 | 0 | 2 | | 0 | 0 | 0 |
| 2400 | | 4 | 18 | 3 | 1 | 2 | | 0 | 0 | 1 |
| 2500 | | 8 | Refusal | 2 | 2 | 2 | | 0 | 0 | 1 |
| 2600 | | 12 | | 1 | 1 | 2 | | 0 | 0 | 1 |
| 2700 | | 10 | | 0 | 2 | 4 | | 1 | 0 | 0 |
| 2800 | | 13 | | 1 | 3 | 4 | | 2 | 0 | 1 |
| 2900 | | 15 | | 2 | 2 | 4 | | 2 | 0 | 1 |
| 3000 | | 17 | | 1 | 0 | 3 | | 3 | 0 | 2 |
| 3100 | | Refusal | | 2 | 0 | 3 | | 3 | 2 | 1 |
| 3200 | | | | 3 | 0 | 4 | | 3 | 4 | 2 |
| 3300 | | | | 2 | 0 | 4 | | 3 | 4 | 1 |
| 3400 | | | | 2 | 2 | 4 | | 2 | 5 | 1 |
| 3500 | | | | 3 | 2 | 4 | | 3 | 5 | 2 |
| 3600 | | | | 5 | 3 | 5 | | 3 | 5 | 2 |
| 3700 | | | | 4 | 2 | 6 | | 3 | 5 | 3 |
| 3800 | | | | 5 | 3 | 4 | | 4 | 5 | 3 |
| 3900 | | | | 5 | 2 | 5 | | 5 | 5 | 3 |
| 4000 | | | | 8 | 2 | 4 | | 6 | 5 | 4 |
| 4100 | | | | 6 | 3 | 5 | | 5 | 7 | 5 |
| 4200 | | | | 7 | 3 | 4 | | 4 | 4 | 5 |
| 4300 | | | | 8 | 5 | 5 | | 5 | 4 | 5 |
| 4400 | | | | DCP Limit | 5 | DCP Limit | | DCP Limit | DCP Limit | 4 |
| 4500 | | | | | 4 | | | | | DCP Limit |
| 4600 | | | | | DCP Limit | | | | | |

*Table 3b - DCP Test Results for DCP11 to DCP20*

| Depth from ground surface (mm) | Blows per 100mm Penetration from Ground Surface | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DCP11 @BH05 | DCP12 | DCP13 | DCP14 @ BH06 | DCP15 | DCP16 | DCP17 @BH07 | DCP18 | DCP19 | DCP20 |
| 100 | 0 | 4 | 7 | 0 | 8 | 0 | 5 | 0 | Refusal | 0 |
| 200 | 0 | Refusal | 7 | 20 | 4 | 2 | 17 | 0 | | 6 |
| 300 | 0 | | 18 | Refusal | 4 | 2 | 4 | 0 | | Refusal |
| 400 | 1 | | Refusal | | 5 | 2 | 3 | 0 | | |
| 500 | 3 | | | | 4 | 2 | 5 | 0 | | |
| 600 | 2 | | | | 2 | 2 | 6 | 0 | | |
| 700 | 1 | | | | 3 | 2 | 7 | 0 | | |
| 800 | 1 | | | | 2 | 2 | 8 | 0 | | |
| 900 | 2 | | | | 2 | 4 | 7 | 0 | | |
| 1000 | 1 | | | | 3 | 2 | 3 | 0 | | |
| 1100 | 0 | | | | 2 | 3 | 3 | 1 | | |
| 1200 | 0 | | | | 2 | 2 | 6 | 0 | | |
| 1300 | 0 | | | | 2 | 2 | 6 | 0 | | |
| 1400 | 0 | | | | 3 | 2 | 7 | 1 | | |
| 1500 | 0 | | | | 3 | 2 | 6 | 0 | | |
| 1600 | 0 | | | | 6 | 2 | 4 | 0 | | |
| 1700 | 0 | | | | 6 | 2 | 2 | 0 | | |
| 1800 | 0 | | | | 7 | 3 | 3 | 1 | | |
| 1900 | 0 | | | | 8 | 3 | 3 | 2 | | |
| 2000 | 1 | | | | 11 | 2 | 4 | 2 | | |
| 2100 | 1 | | | | 11 | 2 | 3 | 2 | | |
| 2200 | 1 | | | | 13 | 3 | 3 | 2 | | |
| 2300 | 1 | | | | 14 | 3 | 4 | 2 | | |
| 2400 | 1 | | | | 15 | 3 | 3 | 2 | | |
| 2500 | 1 | | | | | 3 | 4 | 2 | | |
| 2600 | 1 | | | | | 3 | 4 | 2 | | |
| 2700 | 2 | | | | | 4 | 5 | 2 | | |
| 2800 | 2 | | | | | 5 | 4 | 4 | | |
| 2900 | 3 | | | | | 5 | 4 | 4 | | |
| 3000 | 4 | | | | | 8 | 5 | 4 | | |
| 3100 | 4 | | | | | 5 | 4 | 5 | | |
| 3200 | 4 | | | | | 5 | 4 | 3 | | |
| 3300 | 3 | | | | | 6 | 3 | 4 | | |
| 3400 | 2 | | | | | 7 | 7 | 7 | | |
| 3500 | 3 | | | | | 7 | 7 | 6 | | |
| 3600 | 4 | | | | | 7 | 6 | 6 | | |
| 3700 | 5 | | | | | 8 | 5 | 5 | | |
| 3800 | 4 | | | | | 8 | 6 | 5 | | |
| 3900 | 5 | | | | | 7 | 5 | 6 | | |
| 4000 | 5 | | | | | 12 | 4 | 5 | | |
| 4100 | 5 | | | | | 25 | 3 | 4 | | |
| 4200 | 5 | | | | | Refusal | 4 | 3 | | |
| 4300 | 5 | | | | | | 4 | 4 | | |
| 4400 | 5 | | | | | | 4 | 3 | | |
| 4500 | 5 | | | | | | 4 | 3 | | |
| 4600 | DCP Limit | | | | | | 4 | DCP Limit | | |

*Table 3c - DCP Test Results for DC21 to DCP25*

| Depth from ground surface (mm) | Blows per 100mm Penetration from Ground Surface | | | | |
|---|---|---|---|---|---|
| | DCP21 @BH08 | DCP22 | DCP23 @BH09 | DCP24 | DCP25 @BH10 |
| 100 | Refusal | 11 | 0 | 3 | 6 |
| 200 | | 11 | 0 | 2 | 9 |
| 300 | | Refusal | 0 | 0 | 10 |
| 400 | | | 0 | 0 | 2 |
| 500 | | | 0 | 4 | Refusal |
| 600 | | | 0 | 13 | |
| 700 | | | 0 | Refusal | |
| 800 | | | 0 | | |
| 900 | | | 0 | | |
| 1000 | | | 0 | | |
| 1100 | | | 0 | | |
| 1200 | | | 0 | | |
| 1300 | | | 0 | | |
| 1400 | | | 0 | | |
| 1500 | | | 0 | | |
| 1600 | | | 0 | | |
| 1700 | | | 0 | | |
| 1800 | | | 0 | | |
| 1900 | | | 0 | | |
| 2000 | | | 0 | | |
| 2100 | | | 0 | | |
| 2200 | | | 0 | | |
| 2300 | | | 0 | | |
| 2400 | | | 0 | | |
| 2500 | | | 0 | | |
| 2600 | | | 0 | | |
| 2700 | | | 0 | | |
| 2800 | | | 0 | | |
| 2900 | | | 0 | | |
| 3000 | | | 0 | | |
| 3100 | | | 0 | | |
| 3200 | | | 0 | | |
| 3300 | | | 0 | | |
| 3400 | | | 0 | | |
| 3500 | | | 1 | | |
| 3600 | | | 3 | | |
| 3700 | | | 3 | | |
| 3800 | | | 3 | | |
| 3900 | | | 3 | | |
| 4000 | | | 2 | | |
| 4100 | | | 2 | | |
| 4200 | | | 16 | | |
| 4300 | | | 6 | | |
| 4400 | | | 4 | | |
| 4500 | | | 4 | | |
| 4600 | | | DCP Limit | | |

### 4.3 Laboratory Testing

The results of the soil aggressivity testing performed on the materials taken from site are summarized in Table 4 below. The NATA test certificates are presented in Appendix B.

*Table 4 – Soil Aggressivity Lab Test Results*

| ID | Depth (m) | pH | Chloride (mg/kg) | Sulfate (mg/kg) | Electrical Conductivity @ 25°C (dS/m) | Resistivity @ 25°C (ohmcm) |
|---|---|---|---|---|---|---|
| BH1 | 0.4m-0.6m | 6.5 | 4000 | 615 | 2.46 | 406 |
| BH2 | 0.9m-1.1m | 6.1 | 2820 | 563 | 1.92 | 520 |
| BH3 | 0.4m-0.6m | 6.8 | 2580 | 429 | 1.59 | 628 |
| BH6 | 0.5m-0.8m | 6.8 | 897 | 135 | 0.62 | 1610 |
| BH9 | 0.4m-0.6m | 7.5 | 4920 | 876 | 3.25 | 307 |

## 5 DISCUSSION & RECOMMENDATIONS

### 5.1 Soil and Rock Properties

Soil properties of all encountered soil horizons are presented in Table 5.

*Table 5 – Soil Properties of Encountered Soil Horizons*

| Foundation Material | Bulk Density $\gamma b$ (kN/m$^3$) | C (kPa) | Φ' (degrees) | Elastic Modulus (MPa) | Ka | Kp | Ko |
|---|---|---|---|---|---|---|---|
| Unit 1 (Topsoil) | 18 | 0 | 20 | <5 | 0.49 | 2.03 | 0.66 |
| Unit 2 (Fill) | 19 | 0 | 20 | 10 | 0.49 | 2.03 | 0.66 |
| Unit 3 (Soft/Loose Marine Soil) | 19 | 0 | 25 | <5 | 0.4 | 2.5 | 0.58 |
| Unit 4 and 5 (Medium Dense Clayey SAND/ Gravelly Clayey SAND) | 20 | 0 | 30 | 20 | 0.33 | 3.0 | 0.5 |
| Unit 6 (HW to MW Bedrock | 22 | 50 | 30 | 100 | 0.33 | 3.0 | 0.5 |

## 5.2 Site Classification

Due to the presence of very loose, moisture affected marine soil with inadequate bearing capacity up to 2.0 m, the site is designated as a Class "P" (problem) site in accordance with AS2870.

At a depth of up to 4m, with consideration to the reactivity of the soils within the depth of suction change, in terms of potential shrink-swell movements that may occur due to soil moisture changes. The characteristic ground surface movement "ys" as defined by AS2870 for the range of normal soil moisture conditions is estimated to be between 0mm to 20mm for the encountered profile described in Section 2. Normal moisture conditions are those caused by seasonal and regular climatic effects.

Should earthworks (cut or fill) be undertaken on the site, or other activities which may cause abnormal moisture conditions to impact the soils within or near the building envelope beyond those addressed herein, the site classification shall be reassessed.

## 5.3 Footings

As the site has been classified as Class P, footing design shall be undertaken in accordance with engineering principles, based upon the requirements on AS2870 and the characteristic ground surface movement estimate of 0mm to 20mm.

Footings including thickened sections of slabs must be founded below any topsoil, fill and very loose, moisture affected marine soil into the underlying medium dense to dense sands or highly weathered to moderately weathered bedrock. A suitable founding depth of between 0.4m and up to 4m is expected. Therefore, pile footings would be the most suitable footing solution. Given the presence of groundwater and the likely instability of bored pier holes, it is recommended that either screw piles or driven piles are used. Footings should be inspected by a geotechnical engineer to confirm the ground conditions. Table 6 below gives recommended allowable end bearing pressures for design purposes.

*Table 6 – Recommended Allowable End-Bearing Pressures and Shaft Adhesion for Footings*

| Foundation Material Type | Depth Below existing surface level | Allowable End-Bearing Pressure[1] | | | Allowable Shaft Adhesion on Piles | |
|---|---|---|---|---|---|---|
| | | Strips/Beams | Pads | Piles[2] | Downward Loading | Uplift |
| Unit 1 (Topsoil) | 0m – 0.15m | Unsuitable | | | | |
| Unit 2 (Fill) | 0m – 0.2m | Unsuitable | | | | |
| Unit 3 (Very Loose to Loose Marine Soil) | 0m/0.2m – 1.8m/4.0m | Unsuitable | | | | |
| Newly Placed Controlled Fill | - | 100kPa | 125kPa | N.A. | N.A. | N.A. |
| Unit 4 and 5 (Medium Dense Clayey SAND/Gravelly Clayey SAND) | Below 1.8m/4.0m (All boreholes except BH8 and BH10) | 100kPa | 125kPa | 200kPa | 20kPa | 10kPa |
| Unit 6 (HW to MW Bedrock) | Below 0.4m/4.5 (Only found in BH8 and BH10) | 600kPa | 750kPa | 1000kPa | 100kPa | 50kPa |

[1]End bearing pressure to cause settlement of less than 1% of minimum footing dimensions.
[2]Assumes a minimum embedment depth of 4 pile diameters

Consideration should be given to the design of footings where interaction with slopes, retaining walls, service trenches and existing foundations will occur, and specific geotechnical advice sought.

## 5.4 Excavation Conditions & Use of Excavated Material

Excavations to at least 0.1m/4.0m depth will be through very loose to loose marine soils and into medium dense to dense soils or weak bedrock and are readily diggable by backhoe and medium sized excavator. Low to Medium strong rock could be encountered below this depth and may require ripping or rock hammering. Bored piers could be drilled into the weak bedrock using an auger attachment on a backhoe or excavator; however, liners would be required due to the collapsible nature of the soils below groundwater level.

Any low/medium plasticity soils can be used in controlled fill construction of building platforms, provided all particles are less than <75mm size. Topsoil and medium to high plasticity clays are not generally suitable for controlled fill but could be used in non-structural applications such as landscaping.

If imported fill is required, a suitable select fill material would include a low or medium plasticity soil such as clayey sand or gravelly clayey sand, containing between 25% and 50% fines less than 0.075mm size (silt and clay), and no particles greater than 75mm size.

Permanent groundwater is expected within proposed excavation depths.

## 5.5 Controlled Fill Construction

For construction of any new fill foundation platforms and road subgrades, it is recommended that:

- Areas be fully stripped of all uncontrolled fill, topsoil, and moisture-affected soils. A general stripping depth of >2m, possibly as deep as 4m is expected. Stripped foundations should be proof-rolled by a vibratory pad-foot roller of not less than 9 tonne static mass to check for any weak or wet areas that would require replacement. No fill should be placed until a geotechnical engineer has confirmed the suitability of the foundation. Given the loose/wet foundation soils, a bridging layer may be more practical than stripping unsuitable soils.

- Controlled fill comprising suitable site excavated or imported materials of not greater than 75mm maximum particle size, be compacted in not greater than 150mm layers to not less than 98%StdMDD at about OMC.

- Fill placement and control testing be overviewed and certified by a geotechnical engineer at Level 1 or 2 involvement of AS3798 – 1996 "Guidelines on Earthworks for Commercial & Residential Developments" (Reference 3).

## 5.6 Design CBR Values

Any underlying uncontrolled fill and loose marine deposits, and soil subgrades must be removed then proof-rolled by a pad-foot roller to check for any wet or otherwise weak spots which may require additional removal. Suitable replacement fill can be compacted in not thicker than 150mm layers, to not less than 95%ModMDD.

Based upon the soil profile encountered, the natural design CBR value has been determined as 5%. The expansive nature (swell) of the subgrade material is low. The natural design CBR value is based on the laboratory and in situ CBR tests and is based on a statistical review of the lab and field testing. It is not the lowest CBR value that was encountered but rather based on a statistical likelihood and engineering judgement based on the characteristics of the subgrade materials. There is potential

that there are zones where the subgrade soils have an in situ CBR of less than the design CBR. Care will be required during construction to confirm that the design CBR has been achieved.

## 5.7 Exposure Classification

Section 6.4.2 of AS2159-2009 "Piling – Design and Installation" provides guidelines for exposure classification for concrete piles. Table 6.4.2(A) under the above section lists concrete piles in sea water – Tidal/Splash Zone as "Severe".

Similarly, Section 6.5.2 provides guidelines for exposure classification for steel piles. Table 6.5.2(A) under the above section lists steel piles in sea water – tidal/splash zone – Cold water (south of 30°S) as "Severe".

Therefore, the exposure classification for both steel and concrete piles is "Severe".

## 5.8 Earthquake Site Factor

Table 2.3 of AS1170.4 "Minimum Design Loads on Structures - Part 4: Earthquake Loads" (Reference 4) lists the earthquake acceleration coefficients for major centres to be considered in structural design. The Merimbula area has an acceleration coefficient of 0.08.

Section 4.2 of AS1170.4 "Minimum Design Loads on Structures – Part 4: Earthquake Loads" lists the site sub-soil classes to be considered in structural design. The site is classified as a "Class $D_e$ – Deep or Soft Soil Site".

**ACT Geotechnical Engineers Pty Ltd**


**BEGA VALLEY SHIRE COUNCIL**
**MERIMBULA FORESHORE BOARDWALK, MERIMBULA, NSW**
**AERIAL IMAGE WITH APPROXIMATE BOREHOLES AND DCP LOCATION**

| | | |
|---|---|---|
| ACT Geotechnical Engineers | C14315 | FIGURE 1 |

**APPENDIX A**
**Borehole Logs**

# Borehole Log

| | |
|---|---|
| Borehole No. | **BH01** |
| Sheet | 1 of 1 |
| Job No. | C14315 |

CLIENT: Bega Valley Shire Council

PROJECT: Merimbula Foreshore Board Walk
Merimbula, NSW

Location :

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : Pushtube
Hole Diameter : 50mm

| Samples | Water | Casing | Depth (Metres) | Graphic Log | U.S.C.S. | Material Description, Structure<br>Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure | Consistency or Relative Density | Field Test Results (DCP) | Geological Profile |
|---|---|---|---|---|---|---|---|---|---|
| | None Encountered | | 0.9 | | SP-SM | SAND; fine to medium sand, pale grey, with low plasticity silt, wet | Very Loose | 0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0 | Marine Soil |
| | | | 1.0 | | SM | Silty SAND; fine to medium sand, pale grey, grey, low plasticity silt, with organic (dark grey oceanic plants/roots), wet | Very Loose | 0<br>0<br>0<br>0 | |
| | | | 1.3 | | SM | Silty SAND; fine to medium sand, pale grey, orange-white, with shells, wet | Loose | 1<br>2<br>8<br>0<br>0 | |
| | | | 1.8 | | ML | Sandy SILT; low plasticity, dark grey, fine to coarse sand, trace of organic material and shells, wet | Very Loose | 0<br>0 | |
| | | | 2.0 | | | BOREHOLE TERMINATED AT 2m<br>Target Depth | | 0<br>0<br>0<br>4<br>8<br>12<br>10<br>13<br>15<br>17 | |
| | | | 3.0 | | | | | | |
| | | | 4.0 | | | | | | |
| | | | 4.7 | | | | | | |

Dynamic Cone Penetrometer Test, Results in Blows per 100mm

Logged By : SA/AP Date : 6/5/23 | Checked By : JM Date : 6/7/23

BOREHOLE/EXCAVATION LOG C14315 GINT.GPJ ACT GEO.GDT 6/7/23

ACT Geotechnical Engineers

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# Borehole Log

| | |
|---|---|
| Borehole No. | **BH02** |
| Sheet | 1 of 1 |
| Job No. | C14315 |

CLIENT: Bega Valley Shire Council

PROJECT: Merimbula Foreshore Board Walk
Merimbula, NSW

Location :

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : Pushtube
Hole Diameter : 50mm

| Samples | Water | Casing | Depth Metres | Graphic Log | U.S.C.S. | Material Description, Structure<br>Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure | Consistency or Relative Density | Field Test Results<br>Dynamic Cone Penetrometer Test, Results in Blows per 100mm | Geological Profile |
|---|---|---|---|---|---|---|---|---|---|
| | None Encountered | | 0.5 | | SP | SAND; fine to medium, pale brown, pale grey, trace of low plasticity silt, fine to coarse sub-angular to angular gravel, moist to wet | Loose | DCP<br>0<br>0<br>3<br>3<br>0 | Marine Soil |
| | | | 1.0 | | SM | Silty SAND; fine to medium sand, dark grey, low plasticity silt, with organic content, wet | Very Loose | 0<br>0<br>2<br>2<br>0<br>0<br>0<br>1<br>1<br>0<br>2<br>2<br>5 | |
| | | | 1.8<br>2.0 | | SC | Clayey SAND; fine to medium sand, pale brown, low to medium plasticity clay, trace of fine sub-angular to angular gravel, wet, moisture greater than plastic limit | Medium Dense | 5<br>8 | Residual Soil |
| | | | 3.0 | | | BOREHOLE TERMINATED AT 2m<br>Target Depth | | 8<br>9<br>18<br>18 | |
| | | | 4.0 | | | | | | |
| | | | 4.7 | | | | | | |

Logged By : SA/AP Date : 6/5/23 | Checked By : JM Date : 6/7/23

BOREHOLE/EXCAVATION LOG C14315 GINT.GPJ ACT GEO.GDT 6/7/23

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# Borehole Log

| | |
|---|---|
| Borehole No. | **BH03** |
| Sheet | 1 of 1 |
| Job No. | C14315 |

CLIENT: Bega Valley Shire Council

PROJECT: Merimbula Foreshore Board Walk
Merimbula, NSW

Location :

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : Pushtube
Hole Diameter : 50mm

| Depth (Metres) | Graphic Log | U.S.C.S. | Material Description, Structure<br>Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure | Consistency or Relative Density | Field Test Results (DCP; Dynamic Cone Penetrometer Test, Results in Blows per 100mm) | Geological Profile |
|---|---|---|---|---|---|---|
| 0.0 | | SM | Silty SAND; fine to medium sand, pale grey, low plasticity, trace of organic content, moist to wet | Loose | 2, 4, 3, 0 | Marine Soil |
| 0.4 | | SP | SAND; fine to medium sand, pale brown, trace of low plasticity silt, moist to wet | Very Loose | 0, 1, 1, 2, 2 | |
| 0.9 | | ML | Sandy SILT; low plasticity, dark grey, fine to coarse sand, trace of organic content, wet | Loose | 2, 1, 1, 0, 0, 1, 1, 2, 2, 2, 2 | |
| 2.0 | | | BOREHOLE TERMINATED AT 2m<br>Target Depth | | 2, 1, 2, 2, 2, 2, 4, 4, 4, 3, 3, 4, 4, 4, 4, 5, 6, 4, 5, 4, 5, 4, 5 | |
| 4.7 | | | | | | |

Water: None Encountered

Casing:

Logged By : SA/AP Date : 6/5/23

Checked By : JM Date : 6/7/23

BOREHOLE/EXCAVATION LOG C14315 GINT.GPJ ACT GEO.GDT 6/7/23

ACT Geotechnical Engineers

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# Borehole Log

| | |
|---|---|
| Borehole No. | **BH04** |
| Sheet | 1 of 1 |
| Job No. | C14315 |

CLIENT: Bega Valley Shire Council

PROJECT: Merimbula Foreshore Board Walk
Merimbula, NSW

Location :

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : Pushtube
Hole Diameter : 50mm

| Depth (Metres) | Graphic Log | U.S.C.S. | Material Description, Structure<br>Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure | Consistency or Relative Density | Field Test Results<br>DCP<br>Dynamic Cone Penetrometer Test, Results in Blows per 100mm | Geological Profile |
|---|---|---|---|---|---|---|
| 0.1 | | SW | SAND; fine to coarse sand, orange-white, moist to wet | Very Loose | 0 | Marine Soil |
| | | SP | SAND; fine to medium sand, pale grey, with low plasticity silt, moist to wet | Very Loose | 0<br>0<br>0<br>1<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>1<br>1<br>0 | |
| 1.0 | | | | | | |
| 1.6 | | SM | Silty SAND; fine to medium sand, dark grey, grey, low plasticity silt, wet | Very Loose | 0<br>0<br>1<br>1 | |
| 2.0 | | | BOREHOLE TERMINATED AT 2m<br>Target Depth | | 0<br>0<br>0<br>0<br>0<br>0<br>1<br>2<br>2<br>3<br>3<br>3<br>3<br>2<br>3<br>3<br>3<br>4<br>5<br>6<br>5<br>4<br>5 | |
| 3.0 | | | | | | |
| 4.0 | | | | | | |
| 4.7 | | | | | | |

Logged By : SA/AP Date : 6/5/23 | Checked By : JM Date : 6/7/23

BOREHOLE/EXCAVATION LOG C14315 GINT.GPJ ACT GEO.GDT 6/7/23

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# Borehole Log

| | |
|---|---|
| Borehole No. | **BH05** |
| Sheet | 1 of 1 |
| Job No. | C14315 |

CLIENT: Bega Valley Shire Council

PROJECT: Merimbula Foreshore Board Walk
Merimbula, NSW

Location :

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : Pushtube
Hole Diameter : 50mm

| Samples | Water | Casing | Depth (Metres) | Graphic Log | U.S.C.S. | Material Description, Structure<br>Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure | Consistency or Relative Density | Field Test Results<br>DCP<br>Dynamic Cone Penetrometer Test, Results in Blows per 100mm | Geological Profile |
|---|---|---|---|---|---|---|---|---|---|
| | None Encountered | | 0.05 | | SW | SAND; fine to coarse sand, orange-white, moist to wet | Very Loose | 0 | Marine Soil |
| | | | | | SP | SAND; fine to medium sand, pale grey, with low plasticity silt, moist to wet | Very Loose to Loose | 0<br>0<br>1<br>3<br>2<br>1<br>1<br>2<br>1<br>0<br>0<br>0<br>0 | |
| | | | 1.0 | | | | | | |
| | | | 1.4 | | SM | Silty SAND; fine to medium sand, dark grey, grey, low plasticity silt, wet | Very Loose | 0<br>0<br>0<br>0<br>0<br>1 | |
| | | | 2.0 | | | BOREHOLE TERMINATED AT 2m<br>Target Depth | | 1<br>1<br>1<br>1<br>1<br>1<br>2<br>2<br>3<br>4<br>4<br>4<br>3<br>2<br>3<br>4<br>5<br>4<br>5<br>5<br>5<br>5<br>5<br>5<br>5 | |
| | | | 3.0 | | | | | | |
| | | | 4.0 | | | | | | |
| | | | 4.7 | | | | | | |

Logged By : SA/AP Date : 6/5/23 | Checked By : JM Date : 6/7/23

BOREHOLE/EXCAVATION LOG C14315 GINT.GPJ ACT GEO.GDT 6/7/23

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# Borehole Log

| Borehole No. | BH06 |
|---|---|
| Sheet | 1 of 1 |
| Job No. | C14315 |

CLIENT: Bega Valley Shire Council

PROJECT: Merimbula Foreshore Board Walk
Merimbula, NSW

Location :

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : Pushtube
Hole Diameter : 50mm

| Samples | Water | Casing | Depth (Metres) | Graphic Log | U.S.C.S. | Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure) | Consistency or Relative Density | Field Test Results | Geological Profile |
|---|---|---|---|---|---|---|---|---|---|
| | None Encountered | | 0.2 | | GC | FILL; Clayey GRAVEL; fine to coarse gravel, low to medium plasticity, red brown, brown, dry to wet | | DCP 6 / 20 | FILL |
| | | | 0.5 | | SM | Silty SAND; fine to medium sand, low plasticity silt, grey, trace of organics, wet | Very Loose to Loose | | Marine Soil |
| | | | 1.0 | | SP | SAND; fine to medium sand, pale grey, with low plasticity silt, wet | Very Loose to Loose | | |
| | | | 2.0 | | SM | Silty SAND; fine to medium sand, low plasticity silt, dark grey, wet | Very Loose to Loose | | |
| | | | 3.0 | | | BOREHOLE TERMINATED AT 2m<br>Target Depth | | | |
| | | | 4.0 | | | | | | |
| | | | 4.7 | | | | | | |

Dynamic Cone Penetrometer Test, Results in Blows per 100mm

Logged By : SA/AP Date : 6/5/23 | Checked By : JM Date : 6/7/23

BOREHOLE/EXCAVATION LOG C14315 GINT.GPJ ACT GEO.GDT 6/7/23

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# Borehole Log

| | |
|---|---|
| Borehole No. | **BH07** |
| Sheet | 1 of 1 |
| Job No. | C14315 |

CLIENT: Bega Valley Shire Council

PROJECT: Merimbula Foreshore Board Walk
Merimbula, NSW

Location :

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : Pushtube
Hole Diameter : 50mm

| Samples | Water | Casing | Depth Metres | Graphic Log | U.S.C.S. | Material Description, Structure<br>Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure | Consistency or Relative Density | Field Test Results | Geological Profile |
|---|---|---|---|---|---|---|---|---|---|
| | None Encountered | | 0.15 | | ML | Sandy SILT; low plasticity silt, fine to coarse sand, pale brown, with fine to coarse sub-angular to angular gravel, moist | Loose | DCP 5 17 | TOPSOIL |
| | | | | | | BOREHOLE TERMINATED AT 0.15m<br>Target Depth | | 4 3 5 6 7 8 7 3 3 6 6 7 6 4 2 3 3 4 3 3 4 3 4 4 5 4 4 5 4 4 3 7 7 6 5 6 5 4 3 4 4 4 4 4 | |
| | | | 1.0 | | | | | | |
| | | | 2.0 | | | | | | |
| | | | 3.0 | | | | | | |
| | | | 4.0 | | | | | | |
| | | | 4.7 | | | | | | |

Dynamic Cone Penetrometer Test, Results in Blows per 100mm

Logged By : SA/AP Date : 6/5/23 | Checked By : JM Date : 6/7/23

BOREHOLE/EXCAVATION LOG C14315 GINT.GPJ ACT GEO.GDT 6/7/23

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# Borehole Log

| | |
|---|---|
| Borehole No. | **BH08** |
| Sheet | 1 of 1 |
| Job No. | C14315 |

CLIENT: Bega Valley Shire Council

PROJECT: Merimbula Foreshore Board Walk
Merimbula, NSW

Location :

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : Pushtube
Hole Diameter : 50mm

| Samples | Water | Casing | Depth Metres | Graphic Log | U.S.C.S. | Material Description, Structure<br>Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure | Consistency or Relative Density | Field Test Results | Geological Profile |
|---|---|---|---|---|---|---|---|---|---|
| | None Encountered | | 0.1 | | SW | SAND; fine to coarse sand, pale grey, wet | Loose | | Marine Soil |
| | | | 0.15 | | | Highly Weathered (HW) to Moderately Weathered (MW) SANDSTONE; fine to medium grained, red-brown, inferred low to medium strength | | | Bedrock |
| | | | | | | BOREHOLE TERMINATED AT 0.15m<br>Target Depth | | | |
| | | | 1.0 | | | | | | |
| | | | 2.0 | | | | | | |
| | | | 3.0 | | | | | | |
| | | | 4.0 | | | | | | |
| | | | 4.7 | | | | | | |

Logged By : SA/AP Date : 6/5/23 | Checked By : JM Date : 6/7/23

BOREHOLE/EXCAVATION LOG C14315 GINT.GPJ ACT GEO.GDT 6/7/23

ACT Geotechnical Engineers

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# Borehole Log

| Borehole No. | BH09 |
|---|---|
| Sheet | 1 of 1 |
| Job No. | C14315 |

CLIENT: Bega Valley Shire Council

PROJECT: Merimbula Foreshore Board Walk
Merimbula, NSW

Location :

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : Pushtube
Hole Diameter : 50mm

| Samples | Water | Casing | Depth (Metres) | Graphic Log | U.S.C.S. | Material Description, Structure<br>Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure | Consistency or Relative Density | Field Test Results<br>Dynamic Cone Penetrometer Test, Results in Blows per 100mm | Geological Profile |
|---|---|---|---|---|---|---|---|---|---|
| | None Encountered | | 1.0 | | SM | Silty SAND; fine to medium sand, low plasticity silt, dark brown, wet | Very Loose to Loose | DCP: 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 | Marine Soil |
| | | | 2.0 | | | BOREHOLE TERMINATED AT 2m<br>Target Depth | | 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 3, 3, 3, 3, 2, 2, 16, 6, 4, 4 | |
| | | | 3.0 | | | | | | |
| | | | 4.0 | | | | | | |
| | | | 4.7 | | | | | | |

Logged By : SA/AP Date : 6/5/23 | Checked By : JM Date : 6/7/23

BOREHOLE/EXCAVATION LOG C14315 GINT.GPJ ACT GEO.GDT 6/7/23

ACT Geotechnical Engineers

asda

# Borehole Log

| | |
|---|---|
| Borehole No. | **BH10** |
| Sheet | 1 of 1 |
| Job No. | C14315 |

CLIENT: Bega Valley Shire Council

PROJECT: Merimbula Foreshore Board Walk
Merimbula, NSW

Location :

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : Pushtube
Hole Diameter : 50mm

| Samples | Water | Casing | Depth Metres | Graphic Log | U.S.C.S. | Material Description, Structure<br>Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure | Consistency or Relative Density | Field Test Results | Geological Profile |
|---|---|---|---|---|---|---|---|---|---|
| | None Encountered | | | | SC | Gravelly Clayey SAND; fine to coarse sand, red-brown, fine to coarse sub-angular to angular gravel, low to medium plasticity clay, moist | Medium Dense | DCP 6 / 9 / 10 / 2 (Dynamic Cone Penetrometer Test, Results in Blows per 100mm) | Colluvial Soil |
| | | | 0.4<br>0.45 | | | Highly Weathered (HW) to Moderately Weathered (MW) SANDSTONE; red-grey<br>BOREHOLE TERMINATED AT 0.45m<br>Target Depth | | | Bedrock |
| | | | 1.0 | | | | | | |
| | | | 2.0 | | | | | | |
| | | | 3.0 | | | | | | |
| | | | 4.0 | | | | | | |
| | | | 4.7 | | | | | | |

Logged By : SA/AP Date : 6/5/23 | Checked By : JM Date : 6/7/23

BOREHOLE/EXCAVATION LOG C14315 GINT.GPJ ACT GEO.GDT 6/7/23

ACT Geotechnical Engineers

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**APPENDIX B**
**Laboratory Test Certificates**

# CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| **Work Order** | : **CA2303570** | Page | : 1 of 2 |
| Client | : **ACT Geotechnical Engineers Pty Ltd** | Laboratory | : ALS Water Resources Group |
| Contact | : Salim Mahmud | Contact | : Client Services |
| Address | : 5/9 Beaconsfield Street<br>Fyshwick ACT 2609 | Address | : 2/33 Couranga Cr Hume ACT Australia 2620 |
| Telephone | : ---- | Telephone | : +61 2 6202 5404 |
| Project | : ---- | Date Samples Received | : 08-Jun-2023 14:00 |
| Order number | : ---- | Date Analysis Commenced | : 14-Jun-2023 |
| C-O-C number | : ---- | Issue Date | : 20-Jun-2023 11:33 |
| Sampler | : ---- | | |
| Site | : ---- | | |
| Quote number | : ---- | | |
| No. of samples received | : 5 | | |
| No. of samples analysed | : 5 | | |

Accreditation No. 992
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

**Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.**

## *Signatories*

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| Geetha Ramasundara | Chemistry Teamleader | Inorganics, Hume, ACT |

## General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- **For samples collected by ALS WRG, sampling was carried out in accordance with Procedure EN67**

## Analytical Results

| Sub-Matrix: SOLID (Matrix: SOLID) | | | | Sample ID | BH1 0.4m-0.6m | BH2 0.9m-1.1m | BH3 0.4m-0.6m | BH6 0.5m-0.8m | BH9 0.4m-0.6m |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Sampling date / time | 05-Jun-2023 00:00 | 05-Jun-2023 00:00 | 05-Jun-2023 00:00 | 05-Jun-2023 00:00 | 06-Jun-2023 00:00 |
| Compound | CAS Number | LOR | Unit | | CA2303570-001 | CA2303570-002 | CA2303570-003 | CA2303570-004 | CA2303570-005 |
| | | | | | Result | Result | Result | Result | Result |
| **EA002CA: pH in Soil** | | | | | | | | | |
| ø **pH Value** | ---- | 0.1 | pH Unit | | **6.5** | **6.1** | **6.8** | **6.8** | **7.5** |
| **EA010CA: Conductivity** | | | | | | | | | |
| ø **Electrical Conductivity @ 25°C** | ---- | 0.01 | dS/m | | **2.46** | **1.92** | **1.59** | **0.62** | **3.25** |
| **EA080CA: Resistivity** | | | | | | | | | |
| **Resistivity at 25°C** | ---- | 1 | ohm cm | | **406** | **520** | **628** | **1610** | **307** |
| **ED009CA: Anions** | | | | | | | | | |
| **Chloride** | 16887-00-6 | 1 | mg/kg | | **4000** | **2820** | **2580** | **897** | **4920** |
| **Sulfate** | 14808-79-8 | 2 | mg/kg | | **615** | **563** | **429** | **135** | **876** |

**APPENDIX C**
**Definitions of Geotechnical Engineering Terms**

## DESCRIPTION AND CLASSIFICATION OF SOILS

The methods of description and classification of soils used in this report are based on the Australian Standard 1726 – 1993, Geotechnical site investigations. In general, descriptions cover the following properties – soil type, colour, secondary grain size, structure, inclusions, strength or density and geological description.

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (e.g. sandy clay) on the following basis:

| **Classification** | **Particle Size** |
|---|---|
| Clay | Less than 0.002mm |
| Silt | 0.002mm to 0.06mm |
| Sand | 0.06mm to 2.00mm |
| Gravel | 2.00mm to 60.00mm |
| Cobbles | 60mm (63mm) to 200mm |
| Boulders | >200mm |

Soils are also classified according to the Unified Soil Classifications System which is included in this Appendix. Rock types are classified by their geological names.

Cohesive soils are classified on the basis of strength either by laboratory testing or engineering examination. The terms are defined as follows:

| **Consistency** | **Shear Strength su(kPa) (Representative Undrained Shear)** | |
|---|---|---|
| Very soft | < 12 | <2 (~SPT "N") |
| Soft | 12 - 25 | 2-4 |
| Firm | 25 - 50 | 4-8 |
| Stiff | 50 – 100 | 8-15 |
| Very Stiff | 100 – 200 | 15-30 |
| Hard | > 200 | >30 |

Non-cohesive soils are classified on the basis of relative density, generally from the results of in-situ standard penetration tests as below:

| **Term** | **Relative Density (%)** | **SPT Blows/300mm 'N'** |
|---|---|---|
| Very loose | < 15 | <4 |
| Loose | 15-35 | 4-10 |
| Medium dense | 35-65 | 10-30 |
| Dense | 65-85 | 30-50 |
| Very Dense | >85 | >50 |

## SAMPLING

Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of 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 generally taken by one of two methods:

1. Driving or pushing a thin walled sample tube into the soil and withdrawing with a sample of soil in a relatively undisturbed state.

2. Core drilling using a retractable inner tube (R.I.T.) core barrel.

Such samples yield information on structure and strength in additions to that obtained from disturbed samples and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling are given in the report.

## PENETRATION TESTING

The relative density of non-cohesive soils is generally assessed by in-situ penetration tests, the most common of which is the standard penetration test. The test procedure is described in Australian Standard 1289 “Testing Soils for Engineering Purposes” Testing Soils for Engineering Purposes” – Test No. F3.1.

The standard penetration test is carried out by driving a 50mm diameter split tube penetrometer of standard dimensions under the impact of a 63 kg hammer having a free fall of 750mm.

The “N” value is determined as the number of blows to achieve 300mm of penetration (generally after disregarding the first 150mm penetration through possibly disturbed material). The results of these tests can be related empirically to the engineering properties of the soil.

The test is also used to provide useful information in cohesive soils under certain conditions, a good quality disturbed sample being recovered with each test. Other forms of in situ testing are used under certain conditions and where this occurs, details are given in the report.

## DEFINITIONS OF ROCK, SOIL, AND DEGREES OF CHEMICAL WEATHERING

### GENERAL DEFINITIONS – ROCK AND SOIL

ROCK In engineering usage, rock is a natural aggregate of minerals connected by strong and permanent cohesive forces.

Note: Since "strong" and "permanent" are subject to different interpretations, the boundary between rock and soil is necessarily an arbitrary one.

SOIL In engineering usage, soil is a natural aggregate of mineral grains which can be separated by such gentle mechanical means as agitation in water, can be remoulded and can be classified according to the Unified Soil Classification System. Three principal classes of soil recognized are:

Residual soils: soils which have been formed in-situ by the chemical weathering of parent rock. Residual soil may retain evidence of the original rock texture or fabric or, when mature, the original rock texture may be destroyed.

Transported soils: soils which have been moved from their places of origin and deposited elsewhere. The principal agents of erosion, transport and deposition are water, wind and gravity. Two important types of transported soil in engineering geology and materials investigations are:

Colluvium – a soil, often including angular rock fragments and boulders, which has been transported downslope predominantly under the action of gravity assisted by water. The principle forming process is that of soil creep in which the soil moves after it has been weakened by saturation. It may be water borne for short distances.

Alluvium – a soil which has been transported and deposited by running water. The larger particles (sand and gravel size) are water worn.

Lateritic soils: soils which have formed in situ under the effects of tropical weathering include all reddish residual and non residual soils which genetically form a chain of material ranging from decomposed rock through clay to sesqui-oxide rich crusts. The term does not necessarily imply any compositional, textural or morphological definition; all distinctions useful for engineering purposes are based on the differences in geotechnical characteristics.

### ROCK WEATHERING DEFINITIONS

| | |
|---|---|
| Extremely Weathered (EW) | Rock substance affected by weathering to the extent that the rock exhibits soil properties, i.e. it can be remoulded and can be classified according to the Unified Classification System, but the texture of the original rock is still evident. |
| Highly Weathered (HW) | Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance and other signs of the chemical or physical decomposition are evident. Porosity and strength may be increased or decreased compared to the fresh rock usually as a result of iron leaching or deposition. The colour and strength of the original fresh rock substance is no longer recognisable. |
| Moderately Weathered (MW) | Rock substance affected by weathering to the extent that staining extends throughout the whole of the rock substance and the original colour of the fresh rock is no longer recognisable. |
| Slightly Weathered (SW) | Rock substance affected by weathering to the extent that partial staining or discolouration of the rock substance, usually by limonite, has taken place. The colour and texture of the fresh rock is recognisable. |
| Fresh (Fr) | Rock substance unaffected by weathering. |

The degrees of rock weathering may be gradational. Intermediate stages are described by dual symbols with the prominent degree of weathering first (e.g. EW-HW).

The various degrees of weathering do not necessarily define strength parameters as some rocks are weak, even when fresh, to the extent that they can be broken by hand across the fabric, and some rocks may increase in strength during the weathering process.

Fresh drill cores of some rock types, such as basalt and shale may disintegrate after exposure to the atmosphere due to slaking, desiccation, expansion or contraction, stress relief or a combination of any of these factors.

## AN ENGINEERING CLASSIFICATION OF SEDIMENTARY ROCKS

This classification system provides a standardised terminology for the engineering description of the sandstone and shales in the Sydney area, but the terms and definitions may be used elsewhere when applicable. Where other rock types are encountered, such as in dykes, standard geological descriptions are used for rock types and the same descriptions as below are used for strength, fracturing and weathering.

Under this system rocks are classified by Rock Type, Strength, Stratification Spacing, Degree of Fracturing and Degree of Weathering. These terms do not cover the full range of engineering properties. Descriptions of rock may also need to refer to other properties (e.g. durability, abrasiveness, etc) where these are relevant.

## ROCK TYPE DEFINITIONS

| ROCK TYPE | DEFINITION |
|---|---|
| Conglomerate: | More than 50% of the rock consists of gravel sized (greater than 2mm) fragments. |
| Sandstone: | More than 50% of the rock consists of sand sized (0.06 to 2mm) grains. |
| Siltstone: | More than 50% of the rock consists of silt-sized (less than 0.06mm) granular particles and the rock is not laminated. |
| Claystone: | More than 50% of the rock consists of silt or clay sized particles and the rock is not laminated. |
| Shale: | More than 50% of the rock consists of silt or clay sized particles and the rock is laminated. |

Rocks possessing characteristics of two groups are described by their predominant particle size with reference also to the minor constituents, e.g. clayey sandstone, sandy shale.

## STRATIFICATION SPACING

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

## DEGREE OF FRACTURING

This classification applies to diamond drill cores and refers to the spacing of all types of natural fractures along which the core is discontinuous. These include bedding plane partings, joints and other rock defects, but exclude known artificial fractures such as drilling breaks.

| Term | Description |
|---|---|
| Fragmented: | The core is comprised primarily of fragments of length less than 20mm, and mostly of width less than the core diameter |
| Highly Fractured: | Core lengths are generally less than 20mm – 40mm with occasional fragments. |
| Fractured: | Core lengths are mainly 30mm – 100mm with occasional shorter and longer section. |
| Slightly Fractured: | Core lengths are generally 300mm – 1000mm with occasional longer sections and occasional sections of 100mm – 300mm. |
| Unbroken: | The core does not contain any fracture. |

## ROCK STRENGTH

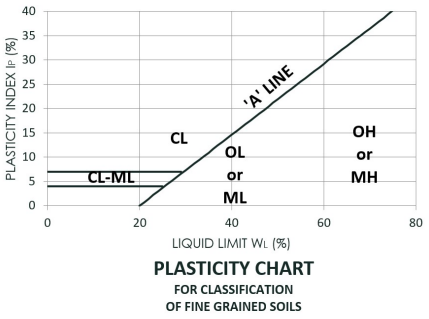
Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance in the direction normal to the bedding. The test procedure is described by the International Society of Rock Mechanics.

| Term | Point Load Index Is(50) MPa | Field Guide | Approx qu MPa* |
|---|---|---|---|
| Extremely Weak: | 0.03 | Easily remoulded by hand to a material with soil properties. | 0.7 |
| Very Weak: | 0.1 | May be crumbled in the hand. Sandstone is “sugary” and friable. | 2.4 |
| Weak: | 0.3 | A piece of core 150mm long x 50mm dia. May be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling. | 7 |
| Medium Strong: | 1 | A piece of core 150mm long x 50mm dia. can be broken by hand with considerable difficulty. Readily scored with knife. | 24 |
| Strong: (SW) | 3 | A piece of core 150mm long x 50mm dia. core cannot be broken by unaided hands, can be slightly scratched or scored with knife. | 70 |
| Very Strong (SW) | 10 | A piece of core 150mm long x 50mm dia. may be broken readily with hand held hammer. Cannot be scratched with pen knife. | 240 |
| Extremely Strong (Fr) | >10 | A piece of core 150mm long x 50mm dia. is difficult to break with hand held hammer. Rings when struck with a hammer. | >240 |

The approximate unconfined compressive strength (qu) shown in the table is based on an assumed ration to the point load index of 24:1. This ratio may vary widely.

# Unified Soil Classification System (Metricated)
## Data for Description Indentification and Classification of Soils

| MAJOR DIVISIONS | | | | DESCRIPTION | | | | FIELD IDENTIFICATION | | | | | LABORATORY CLASSIFICATION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Group Symbol | Graphic Symbol | TYPICAL NAME | DESCRIPTIVE DATA | | | | | | % [2] < 0.06mm | PLASTICITY OF FINE FRACTION | | | NOTES |
| COARSE GRAINED SOILS | More than 50% by dry mass, less than 60mm is greater than 0.06mm. | GRAVELS | More than 50% of coarse grains are greater than 2.0mm | GW | | Well graded gravels and gravel-sand mixtures, little or no fines | Give typical name, indicate approximate percentages of sand and gravel, maximum size, angularity, surface condition and hardness of the coarse grains, local or geological name and other pertinent descriptive information, symbols in parenthesis.<br><br>For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics.<br><br>EXAMPLE:<br>Silty Sand, gravelly, about 20% hard, angular gravel particles, 10mm maximum size, rounded and sub angular sand grains coarse to fine, about 15% non-plastic fines with low dry strength, well compacted and moist in place, light brown alluvial sand, (SM) | Determine approximate percentages of material over 60mm size, maximum size, shape, surface texture, hardness of material, geological description. Identify on estimated percentage mass of the various fractions. | COARSE GRAINED SOILS | More than half of the material less than 60mm is larger than 0.06mm | 0.06mm is about the smallest particle visible to the naked eye | GRAVELS AND SANDS | GRADATIONS | NATURE OF FINES | DRY STRENGTH | Group Symbol | Use the gradation curve of material passing 60mm for classification of fractions according to criteria given under 'Major Division'. | 0-5 | - | >4 | Between 1 and 3 | 1. Identify Fines by the method given for fine grained soils.<br><br>2. Borderline classifications occur when the percentage of fines (fraction smaller than 0.06mm size) is greater than 5% and less than 12%.<br><br>Borderline classifications require the use of dual symbols<br>eg SP-SM<br>GW-GC |
| | | | | GP | | Poorly graded gravels and gravel-sand mixtures, little or no fines | | | | | | GOOD | Wide range in grain size | "Clean" materials (not enough fines to band coarse grains) | None | GW | | 0-5 | - | Fails to comply with above | | |
| | | GRAVELLY SOILS | | GM | | Silty gravels, gravel-sand-silt mixtures | | | | | | POOR | Predominantly one size or range of sizes | | | GP | | 12-50 | Below 'A' line and Ip >7 | - | - | |
| | | | | GC | | Clayey gravels gravel-sand-clay mixtures | | | | | | GOOD TO FAIR | "Dirty" materials (Excess of fines) | Fines are non-plastic (1) | None to medium | GM | | 12-50 | Above 'A' line and Ip > 7 | - | - | |
| | | SANDS | More than 50% of coarse grains are greater than 2.0mm | SW | | Well graded sands and gravelly sands, little or no fines | | | | | | | | Fines are plastic (1) | | GC | | 0-5 | - | >6 | between 1 and 3 | |
| | | | | SP | | Poorly graded sands and gravelly sands, little or no fines | | | | | | GOOD | Wide range in grain size | "Clean" materials (not enough fines to band coarse grains) | None | SW | | 0-5 | - | Fails to comply with above | | |
| | | SANDY SOILS | | SM | | Silty sand, sand-silt mixtures | | | | | | POOR | Predominantly one size or range of sizes | | | SP | | 12-50 | Below 'A' line or Ip < 4 | - | - | |
| | | | | SC | | Clayey sands, sand-clay mixtures | | | | | | GOOD TO FAIR | "Dirty" materials (Excess of fines) | Fines are non-plastic (1) | None to medium | SM | | 12-50 | Above 'A' line and Ip > 7 | - | - | |
| | | | | | | | | | | | | | | Fines are plastic (1) | | SC | | | | | | |
| FINE GRAINED SOILS | More than 50% by dry mass, less than 60mm is less than 0.06mm | Liquid Limit less than 50% | | ML | | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands. | Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, colour in wet condition, odour if any, local or geological name and r pertinent descriptive information, symbols in parenthesis.<br><br>For undisturbed soil add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions.<br><br>EXAMPLE<br>Clayey Silt, brown, low plasticity, small percentage of fine sand, numerous vertical root-holes, firm and dry in place, fill, (ML). | | FINE GRAINED SOILS | More than half of the material less than 50mm is less than 0.06mm | | SILT AND CLAY FRACTION | | | | | | | | | |
| | | | | CL | | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. | | | | | | Fraction smaller than 0 20mm AS sieve size | | | | | | | | | | |
| | | | | OL | | Organic silts and organic silty clays of low plasticity | | | | | | DRY STRENGTH | DILATANCY | TOUGHNESS | | | | | | | | |
| | | Liquid Limit more than 50% | | MH | | Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts. | | | | | | None to low | Quick to slow | None | | ML | | Below 'A' line | | | | |
| | | | | CH | | Inorganic clays of high plasticity, fat clays. | | | | | | Medium to high | None to very slow | Medium | | CL | | Above 'A' line | | | | |
| | | | | OH | | Organic clays of medium to high plasticity. | | | | | | Low to medium | Slow | Low | | OL | | Below 'A' line | | | | |
| | | | | | | | | | | | | Low to medium | Slow to none | Low to medium | | MH | | Below 'A' line | | | | |
| | | | | | | | | | | | | High to very high | None | High | | CH | | Above 'A' line | | | | |
| | | | | | | | | | | | | Medium to high | None to very slow | Low to medium | | OH | | Below 'A' line | | | | |
| | | | | Pt | | Peat muck and other highly organic soils. | | Readily identified by colour, odour, spongy feel and generally by fibrous texture | | | | | | | | Pt* | *Effervescence with H2O2 | | | | | |




**PLASTICITY CHART**
**FOR CLASSIFICATION OF FINE GRAINED SOILS**

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# Limitations in the Use and Interpretation of this Geotechnical Report

Our Professional services were performed, our findings obtained, and our recommendations prepared in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

The geotechnical report was prepared for the use of the Owner in the design of the subject development and should be made available to potential contractors and/or the Contractor for information on factual data only. This report should not be used for contractual purposes as a warranty of interpreted subsurface conditions such as those indicated by the interpretive borehole and test pit logs, cross- sections, or discussion of subsurface conditions contained herein.

The analyses, conclusions and recommendations contained in the report are based on site conditions as they presently exist and assume that the exploratory bore holes, test pits, and/or probes are representative of the subsurface conditions of the site. If, during construction, subsurface conditions are found which are significantly different from those observed in the exploratory bore holes and test pits, or assumed to exist in the excavations, we should be advised at once so that we can review these conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time between conducting this investigation and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, this report should be reviewed to determine the applicability of the conclusions and the recommendations considering the changed conditions and time lapse.

The summary bore hole and test pit logs are our opinion of the subsurface conditions revealed by periodic sampling of the ground as the test holes progressed. The soil descriptions and interfaces between strata are interpretive and actual changes may be gradual.

The bore hole and test pit logs and related information depict subsurface conditions only at the specific locations and at the particular time designated on the logs. Soil conditions at the other locations may differ from conditions occurring at these bore hole and test pit locations. Also, the passage of time may result in a change in the soil conditions at these test locations.

Groundwater levels often vary seasonally. Groundwater levels reported on the boring logs or in the body of the report are factual data only for the dates shown.

Unanticipated soil conditions are commonly encountered on construction sites and cannot be fully anticipated by merely taking soil samples, bore holes or test pits. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. It is recommended that the Owner consider providing a contingency fund to accommodate such potential extra costs.

This firm cannot be responsible for any deviation from the intent of this report including, but not restricted to, any changes to the scheduled time of construction, the nature of the project or the specific construction methods or means indicated in this report: nor can our company be responsible for any construction activity on sites other than the specific site referred to in this report.