ACT Geotechnical Engineers

ACT Geotechnical Engineers Pty Ltd
ACN 063 673 530

5/9 Beaconsfield Street, Fyshwick ACT 2609
PO Box 9225, Deakin ACT 2600
Ph: (02) 6285 1547

22 April 2020
Our ref: MD/C10638.228

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

Attention: Andrew Stewart

Dear Sir

PROPOSED REPLACEMENT OF CUTTAGEE BRIDGE
TATHRA-BERMAGUI ROAD, CUTTAGEE, NSW, 2546
GEOTECHNICAL INVESTIGATION REPORT

We are pleased to present our geotechnical investigation for the proposed replacement of Cuttagee Bridge on Tathra-Bermagui Road, Cuttagee. It is understood the project involves the replacement of an existing bridge.

The report outlines the methods and results of exploration, describes site subsurface conditions, and provides recommendations for site earthworks and building 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

Jeremy Murray
Director

BEGA VALLEY SHIRE COUNCIL

PROPOSED REPLACEMENT OF CUTTAGEE BRIDGE
TATHRA-BERMAGUI ROAD, CUTTAGEE, NSW

GEOTECHNICAL INVESTIGATION REPORT

APRIL 2020

BEGA VALLEY SHIRE COUNCIL

PROPOSED REPLACEMENT OF CUTTAGEE BRIDGE

GEOTECHNICAL INVESTIGATION REPORT

TABLE OF CONTENTS

BEGA VALLEY SHIRE COUNCIL

PROPOSED REPLACEMENT OF CUTTAGEE BRIDGE
TATHRA-BERMAGUI ROAD, CUTTAGEE

GEOTECHNICAL INVESTIGATION REPORT

1 INTRODUCTION

In response to a request by Andrew Stewart of Bega Valley Shire Council, ACT Geotechnical Engineers Pty Ltd conducted a geotechnical investigation for proposed replacement of Cuttagee Bridge on Tathra-Bermagui Road in Cuttagee. It is understood the project involves the replacement of the existing timber bridge with a new two-lane, 9m wide x 110m long bridge.

The aim of the investigation was to:

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

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

(iii) Recommend suitable footing systems for the new bridge including founding depths and recommended allowable bearing pressures.

(iv) Standard Penetration Test and Point Load Test results,

(v) Advise on preparation of subgrades for building slabs, vehicle pavements.

(vi) Advise on excavation conditions, suitability of excavated material for use in controlled fill platforms, and advice for construction of controlled fill platforms.

(vii) Advise on stability of cut and fill batters, and earth pressure parameter values for abutment walls

(viii) Advise on pavement subgrade preparation and provide indicative design CBR values.

(ix) Provide the Earthquake Site Factor.

(x) Advise on site drainage and other relevant geotechnical issues.

2 SITE DESCRIPTION & GEOLOGY

Cuttagee Bridge is located at 3599 Tathra-Bermagui Road, Cuttagee, NSW. Figure 1 shows the site locality while Figure 2 is a recent aerial photo that shows the existing site layout and the location of the boreholes.

The 1: 250,000 Bega-Mallacoota Geology Map (Reference 1) documents the area at Cuttagee bridge to be covered by Cainozoic age Quarternary coastal marine deposits as well as Paleozoic age, Adaminaby Group bedrock which includes undifferentiated sediments, turbidites, sandstone, mudstone and shale.

3 INVESTIGATION METHODS

To establish the subsurface conditions, a track mounted drill rig with a 110mm auger attachment was used to drill an investigation borehole on either side of the bridge. Three boreholes were drilled at the Cuttagee Bridge location, designated BH1-BH3 on 2-3 April 2020. BH1 and BH2 were augered to a 10m target depth with an SPT conducted at the end of the hole, as per the requirement. BH3 was augered to refusal and then >3m of rock core obtained. Borehole logs are presented in Appendix A.

The cored borehole, BH3, was drilled by a track mounted drill rig. The overburden soils were augered using a 110mm continuous flighted helix auger equipped with a tungsten tipped "V" bit. An NMLC triple-tube core barrel (~52mm internal diameter), with diamond impregnated drill-bit, was used to core the bedrock. Water was used as the recirculating fluid.

Core retrieved from BH3 was placed in a metal core tray. Following drilling, the core was photographed and selected sections tested for point-load strength. Borehole logs, including core photographs, are presented in Appendix A.

The auger profiles were visually logged in accordance with the Unified Soil Classification System (USCS). Definitions of geotechnical engineering terms used on the logs and in this report, including a copy of the USCS chart, are provided in Appendix C.

4 INVESTIGATION RESULTS

4.1 Subsurface Conditions – Northern End (BH3)

Investigation borehole BH3 found a subsurface profile of the site, comprising:

Geological Profile	Typical Depth Interval	Description
CONCRETE	0m to 0.05m	ASHPHALTIC CONCRETE
FILL	0.05m to 0.2m	GRAVELLY SILTY SAND; fine to coarse grained sand, sub angular and angular gravels to 25mm size, brown, dry to moist, loose to medium dense.
WEATHERED BEDROCK	Below 0.2m	SILTSTONE; EW, HW, MW/SW, FR, extremely weak rock, weak rock, moderately strong rock, extremely strong rock, very fine grained, fine grained, pale brown, grey to brown, grey, iron staining, dry.

4.2 Subsurface Conditions – Southern End (BH1 and BH2)

Investigation boreholes BH1 and BH2 found a subsurface profile of the site, comprising:

Geological Profile	Typical Depth Interval	Description
FILL	0m to 0.2m/0.25m	GRAVELLY SILTY SAND/GRAVELLY SANDY SILT; fine to coarse grained sand, angular gravels to 15mm size, grey to brown, some pink, dry, dry to moist, medium dense.
RESIDUAL/ALLUVIUM/MARINE SOILS	0.2m/0.25m to >10.45m/10.65m	CLAYEY SAND, SAND, GRAVELLEY SILTY SAND, SANDY SILT/SILTY SAND; fine to medium grained sand, medium grained sand, medium to coarse grained sand, low plasticity clay, sub angular and angular gravels to 10mm size, pale brown, brown, grey, yellow to brown, some angular gravels to 15mm size, some shells and gravel, dry, dry to moist, moist, wet, medium dense, dense, loose.

4.3 Point-Load Strength Testing

Point-load strength index tests were carried out on selected representative rock core specimens. The index values were used to derive the approximate compressive strength of the rock by applying the empirical relationship $q_U = 24 \times I_s(50)$ (Reference 2), where q_U is the ultimate compressive strength. The test method and calculation of point load strength index $I_s(50)$ is in accordance with the test methods outlined by the International Society for Rock Mechanics (Reference 3). The results of the testing are tabulated in Appendix C.

The estimated compressive strengths of the granodiorite bedrock is summarised in Table 1 below.

TABLE 1
Estimated Rock Compressive Strengths

Location (borehole)	Rock Weathering Grade	Estimated Compressive Strength (MPa)		No. of Point Load Tests
		Range	Average	
(BH3)	MW/SW – FR Siltstone	2.4 - 47.28	47.28	4

The MW/SW and FR Siltstone could have intact compressive strengths varying between 2.4MPa and 47.28MPa.

4.4 SPT Results

Investigation auger holes BH1 and BH2 yielded the following SPT results at the end of the augering:

Borehole	Depth	Blows	N-Value
BH1	10m-10.15m	6	>17
	10.15m-10.3m	7	
	10.3m-10.45m	10	
BH2	10.2m-10.35m	8	21
	10.35m-10.5m	9	
	10.5m-10.65m	12	

4.5 Groundwater

Groundwater was encountered in BH1 at 4m and the soils were mostly moist, moist to wet and wet on the southern side of the bridge. Groundwater was not encountered on the Northern side of the bridge in BH3. Temporary, perched seepages could be encountered following rainfall within the more pervious soils. Permanent groundwater is expected to correspond to the water level in the adjacent Cuttagee Creek, but this should be confirmed during construction. Temporary, perched seepages could also occur at shallower depth within the more pervious soils following rainfall.

5 DISCUSSION & RECOMMENDATIONS

5.1 Site Classification

The upper (low plasticity clays) soils are slightly reactive in terms of potential shrink-swell movements that may occur due to seasonal ground moisture changes. The characteristic ground surface movement "Y_s", as defined by AS2870 for the range of extreme dry to extreme wet moisture conditions is estimated to be between 0mm and 20mm in size. The site is therefore Class "S" (slightly reactive).

Deemed-to-comply footing designs provided by AS2870 are applicable specifically to residential-style one and two-storey structures, or buildings with similar loads and superstructure stiffness.

5.2 Bridge Footings & Ground Slabs

Suitable footings for the structure would include pads/strips, the pads/strips including thickened sections of slabs forming footings should be founded in the dense/stiff alluvial soil below 0.2m/0.25m depth or in newly placed controlled fill (Section 5.5).

The investigation found shallow bedrock at the northern end of the bridge (BH3), but bedrock was not encountered within the 10.45m/10.65m drilling depth of the southern end of the bridge (BH1 and BH2).

Preferably, piers extending to bedrock should be used. Bored piers would require liners, as pier holes will collapse below groundwater level. Therefore, CFA (Continuous flights auger), screw in piers or concrete/steel driven piles may be more practical.

Recommended allowable end-bearing pressures for various footing systems are provided in Table 2 below.

TABLE 2

Recommended Allowable Bearing Pressures for Footings

Foundation Material Type	Depth Below Existing Surface	Allowable End-Bearing Pressure			Allowable Shaft Resistance	
		Strips	Pads	Driven or Screw Piles	Downward Loading	Uplift
Newly Constructed Controlled Fill	-	100kPa	125kPa	N/A	N/A	N/A
Medium Dense / Stiff Alluvial Soil	0.2m/0.25m	75kPa	100kPa	150kPa	7kPa	3kPa
MW/SW & less weathered Bedrock	1.0m (BH3) >10.45m (BH1 & BH2)	3000kPa	2500kPa	4000kPa	400kPa	200kPa

Note: Ultimate bearing capacities would be 3 times the allowable values.

All footing excavations should be inspected and approved by an experienced geotechnical engineer to confirm the foundation material and design values, and to ensure the excavations are clean and stable.

Groundslabs can be constructed on the natural alluvial soil, newly constructed controlled fill following the removal of any moisture-affected alluvial soil, and disturbed ground. Following excavation to required level, slab areas on soil should be proof-rolled by a pad-foot roller to check for any weak, wet or deforming soils that may require replacement. Suitable replacement fill should be compacted at about OMC in not thicker than 150mm layers to not less than 95%ModMDD.

If required for design of ground slabs, a modulus of subgrade reaction of 30kPa/mm can be assumed for a natural soil or controlled fill foundation.

5.3 Excavation Conditions & Use of Excavated Material

Proposed excavation depths have not been indicated. The soils and any encountered extremely weak to weak bedrock can be dug by backhoe and excavator.

Bored piers below groundwater level will be prone to collapse and would require liners. The low plasticity clayey and sandy, alluvial soils and any excavated bedrock could be used in controlled fill construction provided all particles are less than 75mm size.

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.

Groundwater was at 4m in BH1 during the excavation and is expected to correspond with water level in the adjacent creek. Temporary seepages could occur at shallower depth following rain. Seepages may also be present as within the alluvial soil. Such seepage should be readily controllable during the bulk excavation by means of a temporary sump and pump.

5.4 Stable Cut/Fill Batter Slopes

Temporary site excavations to 1.5m depth can be formed near-vertical, although excavations below groundwater will be prone to collapse. If required, deeper temporary cuts can be benched or formed at 1(H):1(V). Excavations below groundwater level are expected to be unstable, and would require shoring. Exposed temporary batters in soil should be protected from the weather by black plastic pinned to the face with link-wire mesh or similar, and should be inspected during construction by a geotechnical engineer.

Permanent cut and fill soil batters should be formed at no steeper than 2(H):1(V). All soil cut and fill surfaces should be protected against erosion by topsoiling and grassing, or other suitable means. It is advisable that permanent batters are inspected during excavation by an experienced geotechnical engineer to confirm stability.

5.5 Controlled Fill Construction

The following procedure is recommended for construction of controlled fill foundation platforms for buildings and pavements:

1) Areas be fully stripped of any topsoil and underlying moisture-softened soils.
2) Stripped foundations 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 require replacement.
3) Replacement fill and platform fill of suitable materials (Section 5.3) be compacted to required level in not thicker than 150mm layers to not less than 98%StdMDD at about optimum moisture content.
4) Fill placement and control testing be overviewed and certified by a geotechnical engineer at Level 1 or 2 as defined in AS3798 - 1996 "Guidelines on Earthworks for Commercial & Residential Developments" (Reference 4).

5.6 Pavement Subgrades

Pavement subgrades are expected to comprise natural alluvial soils, or controlled fill of similar material. A design CBR value of 5% can be assumed for the natural soils and controlled fill soils. Exposed subgrades should be inspected by a geotechnical engineer to confirm or vary the design CBR value(s).

5.7 Earthquake Site Factor

The Geoscience website (Reference 5) lists the earthquake acceleration coefficients for major centres to be considered in structural design. The area of the proposed bridge has an acceleration coefficient of 0.03.

Section 4 of AS1170.4 "Minimum Design Loads on Structures - Part 4: Earthquake Loads" (Reference 6) summarises the Site Subsoil Class which depends on the subsurface conditions at the site in question. A Site Subsoil Class C_e is applicable for this project.

5.8 Site Drainage & Scour Protection

Suitable surface drainage should be provided to ensure that rainfall run-off or other surface water cannot pond against buildings or pavements. Subsoil drains should be provided along the upslope sides of buildings and pavements. Drainage should be provided behind all retaining walls.

It is recommended that the abutments of the new bridge are protected against scour, particularly if a shallow footing system is used. Scour protection could comprise rip-rap, mortared stone, gabions, reno-mattress, pre-cast concrete panels, etc.

ACT Geotechnical Engineers Pty Ltd

REFERENCES

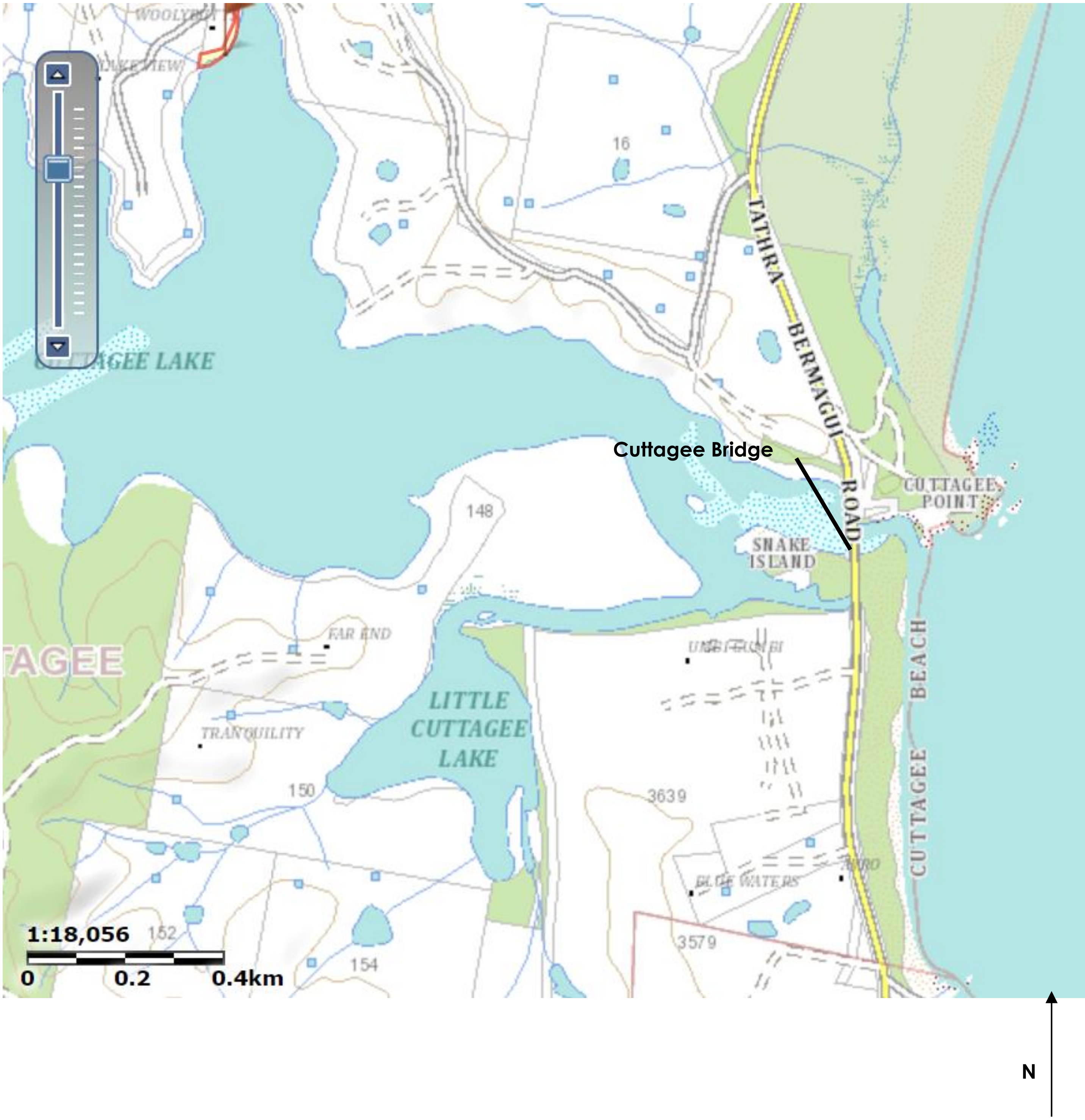
Reference 1 Lewis P.C. and Glen R.A., 1995, Bega - Mallacoota 1:250 000 Geological Sheet SJ/55-04 & part SJ/55-08, 2nd edition, Geological Survey of New South Wales, Sydney

Reference 3 Standards Australia, "AS2870 - Residential slabs and footings - Construction", 2011.

Reference 4 Standards Australia, "AS3798 - Guidelines on Earthworks for Commercial & Residential Developments", 1996.

Reference 5 Geoscience Australia - http://www.ga.gov.au/darwin-view/hazards.xhtml# 15 April 2020.

Reference 6 Standards Australia, "AS1170.4 - 1993 - Minimum Design Loads on Structures Part 4: Earthquake Loads".



BEGA VALLEY SHIRE COUNCIL
PROPOSED CUTTAGEE BRIDGE
SITE LOCALITY

ACT Geotechnical Engineers Pty Ltd	**C10638.228**	**FIGURE 1**

LEGEND

⊗ - Location of Borehole

BEGA VALLEY SHIRE COUNCIL
PROPOSED CUTTAGEE BRIDGE
AERIAL PHOTOGRAPH & LOCATIONS OF BOREHOLES

ACT Geotechnical Engineers Pty Ltd	**C10638.228**	**FIGURE 2**

APPENDIX A

Borehole Logs BH1- BH3 – CUTTAGEE BRIDGE

Borehole Log

Borehole No.	BH1
Sheet	1 of 2
Job No.	C10638.228

CLIENT: Bega Valley Shire Council

PROJECT: Proposed Bridge
Cuttagee Bridge, Tathra-Bernagui Road, NSW

Equipment Type : Track Mounted w/ Auger
Hole Diameter : 55mm

Location :

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

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	AUGERING	0.0–0.2		SM	GRAVELLY SILTY SAND/GRAVELLY SANDY SILT, fine to coarse grained sand, angular gravels to 15mm size, grey to brown, dry to moist	Medium Dense		FILL
			0.2–2.5		SC	CLAYEY SAND; fine to medium grained sand, low plasticity clay, pale brown, some angular gravels to 3mm size, dry to moist	Medium Dense		ALLUVIUM
			2.5–4.0		SC	CLAYEY SAND; fine to medium grained sand, low plasticity clay pale brown, some angular gravels to 15mm size, moist	Medium Dense		
			4.0–5.0		SP	SAND; medium grained, pale brown, wet some shells and gravel	Medium Dense		
		WASH BORING	5.0–6.0		SP	Washbored from 5m; no sample retrieval (presumed to be SAND; medium grained, wet)			MARINE

Logged By : AB Date : 2/4/20 Checked By : Date :

Borehole Log

Borehole No.	BH1
Sheet	2 of 2
Job No.	C10638.228

CLIENT: Bega Valley Shire Council

PROJECT: Proposed Bridge
Cuttagee Bridge, Tathra-Bernagui Road, NSW

Equipment Type : Track Mounted w/ Auger
Hole Diameter : 55mm

Location :

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

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	WASH BORING	7.0, 8.0, 9.0		SP	Washbored from 5m; no sample retrieval (presumed to be SAND; medium grained, wet)			MARINE
			10.0 – 10.45		SP	SAND; medium to coarse grained, brown, wet		SPT 6, 7, 10+ for 150mm N>17	
			11.0, 12.0			BOREHOLE TERMINATED AT 10.45m At Target			

Logged By : AB Date : 2/4/20 Checked By : Date :

ACT Geotechnical Engineers

fortify

Borehole Log

Borehole No.	BH2
Sheet	1 of 2
Job No.	C10638.228

CLIENT: Bega Valley Shire Council

PROJECT: Proposed Bridge
Cuttagee Bridge, Tathra-Bernagui Road, NSW

Location :

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

Equipment Type : Track Mounted w/ Auger
Hole Diameter : 55mm

Samples	Water	Casing	Depth Metres	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	AUGERING	0.00–0.25	SM	GRAVELLY SILTY SAND; fine to coarse grained sand, angular gravels to 5mm size, grey to brown, some pink, dry	Medium Dense		FILL
			0.25–1.5	SM	GRAVELLY SILTY SAND; fine to medium grained, sub angular and angular gravels to 10mm size, yellow to brown, dry	Dense		RESIDUAL
			1.5–1.8	SM	SANDY SILT/SILTY SAND; fine to medium grained sand, grey, dry	Loose		
			1.8–4.0	SP	SAND; medium to coarse grained sand, yellow to brown, moist			MARINE
		WASH BORING	4.0–6.0	SP	Washbored from 4m; no sample retrieval (presumed to be SAND; medium to coarse grained, moist)			

Logged By : AB Date : 2/4/20 Checked By : Date :

Borehole Log

Borehole No.	BH2
Sheet	2 of 2
Job No.	C10638.228

CLIENT: Bega Valley Shire Council

PROJECT: Proposed Bridge
Cuttagee Bridge, Tathra-Bernagui Road, NSW

Location :

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

Equipment Type : Track Mounted w/ Auger
Hole Diameter : 55mm

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	WASH BORING	7.0, 8.0, 9.0, 10.0		SP	Washbored from 4m; no sample retrieval (presumed to be SAND; medium to coarse grained, moist)			
			10.2		SP	SAND; medium to coarse grained sand, pale brown, wet		SPT 8, 9, 12 N=21	
			10.65			BOREHOLE TERMINATED AT 10.65m At Target			
			11.0, 12.0						

Logged By : AB	Date : 2/4/20	Checked By :	Date :

BOREHOLE/EXCAVATION LOG C10638.228.GPJ ACT GEO.GDT 15/4/20

ACT Geotechnical Engineers

fortify

Borehole Log

Borehole No.	BH3
Sheet	1 of 1
Job No.	C10638.228

CLIENT: Bega Valley Shire Council

PROJECT: Proposed Bridge
Cuttagee Bridge, Tathra-Bernagui Road, NSW

Equipment Type : Track Mounted w/ Auger and Rock Corer
Hole Diameter : 55mm

Location :

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

Samples	Water	Casing	Depth Metres	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	AUGERING	0.05		ASPHALTIC CONCRETE			CONCRETE
			0.2	SM	GRAVELLY SILTY SAND; fine to coarse grained sand, sub angular and angular gravels to 25mm size, brown, dry to moist	Loose to Medium Dense		FILL
					SILTSTONE; EW, extremely weak rock, very fine grained, pale brown, dry SILTSTONE; HW, weak rock, very fine grained, pale brown, dry			WEATHERED BEDROCK
		NMLC CORING	1.0		SILTSTONE; MW/SW, strong rock, grey to brown, very fine grained			
			2.3		SILTSTONE; FR, extremely strong rock, grey, fine grained Iron Staining			
			4.5		BOREHOLE TERMINATED AT 4.6m At Target			

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0, 6.0

Logged By : AB	Date : 3/4/20	Checked By :	Date :

BOREHOLE/EXCAVATION LOG C10638.228.GPJ ACT GEO.GDT 15/4/20

ACT Geotechnical Engineers

fortify

Cored Borehole Log

Borehole No.	BH3
	1 of 1
Job No.	C10638.228

CLIENT: Bega Valley Shire Council

PROJECT: Proposed Bridge
Cuttagee Bridge, Tathra-Bernagui Road, NSW

Location :

Collar Level : Not Known
Angle From Horizontal : 90°
Bearing : N.A.

Drill Type :
Barrel Type, Length, Drilling fluid :

Method/Casing	R.Q.D./Lift	Water	Depth Metres	Soil or Rock Substance Description	Degree of Weathering	Is(50) MPa (D = diaxial, A = axial)	Defect Description
AUGERING			0.05	ASPHALTIC CONCRETE			
			0.2	GRAVELLY SILTY SAND; fine to coarse grained sand, sub angular and angular gravels to 25mm size, brown, dry to moist			
				SILTSTONE; EW, extremely weak rock, very fine grained, pale brown, dry SILTSTONE; HW, weak rock, very fine grained, pale brown, dry			
NMLC CORING	83% 100%		1.0	SILTSTONE; MW/SW, strong rock, grey to brown, very fine grained	MW/SW		joint, 40°, planar, rough, - joint, 70°, semi-planar, rough, slight staining, - joint, 20°, irregular, rough, - joint, 80°, -, -, Closed Joint joint, 40°, semi-planar, rough, staining, Iron Staining joint, 80°, planar, rough, - joint, 5°, planar, rough, - 2 joints, 0,85°, planar, rough, staining, Iron Staining joint, 45°, planar, rough, staining, Iron Staining joint, 0°, planar, rough, staining, Iron Staining Fractured and fragmented, Iron Staining
	86% 105%		2.3	SILTSTONE; FR, extremely strong rock, grey, fine grained Iron Staining	FR		Fractured and fragmented, Iron Staining joint, 5°, planar, rough, - joint, 5°, planar, rough, - joint, 20°, planar, rough, slight staining, Iron Staining joint, 45°, planar, rough, staining, Iron Staining Fractured and fragmented, - joint, 1°, semi-planar, rough, staining, Iron Staining joint, 45°, planar, rough, staining, Iron Staining - joints, -°, -, -, -, Quartz Seam, 0.5cm joint, 0°, irregular, rough, - -, Quartz Seam, 1cm -, Quartz Seam, 1.5cm joint, 35°, planar, -, Closed Joint joint, 5°, planar, -, Closed Joint joint, 45°, planar, -, Closed Joint joint, 0,5°, irregular, rough, staining, Iron Staining -, Quartz Seam, 0.8cm joint, 45°, planar, rough, -
			4.5				
				BOREHOLE TERMINATED AT 4.6m At Target			

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0, 6.0

Estimated Strength Range: EW VW W MS S VS ES

Core Length (mm): 30 100 300 1000 3000

Defects

Logged By : AB Date : 3/4/20 Checked By : Date :

APPENDIX B
Point Load Strength Test Results

Point Load Strength Test Results

Borehole	Depth (m)	Diameter (cm)	Gauge Reading (kN)	(Is)50	UCS (Mpa)		Weathering	Description
BH3	*1.5*	*5.2*	*2.34*	**0.87**	**20.88**		MW/SW	Rock Fabric, 5 degrees, irregular, rough
	2.2	*5.2*	*2.96*	**1.09**	**26.16**		MW/SW	Rock Fabric, 70 degrees, planar, smooth
	3.1	*5.2*	*0.27*	**0.1**	**2.4**		FR	Joint, 40 degrees, planar smooth, iron staining
	3.9	*5.2*	*5.34*	**1.97**	**47.28**		FR	Joint, 90 degrees, planer smooth, iron staining

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

DESCRIPTION · FIELD IDENTIFICATION · LABORATORY CLASSIFICATION

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.

0.05mm is about the smallest particle visible to the naked eye

Use the gradation curve of material passing 60mm for classification of fractions according to criteria given under "Major Division".

COARSE GRAINED SOILS — More than 50% by dry mass, less than 60mm is greater than 0.06mm. (Field identification: COARSE GRAINED SOILS — More than half of the material less than 60mm is larger than 0.06mm)

Major Divisions		Group Symbol	Typical Name	Descriptive Data	Gravels and Sands: Gradations		Nature of Fines	Dry Strength	Group Symbol	% (2) < 0.06mm	Plasticity of Fine Fraction		
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. For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics. EXAMPLE: 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)	GOOD	Wide range in grain size	"Clean" materials (not enough fines to band coarse grains)	None	GW	0-5	-	>4	Between 1 and 3
GRAVELS		GP	Poorly graded gravels and gravel sand mixtures, little or no fines		POOR	Predominantly one size or range of sizes			GP	0-5	-	Fails to comply with above	
GRAVELLY SOILS		GM	Silty gravels, gravel-sand-silt mixtures		GOOD TO FAIR	"Dirty" materials (Excess of fines)	Fines are non-plastic (1)	None to medium	GM	12-50	Below 'A' line and Ip >7	-	-
GRAVELLY SOILS		GC	Clayey gravels gravel-sand-clay mixtures				Fines are plastic (1)		GC	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		GOOD	Wide range in grain size	"Clean" materials (not enough fines to band coarse grains)	None	SW	0-5	-	>6	between 1 and 3
SANDS		SP	Poorly graded sands and gravelly sands, little or no fines		POOR	Predominantly one size or range of sizes			SP	0-5	-	Fails to comply with above	
SANDY SOILS		SM	Silty sand, sand-silt mixtures		GOOD TO FAIR	"Dirty" materials (Excess of fines)	Fines are non-plastic (1)	None to medium	SM	12-50	Below 'A' line or Ip < 4	-	-
SANDY SOILS		SC	Clayey sands, sand-clay mixtures				Fines are plastic (1)		SC	12-50	Above 'A' line and Ip > 7	-	-

NOTES

1. Identify Fines by the method given for fine grained soils.

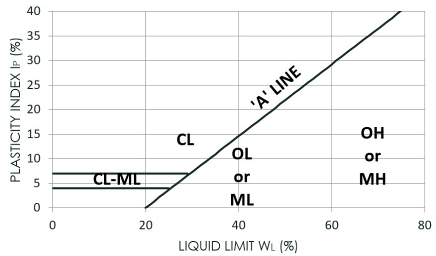
2. Borderline classifications occur when the percentage of fines (fraction smaller than 0.06mm size) is greater than 5% and less than 12%.

Borderline classifications require the use of dual symbols
eg SP-SM
GW-GC

FINE GRAINED SOILS — More than 50% by dry mass, less than 6omm is less than 0.06mm. (Field identification: FINE GRAINED SOILS — More than half of the material less than 50mm is less than 0.06mm)

SILT AND CLAY FRACTION — Fraction smaller than 0 20mm AS sieve size

Major Divisions	Group Symbol	Typical Name	Descriptive Data	Dry Strength	Dilatancy	Toughness	Group Symbol	More than 50% passing 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. For undisturbed soil add information on structure, stratification, consistancy in undisturbed and remoulded states, moisture and drainage conditions. EXAMPLE Clayey Silt, brown, low plasticity, small percentage of fine sand, numerous vertical root-holes, firm and dry in place, fill, (ML).	None to low	Quick to slow	None	ML		Below 'A' line
Liquid Limit less than 50%	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.		Medium to high	None to very slow	Medium	CL		Above 'A' line
Liquid Limit less than 50%	OL	Organic silts and organic silty clays of low plasticity		Low to medium	Slow	Low	OL		Below 'A' line
Liquid Limit more than 50%	MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts.		Low to medium	Slow to none	Low to medium	MH		Below 'A' line
Liquid Limit more than 50%	CH	Inorganic clays of high plasticity, fat clays.		High to very high	None	High	CH		Above 'A' line
Liquid Limit more than 50%	OH	Organic clays of medium to high plasticity.		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

FORTIFY
GEOTECH

BEGA VALLEY SHIRE COUNCIL
CORE PHOTOS
BH3

ACT Geotechnical Engineers Pty Ltd	**C10638.228**