GEOTECHNICAL INVESTIGATION REPORT

PROPOSED POOL HOUSE, SWIMMING POOL AND TERRACE
90 CABBAGE TREE ROAD, BAYVIEW, NEW SOUTH WALES

MR ALEX JENKINS

MMGEO2021AJ_AA REVISION A

AUGUST 2021

Revision	Details	Date	Prepared By
A	Electronic Copy Issued to Client	1 August 2021	Muliadi Merry

MM Geomechanics ABN 78 624 459 534
www.mmgeomechanics.com.au

MM Geomechanics PTY LTD
ABN 78 624 459 534 | ACN 624 459 534

T +61 481 265 169
E info@mmgeomechanics.com.au
W http://www.mmgeomechanics.com.au

Tower 1, Level 11, 495 Victoria Avenue
CHATSWOOD NSW 2067
AUSTRALIA

Sydney, 1 August 2021

Mr Alex Jenkins
90 Cabbage Tree Road
BAYVIEW NSW 2104

Dear Alex,

This report presents the results from a geotechnical investigation undertaken by MM Geomechanics within a property located at 90 Cabbage Tree Road in Bayview, New South Wales (Lot 22 in Deposited Plan 602041). The site investigation was specific to the area to the east of the main house on which a pool house will be constructed. The investigation works was implemented to assess the subsurface conditions across the development site. The investigation data will be relied upon to assist in the project planning and design from a structural perspective. The geotechnical investigation report was complementary to the development application process.

MM Geomechanics, a specialist geotechnical consultant, carried out the work in general accordance with a proposal dated 21 July 2021 reference MMGEO2021SG_AB. MM Geomechanics was awarded with the work on 22 July 2021.

If you require further information, please contact the undersigned on 0400 393 008.

For and on behalf of MM Geomechanics,

Muliadi Merry BEng MEng FIEAust CPEng NER (Civil) RPEQ
Professional Engineer (CPEng) 1401340
Registered Professional Engineer of Queensland (RPEQ) 24119
Professional Engineer Registration – #PRE0000542
Design Practitioner – #DEP0000552
Principal Design Practitioner – #PDP00001180

Distribution: Original held by MM Geomechanics

Electronic copy to Mr Alex Jenkins, also Ms Suzanne Green (Suzanne Green Interior Architecture and Design, and Mr Angelo Silvio (Tall Ideas)

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Fellow, Engineers Australia
Chartered Professional Engineer
National Engineering Register
Registered Professional Engineer of Queensland
Registered Principal Design Practitioner with NSW Fair Trading</td></tr>
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The property covers an area of about 3.2 Ha.
A two-storey dwelling house is evident at the southwestern corner of the site while the remainder of the site is consisted of vacant lands largely covered by dense vegetation.
A gravel driveway is present to the south of the site approximately in a west-east orientation as an extension of an easement that is connected to Cabbage Tree Road.
The development site is located to the east of the house and to the north of the driveway.
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Assessed Residual Risk Levels after Treatments	For Loss of Life	HZ1	2.5×10^{-6}
		HZ2	2.5×10^{-7}
		HZ3	2.5×10^{-7}
		HZ4	5×10^{-6}
Earthworks	Re-use of topsoil as landscaping materials only. The in-situ clays are unsuitable for use as backfill. Imported fill should be a good quality non-expansive material such as sand or ripped rock.		
Excavation Conditions	A hydraulic excavator and bucket is adequate.		
Groundwater	The investigation works did not intercept shallow groundwater. Seepage from perched water could occur, but is manageable by pumping from sumps.		
Temporary Cut Batters	Temporary unsupported batters for excavations less than 1m can be battered at an inclination of no steeper than 2H:1V.		
Footing Systems	Piles socketed into rock are required. The underlying rock is capable of supporting an allowable bearing pressure of 600kPa. Open bored piles may be applicable. Dewatering and temporary liners may be required, if seepage occurs.		
Earthquake Actions in accordance with AS1170.4-2007	Adoption of Site Class C_e and Hazard Factor Z of 0.08.		
Construction Inspection Requirements	If filling is needed: • Assessment of the suitability of imported and in-situ materials for use as backfill. • Inspection and testing during fill placement and compaction. Excavation conditions for advice on safe battering configurations. Footing formation for verification of suitability of exposed geomaterial as founding stratum.		

1. INTRODUCTION

The architectural drawings prepared by Suzanne Green Interior Architecture and Design indicates that an existing residence at 90 Cabbage Tree Road in Bayview, New South Wales (Lot 22 in Deposited Plan 602041) will be further developed, involving the following:

- Formation of a pool house, a swimming pool and a terrace to the east of an existing dwelling house.
- The pool house is a single-storey building structure.
- The building will house a swimming pool, a spa, a terrace, a pergola, a barbeque area, a kitchen and a bathroom.
- The swimming pool is a suspended structure, so is the terrace platform.
- The pool house floor corresponds to an elevation of RL 39.5m AHD.

The Pittwater Local Environmental Plan 2014 Geotechnical Hazard Map Sheet GTH_011 and Sheet GTH_012 identifies that the site is associated with Geotechnical Hazard H1. Hazard Zone H1 denotes geotechnical hazards with the highest likelihood of occurrence. A geotechnical investigation and a landslide risk assessment by an experienced Geotechnical Engineer was required in order to assess the site-specific subsurface conditions and to identify the geotechnical constraints of the site. The findings from the site investigation were relied upon as input to the project structural design. The geotechnical report was complimentary to the development application (DA) process.

Mr Alex Jenkins commissioned MM Geomechanics on 22 July 2021 to undertake the site investigation. The work was carried out in general accordance with our proposal reference MMGEO2021SG_AB dated 21 July 2021.

Presented as part the report are the findings from the site investigation, along with engineering assessment of the following aspects:

- Subsurface conditions (i.e. the nature of the in-situ soils, the depth to the underlying rock and its quality, along with the presence of groundwater table, if any).
- Possibility of encountering acid sulfate soils on site (on the basis of a desktop review).
- Potential geotechnical hazards and risks, along with mitigation measures required for achieving Acceptable Risk for Loss of Property and Loss of Human Life as defined in the Practice Note issued by Australian Geomechanics Society (AGS) in 2007.
- Earthworks.
- Excavation conditions.
- Groundwater.
- Retaining walls and design parameters.
- Foundations and design parameters.
- Earthquake actions in accordance with AS1170.4-2007 *Part 4, Earthquake Actions in Australia*.
- Concrete exposure in accordance with AS5100.5-2004 *Bridge Design – Part 5: Concrete*.
- Geotechnical inspection requirements at construction stage.

2. SITE LOCALITY

The property is located to the north of Cabbage Tree Road in Bayview, New South Wales. The geographic position of the site is identified in Table 2.1.

Table 2.1: Site Geographic Position

Site Address	Latitude	Longitude
90 Cabbage Tree Road Bayview NSW 2104	33° 40' 0" S	151° 17' 8" E

Figure 1 shows the site locality.

3. INVESTIGATION METHODOLOGY

3.1. Desktop Study

Review of the available data listed below was initially carried out:

- Published geological and acid sulfate soil maps.
- Available aerial photographs from nearmap.
- The project architectural drawings reference 0040 prepared by Suzanne Green Interior Architecture and Design.
- A site-specific topographical survey plan prepared by CMS Surveyors (reference 18022detail Issue 2 dated 18 June 2020).

3.2. Fieldwork

A Principal Geotechnical Engineer (also a Chartered Professional Engineer) from MM Geomechanics, accompanied by a geotechnician, subsequently visited the site in Bayview, New South Wales on 23 July 2021 with the aim of achieving the following:

- Gaining an appreciation of site conditions and features.
- Assessment of subsurface conditions within the site by undertaking geotechnical fieldwork.
- Carrying out a landslide risk assessment in general accordance with the landslide risk management guidelines prepared by the AGS, as follows:
  - AGS 2007a: Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning.
  - AGS 2007b: Commentary on Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning.
  - AGS 2007c: Practice Note Guidelines for Landslide Risk Management 2007.
  - AGS 2007d: Commentary on Practice Note Guidelines for Landslide Risk Management 2007.
  - AGS 2007e: The Australian GeoGuides for Slope Management and Maintenance

'Dial Before You Dig' information was collated prior to undertaking the fieldwork.

The investigation employed a combination of the following techniques:

- Auger drilling at three locations (namely 90CTRB-AH01, 90CTRB-AH02 and 90CTRB-AH03) within the footprint of the proposed pool house using a hand-held auger drill.
- A Dynamic Cone Penetrometer (DCP) test adjacent to each augered hole. There were three adjacent DCP tests overall (namely 90CTRB-DCP01, 90CTRB-DCP02 and 90CTRB-DCP03).
- A further standalone DCP test (90CTRB-DCP04) was also implemented.

The geotechnical tests are listed in Table 3.1.

Table 3.1: Summary of Geotechnical Tests

Test ID	Type of Test	Termination Depth (m bgl)	Reason for Ceasing
90CTRB-AH01	Auger drilling	0.4	The presence of a large particle in soil.
90CTRB-AH02		1.1	Increased penetration resistance.
90CTRB-AH03		0.9	
90CTRB-DCP01	DCP test adjacent to 90CTRB-AH01	0.3	The presence of a large particle in soil.
90CTRB-DCP02	DCP test adjacent to 90CTRB-AH02	1.6	Practical refusal on either hard clay or rock.
90CTRB-DCP03	DCP test adjacent to 90CTRB-AH03	1.5	
90CTRB-DCP04	A standalone DCP test	2.2	

Note: bgl = below ground level

Upon completion, the augered hole was backfilled using excavated spoils. Excess spoils were disposed on site, spread level over unpaved areas.

The approximate locations of the geotechnical tests are shown in Figures 2, 3 and 4. The site photographs are presented in Figures 3 and 4, and should be read in conjunction with the photograph view angles and orientations shown in Figure 2.

4. SITE CONDITIONS

The observations we made at the time of the site visit on 23 July 2021, in conjunction with the review of the survey data prepared by CMS Surveyors, indicate the following:

- The property at 90 Cabbage Tree Road in Bayview appears to be resting on the steep flanks of a hill.
- The property is bounded by Cabbage Tree Road to the south and is surrounded by neighbouring properties to the north, west and south.
- The property covers an area of about 3.2 Ha.
- A two-storey dwelling house is evident at the southwestern corner of the site while the remainder of the site is consisted of vacant lands largely covered by dense vegetation.
- A gravel driveway is present to the south of the site approximately in a west-east orientation as an extension of an easement (a right of way) that is connected to Cabbage Tree Road.
- The development site is located to the east of the house and to the north of the driveway.
- The development site will be formed on a northerly dipping slope.
- The existence of a sandstone cliff along the southern site boundary.
- The site and surrounding neighbouring areas have been used mainly for residential purposes in the past decade. The land occupancy based on the available aerial imageries for the period between 20 October 2009 and 2 June 2021 from nearmap agrees with the site observation.

Reference should be made to the site photographs presented in Figures 3 and 4 for an appreciation of the site descriptions provided.

5. SITE GEOLOGY

The Sydney 1:100,000 Geological Series Sheet 9130 (Edition 1, 1983) infers that the Hawkesbury Sandstone geological unit (Rh) underlies the site locality and the boundary with the Newport Formation and Garie Formation geological unit (Rnn) is nearby to the east.

The Hawkesbury Sandstone is described as ‘medium to coarse-grained quartz sandstone, very minor shale and laminite lenses’. The Newport Formation is described to comprise interbedded laminite, shale and quartz to lithic quartz sandstone, minor red claystone. The Garie Formation is consisted of clay pellet sandstone.

An excerpt of the geological map is presented in Figure 5.

6. POTENTIAL OCCURRENCE OF ACID SULFATE SOILS

Searches through the Australian Soil Resource Information System (ASRIS) for National Acid Sulfate Soils Occurrence indicates no known occurrence of acid sulfate soils within the site locality.

An excerpt of the National Acid Sulfate Soils Occurrence map is captured in Figure 6.

7. SUBSURFACE CONDITIONS

The site investigation implemented by MM Geomechanics detected topsoil (Unit 1), colluvium (Unit 2) and residual soil (Unit 3) overlying possibly rock (Unit 4).

Based on the information obtained from the investigation works, an inferred geotechnical model has been developed, and the subsurface conditions at the geotechnical test locations are summarised in Table 7.1. For a detailed description of the subsurface conditions encountered at the geotechnical test locations, refer to the Engineering Logs in Appendix A, together with Explanation Sheets describing the terms and symbols used in the preparation of the logs. The DCP test reports are presented in Appendix B. The results from the DCP tests adjacent to augered holes are also graphically presented in the logs.

Table 7.1: Summary of Subsurface Conditions at Test Locations and Inferred Geotechnical Model

Geotechnical Unit	Description	Depth to Base of Unit (m)	Thickness of Unit (m)
1. Topsoil	Topsoil (Unit 1), typically: • Sandy SILT. • Low liquid limit. • Grey, brown and black.	0.2 to 0.4	0.2 to 0.4
2. Colluvium	Colluvium (Unit 2), typically: • Clayey SAND. • Fine to medium grained. • Yellow brown. • Brown. • Loose to medium dense.	0.4 to 0.6 Only in 90CTRB-AH01 and 90CTRB-AH02	0.2 to 0.3 Only in 90CTRB-AH01 and 90CTRB-AH0
3. Residual Soil	Residual Soil (Unit 3), typically: • Silty CLAY. • Medium to high plasticity. • Yellow brown. • Stiff to very stiff.	1.5 to 1.6[1)] Only in 90CTRB-AH02 and 90CTRB-AH03	0.9 to 1.2[1)] Only in 90CTRB-AH02 and 90CTRB-AH03
4. Rock	Rock (Unit 4) is inferred as Class V Sandstone[2)].	Not known[3)]	Not known[3)]

Note:
1) An inference was made based on the penetration resistance obtained from the DCP testing.
2) Rock class in accordance with the rock classification system established by Pells et al. in 1998.
3) Hand operated auger drilling and DCP testing does not provide a means of penetrating into rock. Class V Sandstone was assumed.

Table 7.2 summarises the depth to the various geotechnical units across the site.

Table 7.2: Summary of Inferred Subsurface Stratigraphy

Development Area	Basis of Assessment	Top of Unit (Reduced Level in m AHD)+			
		1 Topsoil	2 Colluvium	3 Residual Soil	4# Rock
Western side of the pool house	90CTRB-AH01 and 90CTRB-DCP01	39.7	39.5	Not known	Not known
Northern side of the pool house	90CTRB-AH02 and 90CTRB-DCP02	37.5	Not encountered	37.1	35.9
Eastern side of the pool house.	90CTRB-AH03 and 90CTRB-DCP03	40	39.7	39.4	38.5
	90CTRB- DCP04	38	Not known	Not known	35.8

Note:

\+ Reliance to the available survey plan was made to estimate the geotechnical stratigraphic levels.

\# The practical refusal encountered during the DCP testing was inferred as the top of weathered sandstone equating to Class V Sandstone in accordance with the rock classification system established by Pells et al. in 1998.

Groundwater was not observed within the depth of augering. No watermark was noted on the DCP rods within the depth of testing. No long-term groundwater monitoring was carried out.

8. GEOTECHNICAL RISK APPRAISALS

8.1 Qualitative Risk Estimation for Property

Various potential geotechnical hazards that may affect the site were identified and are listed in Table 8.1. An assessment of the risk level corresponding to each hazard was carried out in consideration of the likelihood for the hazard to occur and the associated consequence to various on-site elements at risk (also compiled in Table 8.1).

Table 8.1: Identification of Potential Geotechnical Hazards and Elements at Risk

Hazard ID	Type of Geotechnical Hazard	Elements at Risk
HZ1	Slippage of the colluvium within the site.	The existing house. The pool house, swimming pool and terrace.
HZ2	Deep seated landslide within the site.	
HZ3	Creep soil mass movement within the site.	
HZ4	Erosion within the site.	

Table 8.2 summarises the results from the risk estimation for loss of property.

Table 8.2: Qualitative Risk Estimation for Loss of Property

Hazard ID	Likelihood of Occurrence	Consequence to Property	Risk Level[1]
HZ1	Unlikely	Medium	Low
HZ2	Rare	Medium	Low
HZ3	Rare	Medium	Low
HZ4	Possible	Minor	Low

Note:

1. The risk of instability was assessed to be "Low" as the development site is in natural state, protected by dense vegetation cover. The risk level would remain unaffected on the implementation of piled foundations, re-instatement of vegetation cover and runoff management.

The building is assessed to correspond to an Importance Level of Structure (ILS) of 2. For a new development that involves structures with an ILS of 2, the upper limit of acceptable risk for loss of property is taken as "Low" as defined in Table C10 part of the Commentary on the Practice Note issued by AGS in 2007. The risk estimation resulted in a finding of "Low" risk of slope instability.

8.2 Quantitative Risk Estimation for Loss of Life

For the loss of life, the individual risk can be calculated using:

$$R_{(DI)} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(D:T)}$$

where:

$R_{(DI)}$ is the risk, or annual probability of death, of an individual,

$P_{(H)}$ is the annual probability of the hazardous event,

$P_{(S:H)}$ is the probability of spatial impact by the hazard given the event,

$P_{(T:S)}$ is the temporal probability given the spatial impact, and

$V_{(D:T)}$ is the vulnerability of the individual.

Table 8.3 summarises the results from the quantitative risk estimation for loss of life.

Table 8.3: Quantitative Risk Estimation for Loss of Life

Hazard ID	$P_{(H)}$	$P_{(S:H)}$	$P_{(T:S)}$	$V_{(D:T)}$	$R_{(DI)}$[1]
HZ1	10^{-4}	0.5	0.5	0.1	2.5×10^{-6}
HZ2	10^{-5}	0.5	0.5	0.1	2.5×10^{-7}
HZ3	10^{-5}	0.5	0.5	0.1	2.5×10^{-7}
HZ4	10^{-3}	0.1	0.5	0.1	5×10^{-6}

Note:

1. The risk estimation is conditional upon the implementation of risk mitigation measures such as piled foundations, re-instatement of vegetation cover and runoff management.

AGS suggested the individual life loss risk criteria for the person most at risk of 10^{-6} per annum for acceptable risk and 10^{-5} per annum for tolerable risk. Generally, the risk for loss of human life induced by the various hazards was assessed to be acceptable.

Your attention is drawn to the Important Information about AGS2007 Appendix C, attached to this report for appreciation of typical responses to assessed risk levels. Also incorporated in Appendix C is Appendix G of the Practice Note Guidelines for Landslide Risk Management 2007 (AGS 2007c) that includes some guidelines for hillside construction and provides examples of both good and poor hillside practices.

9. EARTHWORKS

Topsoil should be stripped and stockpiled separately for possible reuse as landscaping material only.

The natural soils comprise mainly clays. The clays are of medium to high plasticity. As such, it is more than likely that the clays are susceptible to volume change with variations in soil moisture. The clays were assessed to be unsuitable for re-use as backfill.

Fill, if required, should be sourced externally and brought in off site.

Imported fill should be a good quality non-expansive material such as sand or ripped rock. The maximum particle size after compaction should be 75mm. Bulk engineered fill should be compacted to a minimum of 98% Standard Maximum Dry Density Ratio (SMDDR) within 2 % of Standard Optimum Moisture Content (SOMC). If uniformly graded sand is used as bulk structural fill, it should be compacted to a Density Index of at least 70%. Fill should be placed in horizontal layers and compacted in a controlled manner, desirably under Level 1 supervision and testing in accordance with AS3798-2007 *Guidelines on Earthworks for Commercial and Residential Developments*. Loose layer thickness should be limited to 200mm maximum.

Advice from a suitably qualified geotechnical engineer should be sought for confirmation that the proposed fill is suitable from a geotechnical perspective and that the fill is free from unsuitable material such as organics, waste or oversized particles.

10. EXCAVATION CONDITIONS

Excavations are required in order to form the building construction platform. The excavation work will likely extend to a depth of no more than 1m below ground surface. The excavations will occur mainly within soils. A hydraulic excavator and bucket should be adequate for excavation in soils. Attention is required for safe operation of the earthmoving plant while working on a slope.

11. GROUNDWATER

No shallow groundwater tables were intercepted by the various geotechnical tests. Encountering seepage inflow from water perched in the soil (especially immediately following a rain event) remains a possibility. Seepage inflow should be able to be controlled by pumping from sumps.

While the investigation did not incorporate long-term groundwater monitoring, we would not anticipate shallow groundwater table within the soil during the excavations. The DCP tests (which penetrated to depths of up to about 2.2m below the existing ground surface) do not appear to have intersected groundwater. Therefore, we assess that the excavations and associated dewatering will unlikely result in a lowering of groundwater below historic levels.

12. TEMPORARY CUT BATTERS AND RETAINING STRUCTURES

Excavations needed to take place on site are associated with the formation of the building construction platform and are expected to be less than 1m deep. Unsupported batters are feasible on the proviso of the following conditions:

- There is no heavy construction plant and surcharge on the ground to the rear of the excavation;
- The rear of the excavation comprises a level ground; and
- A temporary batter is formed at an inclination no steeper than 2H:1V.

Consultation with a suitably qualified geotechnical engineer may be made for opportunities for adopting temporary batters steeper than 2H:1V, which are pending the following factors:

- The nature of the soils exposed;
- The excavation extents;
- The surface protection treatments;
- The weather conditions; and
- The exposure duration.

Where and if required, retaining walls can be designed using the geotechnical design parameters provided in Table 12.1. Where some movement of the retaining wall towards the excavation can be tolerated, 'active' earth pressures may be used in the design of the excavation support. Where lateral movement of the wall towards the excavation is to be limited, 'at rest' earth pressures should be adopted.

Table 12.1: Summary of Geotechnical Design Parameters for Retaining Structures

Geotechnical Unit	γ (kN/m^3)	c' (kPa)	Φ (°)	E' (MPa)	v	Ka[1]	K_o[2]
Engineered Fill	20	0	32	30	0.35	0.31	0.5
Colluvium (loose to medium dense sand)	19	0	30	10	0.35	0.33	0.5
Residual Soil (stiff to very stiff clay)	19	2	28	20	0.35	0.35	0.5
Rock (Class V Sandstone)	20	5	30	60	0.3	0.33	0.5

Note:

γ = Bulk Unit Weight
c' = Effective Cohesion
Φ = Effective Friction Angle
E' = Elastic Modulus
v = Poisson's Ratio
K_a = Active Earth Pressure Coefficient
K_o **=** At Rest' Earth Pressure Coefficient (After some wall movement)

1. Assume no wall friction.
2. Values provided assume a lateral movement of the wall of about 0.2% of the wall height is allowed to occur.

For preliminary estimate purposes, published data suggests that lateral movements of an adequately designed and installed retention system in stiff clay will be between 0.2% and 0.5% of the retained height for adequately engineered walls. Vertical movements could be expected to be of a similar order to the lateral movements. The extent of the horizontal movement behind the excavation face is typically between 1.5 and 3 times the excavated height.

13. FOUNDATIONS

For the reason that the development will be formed on a sloping ground, there is a need to rely on Unit 4 Rock as a founding stratum. Piles socketed in Unit 4 are required. The site investigation infers the possibility of encountering rock at depths varying from about 1.5m to 2.2m below the existing ground surface. Open bored piles should be practical. Dewatering and temporary liners may be required, if seepage occurs.

For piled foundations, our recommendations for end bearing pressures are provided in Table 13.1 for both Limit State and Working Stress design methods. Where Limit State design parameters are used, reference to Section 4.3.2 of Australian Standard AS 2159-2009 *Piling – Design and Installation* should be made for the assessment and selection of suitable geotechnical strength reduction factor, and the Serviceability Limit State deflections should be checked using the elastic moduli presented in Table 13.1.

Table 13.1: Recommended Footing Design Parameters

Geotechnical Unit	Working Stress Design Values		Limit State Design Values		
	Allowable End Bearing Pressures (MPa)	Allowable Shaft Adhesion (kPa)	Ultimate End Bearing (MPa)[1]	Ultimate Shaft Adhesion (kPa)[1]	Elastic Modulus (MPa)
Unit 4 Rock (Class V Sandstone)	0.6	50	1	100	60

Note:
1. Nominated values are appropriate for the modulus provided. Higher values may be possible but a lower modulus would apply and higher settlements may occur.

To prevent slope instability and reduced bearing capacity from occurring, your attention is drawn to the need of applying the setback criteria shown in Diagramme 13.1 for calculation of effective rock socket length. Otherwise there would be a need to downgrade the bearing pressure values given in Table 13.1 by a factor of 0.5.

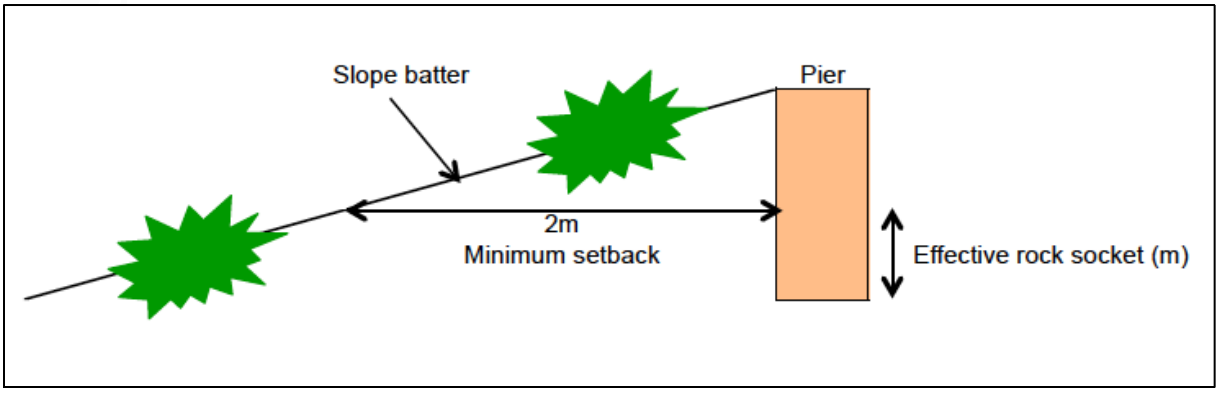


Diagramme 13.1: Required Minimum Setback for Calculation of Effective Rock Socket

Shaft adhesion should only be adopted for piers that have a minimum embedment of at least 3 pier diameters into suitable founding material and a rough socket (at least grooves of depth 1mm to 4mm and width greater than 5mm at spacing of 50mm to 200mm). The socket should be cleaned and roughened by a suitable scraper such as a tooth, orientated perpendicular to the auger shaft.

A reduction factor of 0.6 should be introduced to the shaft adhesion value for uplift capacity.
In addition to shaft adhesion, the uplift capacity should be checked for a cone pullout failure mode assuming a cone angle of 70^o considering the submerged weight of the soil or rock and adopting a factor of safety of 1 against pullout.

An experienced geotechnical engineer should observe boring of the piles in order to assess the rock levels and to confirm that the rock quality is consistent with the adopted design parameters.
The possibility of encountering sandstone floaters cannot be precluded. Potentially unstable floaters cannot be relied upon as bearing strata.

14. EARTHQUAKE ACTIONS

We recommend that the site be classified as Class C_e in accordance with the site sub-soil classes defined in AS1170.4-2007 *Part 4, Earthquake Actions in Australia*. A hazard factor Z of 0.08 is suggested.

15. CONCRETE EXPOSURE

The desktop review indicates no occurrence of acid sulfate soils within the site locality. Exposure classification of B1 in accordance with AS5100.5-2004 *Bridge Design – Part 5: Concrete* may be adopted.

16. CONSTRUCTION INSPECTION REQUIREMENTS

Advice from an experienced Geotechnical Engineer should be sought at construction stage for the observations of the following aspects:

- Where filling is involved:
  - Assessment of the suitability of imported and in-situ materials for use as backfill.
  - Inspection and testing during fill placement and compaction.
- Excavation conditions for advice on safe battering configurations.
- Footing formation for verification of suitability of exposed geomaterial as founding stratum.

17. SITE MAINTENANCE REQUIREMENTS

House owners should be made aware that residential structures constructed to normal standards are likely to suffer some movement and consequent damage. Footings for residential buildings designed in accordance with the standard design guidelines of AS2870-2011 *Residential Slabs and Footings* and those designed in accordance with engineering principles where site characteristics require more rigorous analyses are expected to achieve acceptable probabilities of serviceability and safety during its design life.

The CSIRO publishes a document entitled "Foundation Maintenance and Footing Performance: A Home Owners Guide", which provided advice on maintenance issues. We recommend that all homeowners follow the guidelines in this document to reduce the risk of damage to their homes. Lots, which suffer abnormal factors or that, are not maintained in accordance with the guidelines of Appendix B of AS2870-2011 and the CSIRO publication may experience damage that exceeds the degree and frequency of damage that would normally be expected and may require repairs other than superficial. A copy of the CSIRO publication is attached in Appendix D.

18. LIMITATIONS

MM Geomechanics has prepared this report for a residential development project at 90 Cabbage Tree Road in Bayview, New South Wales in accordance with a proposal dated 21 July 2021 reference MMGEO2021SG_AB and acceptance received from Mr Alex Jenkins on 22 July 2021. The report is provided for the exclusive use of Mr Alex Jenkins for this project only and for the purpose(s) described in the report. The report cannot be used for other projects or by third parties unless a written consent from MM Geomechanics is obtained (with the exception of Suzanne Green Interior Architecture and Design, and Tall Ideas).

In preparing this report, MM Geomechanics has necessarily relied upon information provided by the client and/or their agents, and from third parties. The information may not be verified and MM Geomechanics assumes no responsibility for the adequacy, incompleteness, inaccuracies, or reliability of this information. MM Geomechanics does not assume any responsibility for assessments made partly, or entirely based on information provided by third parties.

The results provided in the report are indicative of the subsurface conditions only at the specific sampling or testing locations, and then only to the depths investigated and at the time the work was carried out. Subsurface conditions can change abruptly due to variable geological processes and also as a result of anthropogenic influences. Such changes may occur after the fieldwork performed by MM Geomechanics.

The advice given by MM Geomechanics in this report is based upon the conditions encountered during this investigation. The accuracy of the advice provided by MM Geomechanics in this report may be limited by undetected variations in ground conditions between sampling locations. The advice may also be limited by budget constraints imposed by others or by site accessibility. Relying on on-site verifications through regular inspections by a suitably qualified Geotechnical Engineer during construction can minimise such a risk.

Project and design changes may affect the validity of the advice given in this report. We recommend that consultation with MM Geomechanics be made should significant changes be identified.

This report must be read in conjunction with all of the attached notes and should be kept in its entirety without separation of individual pages or sections. MM Geomechanics cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion given in this report. This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by MM Geomechanics. This is because this report has been written as advice and opinion rather than instructions for construction.

Contamination assessment and testing is excluded from the current investigation scope.

Your attention is drawn to the Important Information about Your Geotechnical Report attached to this report (as Appendix E), which presents additional information on the uses and limitation of this report.

19. REFERENCE

Australian Geomechanics Society (2007). “Guidelines for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning”. Australian Geomechanics, Vol. 42, No. 1, pp. 13-36. Reference AGS 2007a.

Australian Geomechanics Society (2007). “Commentary on Guidelines for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning”. Australian Geomechanics, Vol. 42, No. 1, pp. 37-62. Reference AGS 2007b.

Australian Geomechanics Society (2007). “Practice Note Guidelines for Landslide Risk Management 2007”. Australian Geomechanics, Vol. 42, No. 1, pp. 63-114. Reference AGS 2007c.

Australian Geomechanics Society (2007). “Commentary on Practice Note Guidelines for Landslide Risk Management 2007”. Australian Geomechanics, Vol. 42, No. 1, pp. 115-158. Reference AGS 2007d.

Australian Geomechanics Society (2007). “The Australian GeoGuides for Slope Management and Maintenance”. Australian Geomechanics, Vol. 42, No. 1, pp. 159-182. Reference AGS 2007e.

Australian Standard Limited (2004). “AS 5100.5-2004 Bridge Design – Part 5: Concrete”. SAI Global.

Australian Standard Limited (2011). “AS2870-2011 Residential Slabs and Footings”. SAI Global.

Australian Standard Limited (2007). “AS1170.4-2007 Part 4, Earthquake Actions in Australia”. SAI Global.

Australian Standard Limited (2017). “AS1726-2017 Geotechnical Site Investigations”. SAI Global.

Carter, M. and Bentley, S. P. (1991). “Correlation of Soil Properties”. Billing & Sons Ltd, Worcester, United Kingdom.

Centre for Geotechnical Research (1998). “Soil Mechanics Data Sheets”. The University of Sydney.

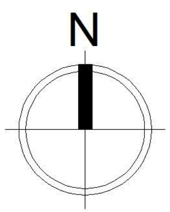
CSIRO (2011). “Foundation Maintenance and Footing Performance: A Homeowner's Guide”. Building Technology File 18-2011. CSIRO Publishing.

Decourt, L. (1995). “Prediction of Load-Settlement Relationships for Foundations on the basis of the SPT-T”. Ciclo de Conferencias Intern. “Leonardo Zeevaert”, UNAM, Mexico, pp. 85-104.

Pells et al. (1998). “Foundations on Sandstone and Shale in the Sydney Region”. Aust. Geomech. Jnl. Dec 1998.

Terzaghi, K. and Peck, R.B. (1948). “Soil Mechanics in Engineering Practice”, John Wiley and Sons.

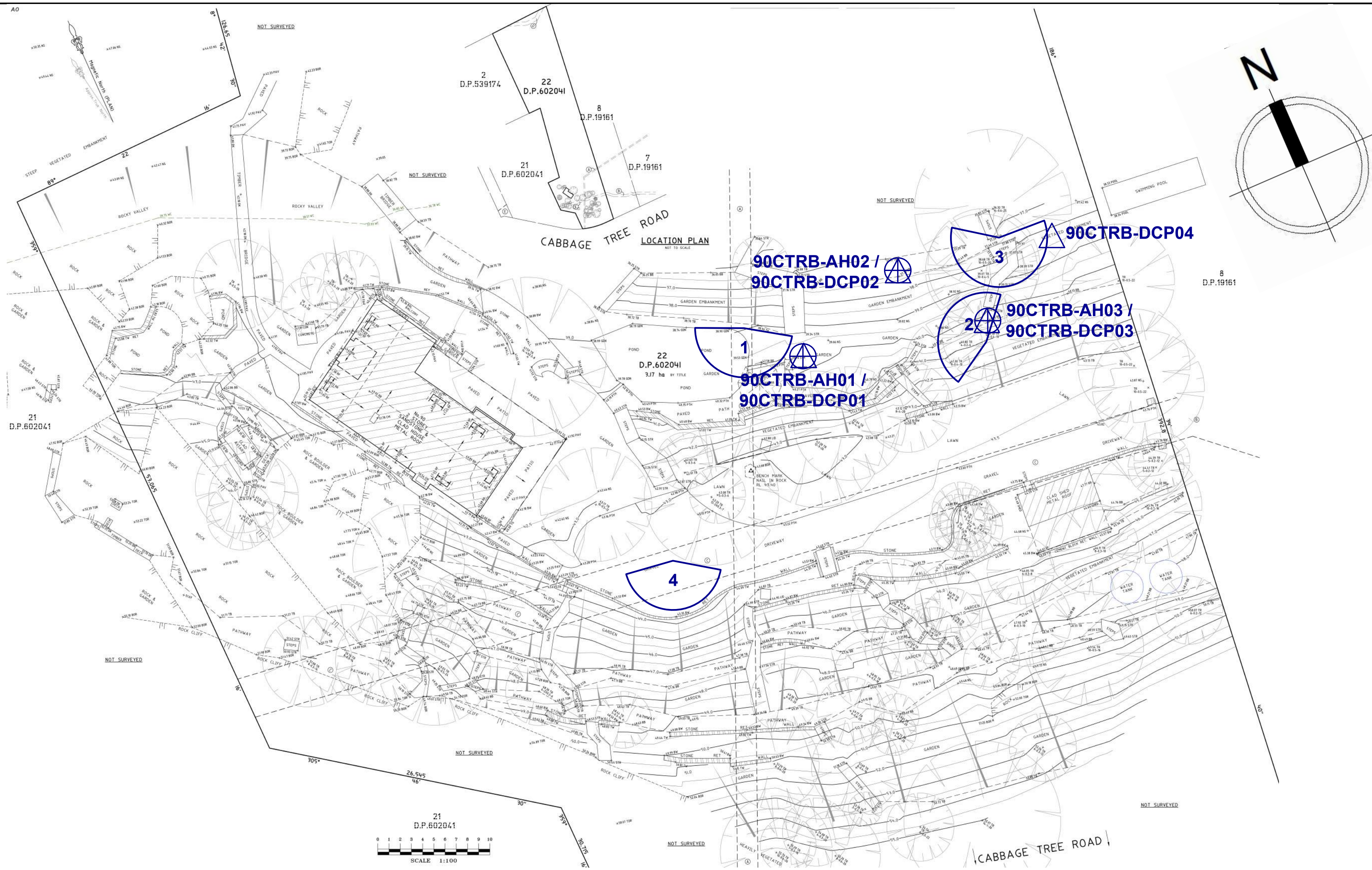
Figures



drawn	MA	client:	MR ALEX JENKINS
approved	MM	project:	PROPOSED POOL HOUSE, SWIMMING POOL AND TERRACE 90 CABBAGE TREE ROAD, BAYVIEW, NEW SOUTH WALES
date	1/8/21		
scale	As Shown	title:	SITE LOCALITY
original size	A4	project no: MMGEO2021AJ_AA	figure no: FIGURE 1

GEO Mechanics

LaCie:MM Geomechanics Pty Ltd:Correspondences:2021:070 SG:[Figures 90CTRB.xls]Figure 1



LEGEND:

Symbol	Description
⊕	Approximate Auger Hole Location
△	Approximate Dynamic Cone Penetrometer Test Location
1	Photograph View Angle and Orientation (see Figure 3)

drawn	MA	client:	MR ALEX JENKINS
approved	MM	project:	PROPOSED POOL HOUSE, SWIMMING POOL AND TERRACE 90 CABBAGE TREE ROAD, BAYVIEW, NEW SOUTH WALES
date	1/8/21		
scale	As Shown	title:	GEOTECHNICAL TEST LOCATION PLAN
original size	A4	project no: MMGEO2021AJ_AA	figure no: FIGURE 2

GEO Mechanics

LaCie:MM Geomechanics Pty Ltd:Correspondences:2021:070 SG:[Figures 90CTRB.xls]Figure 2

PHOTOGRAPH 1 - APPROXIMATE LOCATION OF 90CTRB-AH01 AND 90CTRB-DCP01 (VIEW TO SOUTH)

PHOTOGRAPH 2 - APPROXIMATE LOCATION OF 90CTRB-AH03 AND 90CTRB-DCP03 (VIEW TO WEST)

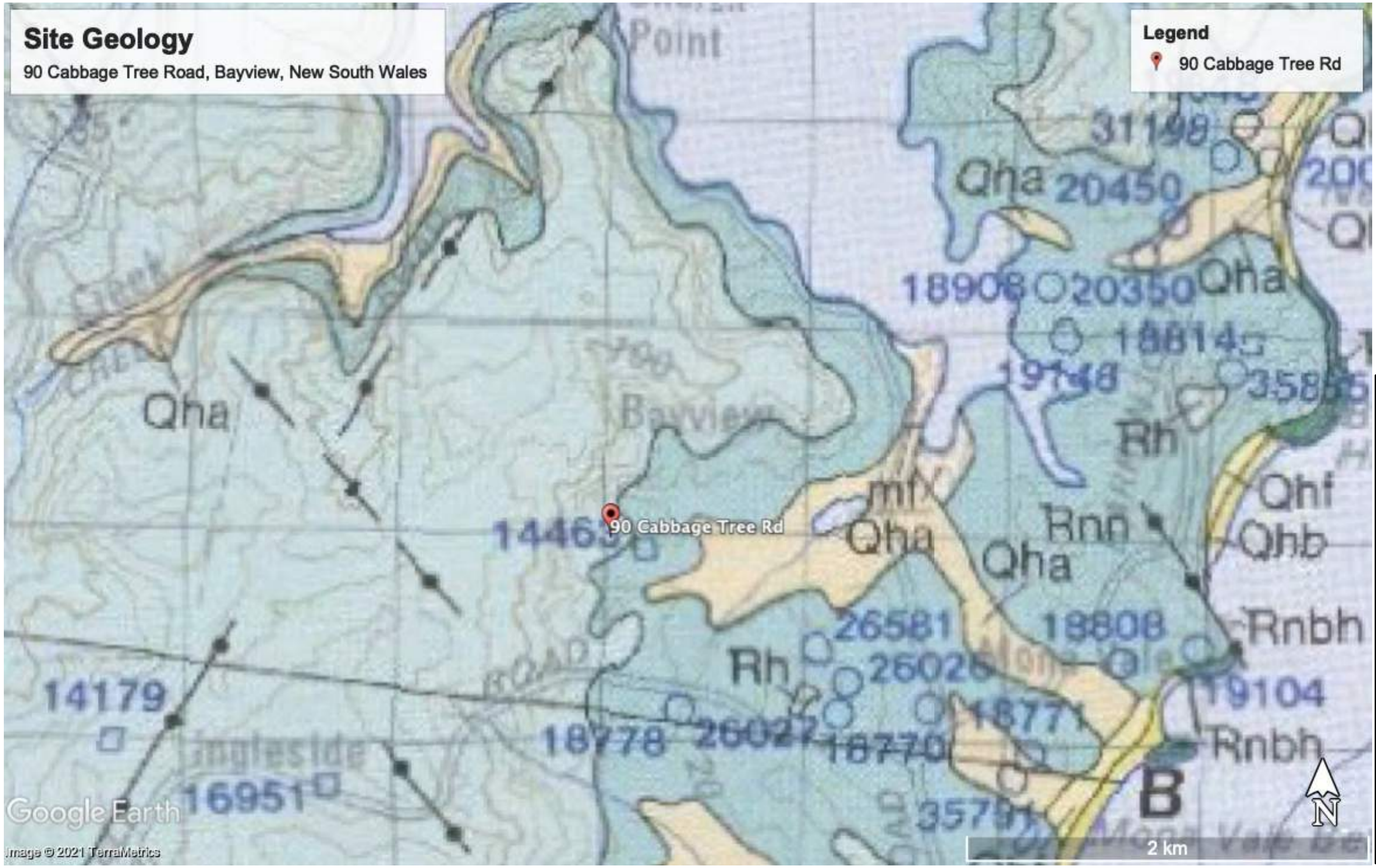
drawn	MA	GEO Mechanics	client:	MR ALEX JENKINS
approved	MM		project:	PROPOSED POOL HOUSE, SWIMMING POOL AND TERRACE 90 CABBAGE TREE ROAD, BAYVIEW, NEW SOUTH WALES
date	1/8/21			
scale	As Shown		title:	SITE PHOTOGRAPHS TAKEN ON 23 JULY 2021 (SHEET 1 OF 2)
original size	A4		project no:	MMGEO2021AJ_AA — figure no: FIGURE 3

PHOTOGRAPH 3 - APPROXIMATE LOCATIONS OF 90CTRB-AH02, 90CTRB-DCP02 AND 90CTRB-DCP04 (VIEW TO SOUTH)

PHOTOGRAPH 4 - SANDSTONE CLIFF (VIEW TO SOUTH)

drawn	MA	GEO Mechanics	client:	MR ALEX JENKINS
approved	MM		project:	PROPOSED POOL HOUSE, SWIMMING POOL AND TERRACE
date	1/8/21			90 CABBAGE TREE ROAD, BAYVIEW, NEW SOUTH WALES
scale	As Shown		title:	SITE PHOTOGRAPHS TAKEN ON 23 JULY 2021 (SHEET 2 OF 2)
original size	A4		project no: MMGEO2021AJ_AA	figure no: FIGURE 3

LaCie:MM Geomechanics Pty Ltd:Correspondences:2021:070 SG:[Figures 90CTRB.xls]Figure 4



LEGEND:

Rh Hawkesbury Sandstone
Rnn Newport Formation and Garie Formation

The Sydney 1:100,000 Geological Series Sheet 9130 (Edition 1, 1983) infers that the Hawkesbury Sandstone geological unit (Rh) underlies the site locality and the boundary with the Newport Formation and Garie Formation geological unit (Rnn) is nearby to the east. The Hawkesbury Sandstone is described as 'medium to coarse-grained quartz sandstone, very minor shale and laminite lenses'. The Newport Formation is described to comprise interbedded laminite, shale and quartz to lithic quartz sandstone, minor red claystone. The Garie Formation is consisted of clay pellet sandstone.

Source:

Gosford-Lake Macquarie Special 1:100,000 Geological Series Sheet 9131 and Part Sheet 9231

drawn	MA	client:	MR ALEX JENKINS
approved	MM	project:	PROPOSED POOL HOUSE, SWIMMING POOL AND TERRACE 90 CABBAGE TREE ROAD, BAYVIEW, NEW SOUTH WALES
date	1/8/21		
scale	As Shown	title:	SITE GEOLOGY
original size	A4	project no: MMGEO2021AJ_AA	figure no: FIGURE 5

GEO Mechanics

LaCie:MM Geomechanics Pty Ltd:Correspondences:2021:070 SG:[Figures 90CTRB.xls]Figure 5

N

Searches through the Australian Soil Resource Information System (ASRIS) for National Acid Sulfate Soils Occurrence indicates that there is no known occurrence of acid sulfate soils within the site locality.

Source: Australian Soil Resource Information System (ASRIS) for National Acid Sulfate Soils Occurrence	drawn	MA		client:	MR ALEX JENKINS
	approved	MM		project:	PROPOSED POOL HOUSE, SWIMMING POOL AND TERRACE
	date	1/8/21			90 CABBAGE TREE ROAD, BAYVIEW, NEW SOUTH WALES
	scale	As Shown		title:	POTENTIAL OCCURRENCE OF ACID SULFATE SOILS
	original size	A4		project no: MMGEO2021AJ_AA	figure no: FIGURE 6

LaCie:MM Geomechanics Pty Ltd:Correspondences:2021:070 SG:[Figures 90CTRB.xls]Figure 6

Appendix A

Engineering Logs and Explanation Sheets

Engineering Log - Auger Hole

GEO Mechanics

Borehole No: **90CTRB_AH01**
Client: **MR ALEX JENKINS**
Project No: **MMGEO2021AJ_AA**
Principal: **MR ALEX JENKINS**
Project ID: **90 CABBAGE TREE ROAD, BAYVIEW, NEW SOUTH WALES**
Borehole Location: See Site Plan
Date started: 23/07/2021
Logged by: MM
Sheet: 1 of 1
Date completed: 23/07/2021
Checked by: MM

drill model and mounting: Hand Augers
hole diameter: 300mm
Easting: Not Surveyed
Northing: Not Surveyed
slope: -90
bearing:
RL Surface: 39.7m (Inferred from survey plan)
Datum: AHD

Drilling Information								Material Substance							
method	penetration (1 2 3 4)	support	water	sample	sample notes	RL	depth (m)	graphic log	classification symbol	material description (soil type: plasticity or particle characteristics, colour, secondary and minor components)	moisture condition	consistency/density	penetration resistance (blow/100mm) (1 2 3 4 5 6 7 8 9 10)	test notes	structure and additional observations
HA		N	N				0.0–0.2			**TOPSOIL: SANDY SILT:** Low liquid limit, brown, with some grass root.	D				TOPSOIL
						39.5	0.2–0.4		SC	**CLAYEY SAND:** Fine grained, brown, with some sandstone cobble and boulders.	M	L		R	COLLUVIUM
						39.3	0.4			90CTRB_AH01 encountered refusal at 0.4m.					POSSIBLE ROCK

Depth scale: 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9

method
AS auger screwing
AD auger drilling
RR roller/tricone
W washbore
CT cable tool
HA hand auger
DT diatube
B blank bit
V V bit
T TC bit
* bit shown by suffix
e.g. ADT

support
M mud N nil
C casing
penetration 1 2 3 4 no resistance ranging to refusal

water
10/2/16 water level on date shown
water inflow
water outflow
N Not Observed

notes, samples, tects
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
V vane shear (kPa)
P pressuremeter
B_s bulk sample
E environmental sample
R refusal
F_h falling head permeability
R_h rising head permeability

test notes
R refusal
DB double bounce
PD pre-drilling
15/50 15 blows for 50mm penetration

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
W_p plastic limit
W_L liquid limit

consistency / density index
VS very soft
S soft
F firm
St stiff
VSt very still
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

Engineering Log - Auger Hole

GEO Mechanics

Borehole No: **90CTRB_AH02**
Client: **MR ALEX JENKINS**
Project No: **MMGEO2021AJ_AA**
Principal: **MR ALEX JENKINS**
Project ID: **90 CABBAGE TREE ROAD, BAYVIEW, NEW SOUTH WALES**
Borehole Location: See Site Plan
Date started: 23/07/2021
Logged by: MM
Sheet: 1 of 1
Date completed: 23/07/2021
Checked by: MM

drill model and mounting: Hand Augers
hole diameter: 200mm
Easting: Not Surveyed
Northing: Not Surveyed
slope: -90
bearing:
RL Surface: 37.5m (Inferred from survey plan)
Datum: AHD

Drilling Information							Material Substance							
method	penetration (1 2 3 4)	support	water	sample	sample notes	RL	depth (m)	graphic log	classification symbol	material description soil type: plasticity or particle characteristics, colour, secondary and minor components	moisture condition	consistency/density	penetration resistance (blow/100mm)	test notes	structure and additional observations
HA		N	N				0.0–0.4			**TOPSOIL: SANDY SILT:** Low liquid limit, dark grey, sand is fine to medium grained, trace of sandstone gravel and cobble.	W				TOPSOIL
						37.1	0.4–1.1		CH	**SILTY CLAY:** Medium to high plasticity, yellow brown motted grey.	M	St			RESIDUAL SOIL Hole diameter changed to 50mm at 0.4m.
						36.4	1.1			90CTRB_AH02 encountered refusal at 1.1m.				R	POSSIBLE ROCK

Depth scale: 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9

Penetration resistance scale: 1 2 3 4 5 6 7 8 9 10

method
AS auger screwing
AD auger drilling
RR roller/tricone
W washbore
CT cable tool
HA hand auger
DT diatube
B blank bit
V V bit
T TC bit
* bit shown by suffix
e.g. ADT

support
M mud N nil
C casing
penetration 1 2 3 4 no resistance ranging to refusal

water
▼ 10/2/16 water level on date shown
▶ water inflow
◀ water outflow
N Not Observed

notes, samples, tects
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
V vane shear (kPa)
P pressuremeter
B_s bulk sample
E environmental sample
R refusal
F_h falling head permeability
R_h rising head permeability

test notes
R refusal
DB double bounce
PD pre-drilling
15/50 15 blows for 50mm penetration

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
W_p plastic limit
W_L liquid limit

consistency / density index
VS very soft
S soft
F firm
St stiff
VSt very still
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

Engineering Log - Auger Hole

Borehole No: **90CTRB_AH03**
Client: **MR ALEX JENKINS**
Project No: **MMGEO2021AJ_AA**
Principal: **MR ALEX JENKINS**
Project ID: **90 CABBAGE TREE ROAD, BAYVIEW, NEW SOUTH WALES**
Borehole Location: See Site Plan
Date started: 23/07/2021
Logged by: MM
Sheet: 1 of 1
Date completed: 23/07/2021
Checked by: MM

GEO Mechanics

drill model and mounting: Hand Augers
hole diameter: 200mm
Easting: Not Surveyed
Northing: Not Surveyed
slope: -90
bearing:
RL Surface: 40m (Inferred from survey plan)
Datum: AHD

Drilling Information							Material Substance							
method	penetration (1 2 3 4)	support	water	sample	sample notes	RL	depth (m)	classification symbol	material description (soil type: plasticity or particle characteristics, colour, secondary and minor components)	moisture condition	consistency/density	penetration resistance (blow/100mm) (1 2 3 4 5 6 7 8 9 10)	test notes	structure and additional observations
HA		N	N				0.0		**TOPSOIL: SANDY SILT:** Low liquid limit, grey black, trace of tree root.	W				TOPSOIL
						39.7	0.3	SC	**CLAYEY SAND:** Fine to medium grained, brown, trace of sandstone cobble.	M	MD			COLLUVIUM Hole diameter changed to 50mm at 0.4m.
						39.4	0.6	CH	**SILTY CLAY:** Medium plasticity, yellow brown.	D	VSt			RESIDUAL SOIL
						39.1	0.9		90CTRB_AH03 encountered refusal at 0.9m.					
							1.5						R	POSSIBLE ROCK

depth (m): 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9

method
AS auger screwing
AD auger drilling
RR roller/tricone
W washbore
CT cable tool
HA hand auger
DT diatube
B blank bit
V V bit
T TC bit
* bit shown by suffix
e.g. ADT

support
M mud N nil
C casing
penetration
1 2 3 4
no resistance ranging to refusal

water
10/2/16 water level on date shown
water inflow
water outflow
N Not Observed

notes, samples, tects
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
V vane shear (kPa)
P pressuremeter
B_s bulk sample
E environmental sample
R refusal
F_h falling head permeability
R_h rising head permeability

test notes
R refusal
DB double bounce
PD pre-drilling
15/50 15 blows for 50mm penetration

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
W_p plastic limit
W_L liquid limit

consistency / density index
VS very soft
S soft
F firm
St stiff
VSt very still
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

Soil Description Explanation Sheet (1 of 2)

DEFINITION:

In engineering terms soil includes every type of uncemented or partially cemented inorganic or organic material found in the ground. In practice, if the material can be remoulded or disintegrated by hand in its field condition or in water it is described as a soil. Other materials are described using rock description terms.

CLASSIFICATION SYMBOL & SOIL NAME

Soils are described in accordance with the Unified Soil Classification (UCS) as shown in the table on Sheet 2.

PARTICLE SIZE DESCRIPTIVE TERMS

NAME	SUBDIVISION	SIZE
Boulders		>200 mm
Cobbles		63 mm to 200 mm
Gravel	coarse	20 mm to 63 mm
	medium	6 mm to 20 mm
	fine	2.36 mm to 6 mm
Sand	coarse	600 µm to 2.36 mm
	medium	200 µm to 600 µm
	fine	75 µm to 200 µm

MOISTURE CONDITION

Dry Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands.

Moist Soil feels cool and darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.

Wet As for moist but with free water forming on hands when handled.

CONSISTENCY OF COHESIVE SOILS

TERM	UNDRAINED STRENGTH s_u (kPa)	FIELD GUIDE
Very Soft	<12	A finger can be pushed well into the soil with little effort.
Soft	12 - 25	A finger can be pushed into the soil to about 25mm depth.
Firm	25 - 50	The soil can be indented about 5mm with the thumb, but not penetrated.
Stiff	50 - 100	The surface of the soil can be indented with the thumb, but not penetrated.
Very Stiff	100 - 200	The surface of the soil can be marked, but not indented with thumb pressure.
Hard	>200	The surface of the soil can be marked only with the thumbnail.
Friable	–	Crumbles or powders when scraped by thumbnail.

DENSITY OF GRANULAR SOILS

TERM	DENSITY INDEX (%)
Very loose	Less than 15
Loose	15 - 35
Medium Dense	35 - 65
Dense	65 - 85
Very Dense	Greater than 85

MINOR COMPONENTS

TERM	ASSESSMENT GUIDE	PROPORTION OF MINOR COMPONENT IN:
Trace of	Presence just detectable by feel or eye, but soil properties little or no different to general properties of primary component.	Coarse grained soils: <5% Fine grained soils: <15%
With some	Presence easily detected by feel or eye, soil properties little different to general properties of primary component.	Coarse grained soils: 5 - 12% Fine grained soils: 15 - 30%

SOIL STRUCTURE

ZONING		CEMENTING	
Layers	Continuous across exposure or sample.	Weakly cemented	Easily broken up by hand in air or water.
Lenses	Discontinuous layers of lenticular shape.	Moderately cemented	Effort is required to break up the soil by hand in air or water.
Pockets	Irregular inclusions of different material.		

GEOLOGICAL ORIGIN

WEATHERED IN PLACE SOILS

Extremely weathered material	Structure and fabric of parent rock visible.
Residual soil	Structure and fabric of parent rock not visible.

TRANSPORTED SOILS

Aeolian soil	Deposited by wind.
Alluvial soil	Deposited by streams and rivers.
Colluvial soil	Deposited on slopes (transported downslope by gravity).
Fill	Man made deposit. Fill may be significantly more variable between tested locations than naturally occurring soils.
Lacustrine soil	Deposited by lakes.
Marine soil	Deposited in ocean basins, bays, beaches and estuaries.

Soil Description Explanation Sheet (2 of 2)

SOIL CLASSIFICATION INCLUDING IDENTIFICATION AND DESCRIPTION

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 60 mm and basing fractions on estimated mass)

(A 0.075 mm particle is about the smallest particle visible to the naked eye)

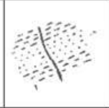
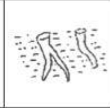
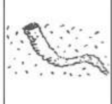
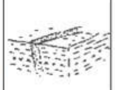
Soil group	Subdivision	Type	Field identification procedures	USC	PRIMARY NAME
COARSE GRAINED SOILS More than 50% of materials less than 63 mm is larger than 0.075 mm	GRAVELS More than half of coarse fraction is larger than 2.0 mm	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	GW	GRAVEL
			Predominantly one size or a range of sizes with more intermediate sizes missing.	GP	GRAVEL
		GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)	GM	SILTY GRAVEL
			Plastic fines (for identification procedures see CL below)	GC	CLAYEY GRAVEL
	SANDS More than half of coarse fraction is smaller than 2.0 mm	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate sizes missing	SW	SAND
			Predominantly one size or a range of sizes with some intermediate sizes missing.	SP	SAND
		SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).	SM	SILTY SAND
			Plastic fines (for identification procedures see CL below).	SC	CLAYEY SAND

IDENTIFICATION PROCEDURES ON FRACTIONS <0.2 mm.

Soil group	Subdivision	DRY STRENGTH	DILATANCY	TOUGHNESS	USC	PRIMARY NAME
FINE GRAINED SOILS More than 50% of material less than 63 mm is smaller than 0.075 mm	SILTS & CLAYS Liquid limit less than 50	None to Low	Quick to slow	None	ML	SILT
		Medium to High	None	Medium	CL	CLAY
		Low to medium	Slow to very slow	Low	OL	ORGANIC SILT
	SILTS & CLAYS Liquid limit greater than 50	Low to medium	Slow to very slow	Low to medium	MH	SILT
		High	None	High	CH	CLAY
		Medium to High	None	Low to medium	OH	ORGANIC CLAY
HIGHLY ORGANIC SOILS		Readily identified by colour, odour, spongy feel and frequently by fibrous texture.			Pt	PEAT

• Low plasticity – Liquid Limit W_L less than 35%. • Medium plasticity – W_L between 35% and 50%.

COMMON DEFECTS IN SOIL

TERM	DEFINITION	DIAGRAM
PARTING	A surface or crack across which the soil has little or no tensile strength. Parallel or sub parallel to layering (eg bedding). May be open or closed.	
JOINT	A surface or crack across which the soil has little or no tensile strength but which is not parallel or sub parallel to layering. May be open or closed. The term 'fissure' may be used for irregular joints <0.2 m in length.	
SHEARED ZONE	Zone in clayey soil with roughly parallel near planar, curved or undulating boundaries containing closely spaced, smooth or slickensided, curved intersecting joints which divide the mass into lenticular or wedge shaped blocks.	
SHEARED SURFACE	A near planar curved or undulating, smooth, polished or slickensided surface in clayey soil. The polished or slickensided surface indicates that movement (in many cases very little) has occurred along the defect.	
SOFTENED ZONE	A zone in clayey soil, usually adjacent to a defect in which the soil has a higher moisture content than elsewhere.	
TUBE	Tubular cavity. May occur singly or as one of a large number of separate or inter-connected tubes. Walls often coated with clay or strengthened by denser packing of grains. May contain organic matter	
TUBE CAST	Roughly cylindrical elongated body of soil different from the soil mass in which it occurs. In some cases the soil which makes up the tube cast is cemented.	
INFILLED SEAM	Sheet or wall like body of soil substance or mass with roughly planar to irregular near parallel boundaries which cuts through a soil mass. Formed by infilling of open joints.	

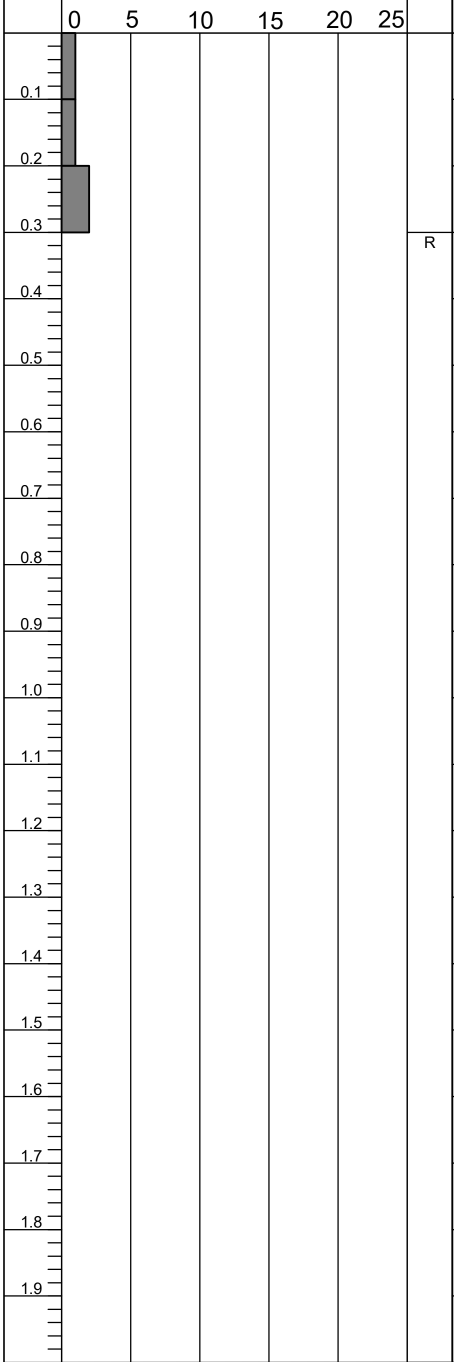
Appendix B

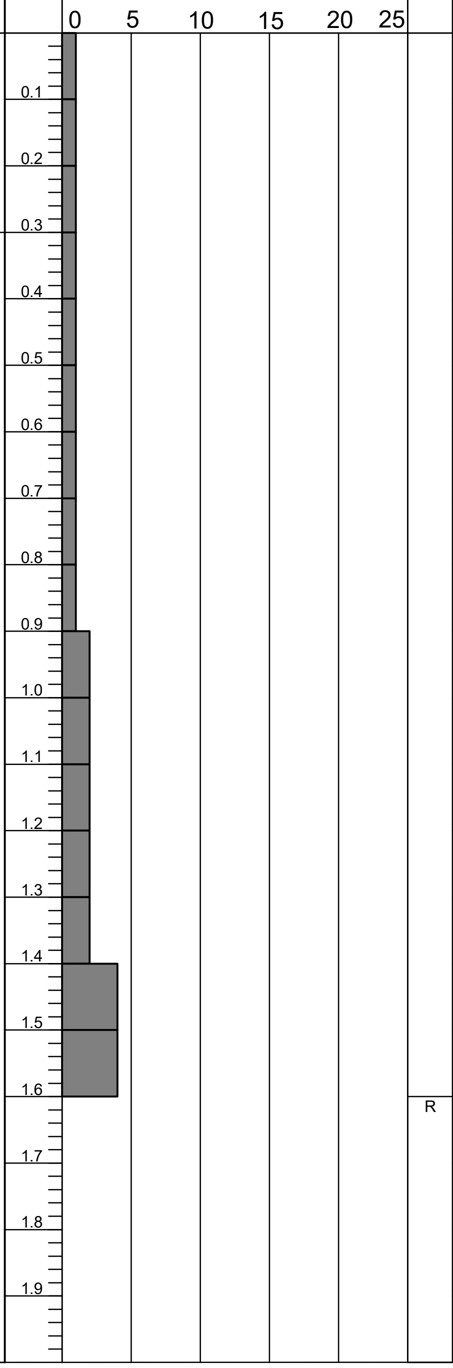
Dynamic Cone Penetrometer Test Results

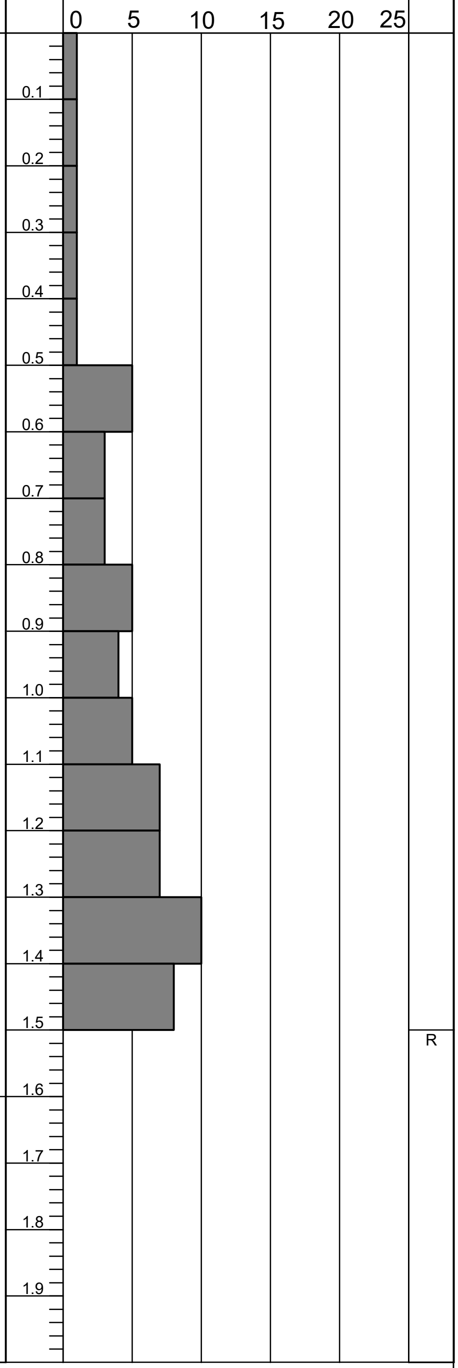
REPORT OF DYNAMIC CONE PENETROMETER (DCP) TESTS

Project No: **MMGEO2021AJ_AA**
Client: **MR ALEX JENKINS**
Project ID: **90 CABBAGE TREE ROAD, BAYVIEW, NEW SOUTH WALES**
Principal: **MR ALEX JENKINS**
DCP Location: See Site Plan
Logged By: MM
Sheet: 1 of 2
Checked By: MM

depth (m)	DCP ID: 90CTRB_DCP01	Notes	depth (m)	DCP ID: 90CTRB_DCP02	Notes	depth (m)	DCP ID: 90CTRB_DCP03	Notes
	Coords: N: Not Surveyed E: Not Surveyed RL: 39.7m Datum: AHD Date: 23/07/2021 penetration resistance (blow/100mm)			Coords: N: Not Surveyed E: Not Surveyed RL: 37.5m Datum: AHD Date: 23/07/2021 penetration resistance (blow/100mm)			Coords: N: Not Surveyed E: Not Surveyed RL: 40m Datum: AHD Date: 23/07/2021 penetration resistance (blow/100mm)	







The DCP report must be read in conjunction with accompanying notes and abbreviations. The test report has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

REPORT OF DYNAMIC CONE PENETROMETER (DCP) TESTS

Project No: **MMGEO2021AJ_AA**

Client: **MR ALEX JENKINS**

Project ID: **90 CABBAGE TREE ROAD, BAYVIEW, NEW SOUTH WALES**

Principal: **MR ALEX JENKINS**

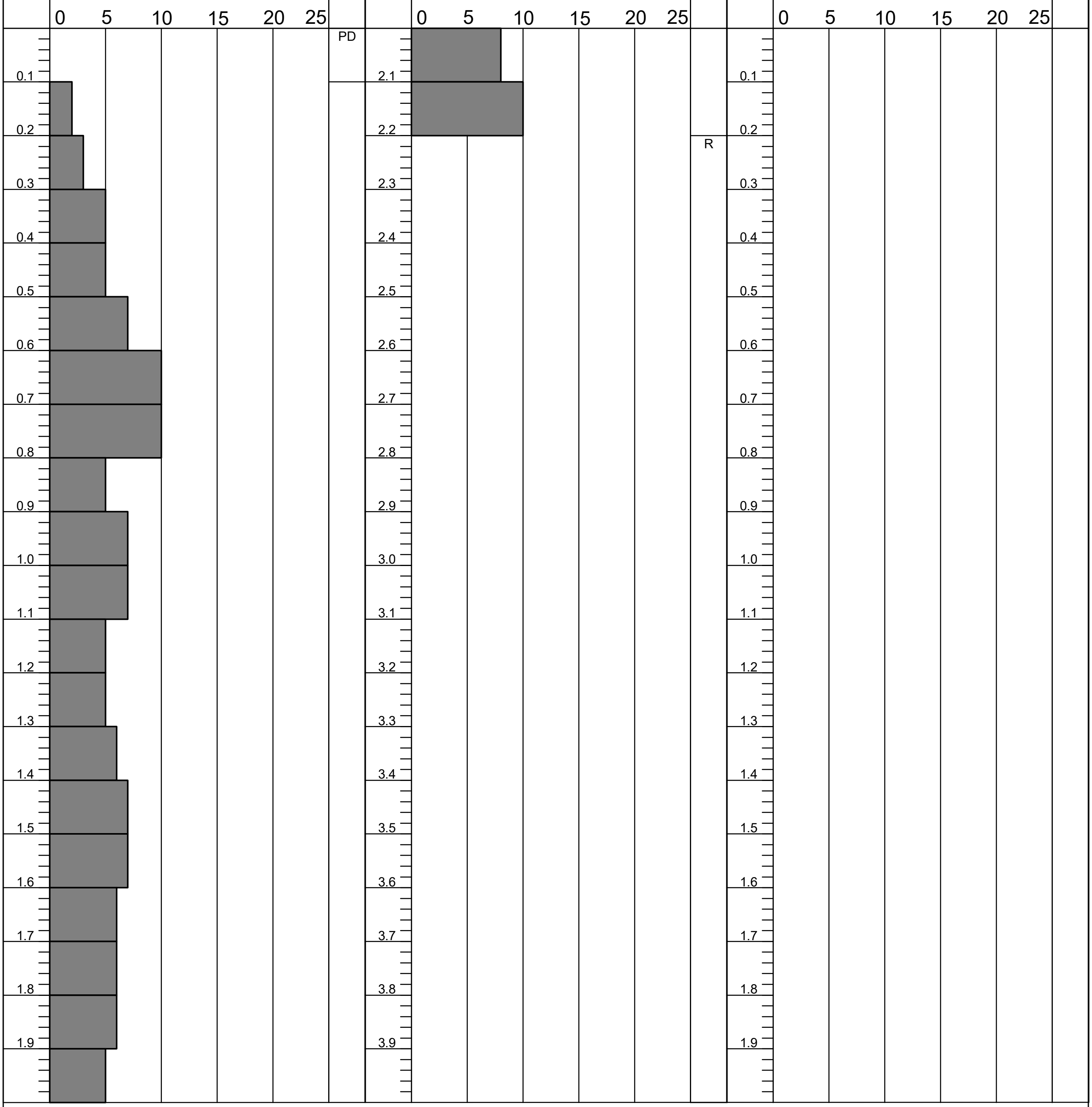
DCP Location: See Site Plan

Logged By: MM

Sheet: 2 of 2

Checked By: MM

depth (m)	**DCP ID: 90CTRB_DCP04** Coords: N: Not Surveyed E: Not Surveyed RL: 38m Datum: AHD Date: 23/07/2021 penetration resistance (blow/100mm)	Notes	depth (m)	**DCP ID: 90CTRB_DCP04** Coords: N: Not Surveyed E: Not Surveyed RL: 38m Datum: AHD Date: 23/07/2021 penetration resistance (blow/100mm)	Notes	depth (m)	**DCP ID:** Coords: N: E: RL: Date: penetration resistance (blow/100mm)	Notes



The DCP report must be read in conjunction with accompanying notes and abbreviations. The test report has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

Appendix C

Important Information about AGS2007 Appendix C

INTRODUCTION

This sheet provides important information on Appendix C from "Practice Note Guidelines for Landslide Risk Management 2007". The "Practice Note" and accompanying "Commentary" (References 1 and 2, hereafter referred to as AGS2007) are part of a series of documents on landslide risk management prepared on behalf of, and endorsed by, the Australian Geomechanics Society. These documents are primarily applicable to residential or similar development.

AGS2007 defines landslides as "the movement of a mass of rock, debris or earth down a slope". Such definition includes falls, topples, slides, spreads and flows from both natural and artificial slopes.

LANDSLIDE LIKELIHOOD ASSESSMENT

The assessment of the likelihood of landsliding requires evidence-based judgements.

Judging how often and how much an existing landslide will move is difficult. Judging the likelihood of a new landslide occurring is even harder. Records of past landslides can provide some information on what has happened, but are invariably incomplete and often provide little or no guidance on less frequent events that may occur. Often judgements have to be made about the likelihood of infrequent events with serious consequences, with little or no help from historical records. Slope models, which reflect evidence-based knowledge of how a slope was formed, how it behaved in the past and how it might behave in the future, are used to support judgements about what might happen. Because of the difficulties in assessing landslide likelihood, different assessors may make different judgements when presented with the same information.

The likelihood terms in Appendix C can be taken to imply that it is possible to distinguish between low probability events (e.g. between events having a probability of 1 in 10,000 and 1 in 100,000). In many circumstances it will not be possible to develop defensibly realistic judgements to do so, and so joint terms need to be used (e.g. Likely or Possible).

CONSEQUENCES OF LANDSLIDES

There can be direct (e.g. property damage, injury / loss of life) and indirect (e.g. litigation, loss of business confidence) consequences of a landslide. The assessment of the importance (seriousness) of the consequences is a value judgement best made by those most affected (e.g. client, owner, regulator, public). The main role of the expert is usually to understand and explain what and who might be affected, and what damage or injury might occur.

Appendix C implies that we can anticipate total cost (direct and indirect) of landslide damage to about half an order of magnitude (e.g. the difference between $30,000 and $100,000). This involves predicting the location, size, travel distance and speed of a landslide, the response of a building (often before it has been built), the nature and the extent of damage, repair costs as well as indirect consequences such as legal costs, accommodation etc. There can be other direct and indirect consequences of a landslide, which can be difficult to anticipate, let alone quantify and cost. The situation is analogous to the cost of work place accidents where the hidden costs can range from less than one to more than 20 times the visible direct costs.

In many circumstances it will not be possible to develop defensibly realistic judgements to enable use of a single consequence descriptor from Appendix C, and so joint terms need to be used (e.g. Minor or Medium). In our experience, explicit descriptions of potential consequences (e.g. rocks up to 0.5m across may fall on a parked car) help those affected to make their own judgements about the seriousness of the consequences.

RISK MATRIX

The main purpose of a risk matrix is to help rank risks, set priorities and help the decision making process. The risk terms should be regarded only as a guide to the relative level of risk as they are the product of an evidence-based quantitative judgement of likelihood and a value judgement about consequences, both of which involve considerable uncertainty. Different assessors may arrive at different judgements on the risk level. Using Appendix C, many existing houses on sloping land will be assessed to have a Moderate Risk.

RISK LEVEL IMPLICATIONS

In general, it is the responsibility of the client and/or owner and/or regulatory authority and/or others who may be affected to decide whether to accept or treat the risk. The risk assessor and/or other advisers may assist by making risk comparisons, discussing treatment options, explaining the risk management process, advising how others have reacted to risk in similar situations, and making recommendations. Attitudes to risk vary widely and risk evaluation often involves considering more than just property damage (e.g. environmental effects, public reaction, political consequences, business confidence etc.).

The risk level implications in Appendix C represent a very specific example and are unlikely to be generally applicable. In our experience the typical response of regulators to assessed risk is as follows:

Assessed risk	Typical response of client/ owner/ regulator/ person affected
Very High, High[1]	Treats seriously. Usually requires action to reduce risk. Will generally avoid development.
Moderate	May accept risk. Usually looks for ways to reduce risk if reasonably practicable.
Low, Very Low[1]	Usually regards risk as acceptable. May reduce risk if reasonably practicable.

1 The distinctions between Very High and High and between Low and Very Low risks are usually used to help set priorities.

REFERENCES

1. AGS (2007). "Practice Note Guidelines for Landslide Risk Management 2007". Australian Geomechanics, Vol. 42, No. 1, pp. 63-114.
2. AGS (2007). "Commentary on Practice Note Guidelines for Landslide Risk Management 2007". Australian Geomechanics, Vol. 42, No. 1, pp. 115-158.

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	Notional Boundary					
10^{-1}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-6}$	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		Description	Descriptor	Level
Indicative Value	Notional Boundary			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	**1: CATASTROPHIC 200%**	**2: MAJOR 60%**	**3: MEDIUM 20%**	**4: MINOR 5%**	**5: INSIGNIFICANT 0.5%**
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.
(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

Appendix D

CSIRO Publication Building Technology File 18-2011

Foundation Maintenance and Footing Performance:

A Homeowner's Guide

BTF 18 replaces Information Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

Settlement due to construction

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

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

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

Erosion

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

Saturation

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

Seasonal swelling and shrinkage of soil

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

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

Shear failure

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

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

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

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

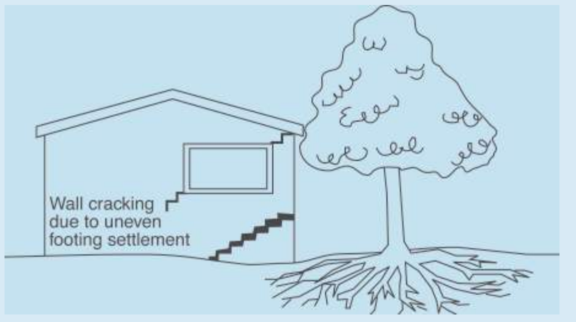
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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

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

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

Trees can cause shrinkage and damage



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

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

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

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

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

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

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

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

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

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

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

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

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

Water Service and Drainage

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

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

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

Seriousness of Cracking

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

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

Prevention/Cure

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

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

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

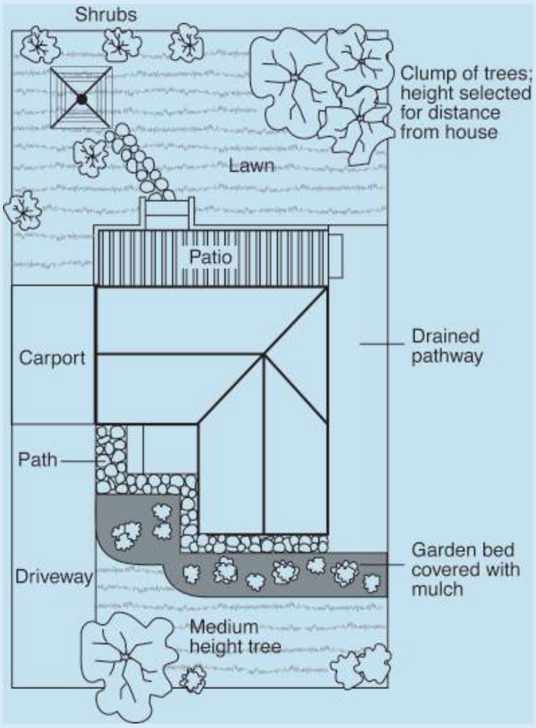
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

Gardens for a reactive site



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

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

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

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

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

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

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

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

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

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

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

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

Remediation

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

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

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

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Appendix E

Important Information About Your Geotechnical Report

Your report are based on project specific criteria

Your report has been developed on the basis of your unique project specific requirements as understood by MM Geomechanics and applies only to the site investigated. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the client. Your report should not be used if there are any changes to the project without first asking MM Geomechanics to assess how factors that changed subsequent to the date of the report affect the report's recommendations. MM Geomechanics cannot accept responsibility for problems that may occur due to changed factors if they are not consulted.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with MM Geomechanics before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

Subsurface conditions can change with time

Natural processes and man induced activity influence subsurface conditions. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions, which existed at the time of subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult MM Geomechanics for advice on how time may have impacted on the project.

Interpretation of factual data

Site assessment identifies actual subsurface conditions only at specific points where samples are taken and when they are taken. Data derived from literature and external data source review, sampling and subsequent laboratory testing are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact on the proposed development and recommended actions.

Actual conditions may differ from those inferred to exist, because no professional, no matter how qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions, which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, owners should retain the services of MM Geomechanics through the development stage, to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

Your report's recommendations are preliminary

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary.

Only MM Geomechanics, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report, there is a risk that the report will be misinterpreted and MM Geomechanics cannot be held responsible for such misinterpretation.

Interpretation by other design professionals

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain MM Geomechanics to work with other project design professionals who are affected by the report. Have MM Geomechanics explain the report implications to design professionals affected by them and then review plans and specifications produced to see how they incorporate the report findings.

Data should not be separated from the report

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way.

Logs, figures, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These logs etc. should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Contamination concerns

Your report is not likely to relate any findings, conclusions, or recommendations about the potential for hazardous materials existing at the site unless specifically required to do so by the client. Specialist equipment, techniques, and personnel are used to perform a contamination assessment.

Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated, you are advised to contact MM Geomechanics.

Rely on MM Geomechanics for additional assistance

MM Geomechanics is experienced with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As the project progresses through design towards construction, consideration should be given to retain the services of MM Geomechanics to develop alternative approaches to problems that may be of genuine benefit both in time and cost.