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REPORT ON GEOTECHNICAL SITE INVESTIGATION

for

PROPOSED RESIDENIAL DWELLING HOUSE

at

LOT 3, 1110 BARRENJOEY ROAD, PALM BEACH

Prepared For

Adam Rytenskild

Project No.: 2020-232

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GEOTECHNICAL REPORT FOR PROPOSED RESIDENTIAL DWELLING HOUSE LOT 3, 1110 BARRENJOEY ROAD, PALM BEACH, NSW

1. INTRODUCTION

This report details the results of geotechnical investigations and assessment carried out for a proposed residential dwelling house at Lot 3, 1110 Barrenjoey Road, Palm Beach, NSW. The investigation was undertaken by Crozier Geotechnical Consultants (CGC) at the written request of Jorge Hrdina Architects on behalf of the client Adam Rytenskild.

It is understood the proposed works involve the construction of a multi-level residential dwelling with a detached secondary structure and swimming pool. The development will include a four storey main structure, comprising a ground floor garage level and three upper living levels, which will require bulk excavation to a maximum depth of approximately 6.0m. A swimming pool and spa will be accessible via decking from the first floor level of the main structure. All levels of the main structure will be connected via a central elevator. The secondary structure will comprise of a single storey dwelling positioned within the south-western corner of the block, this structure will require bulk excavation into the retained soil embankment up to 3.2m depth. Further alterations to the existing retaining systems towards the front of the site are also proposed.

It is further understood that the proposed works have been submitted to Council under a Development Application (DA2021/02000). According to the Minutes of Local Planning Panel Meeting (Northern Beaches Council) Section 3.2, Dated: 21st July 2021;

> *The Northern Beaches Local Planning Panel, on behalf of Northern Beaches Council as the consent authority, grants deferred commencement approval Application No. DA2021/0200…*
>
> *The following must be undertaken prior to the development consent becoming operational.*
>
> > *(a) A Stage 1 geotechnical investigation is to be undertaken, comprising boreholes and any further investigations as required.*
> >
> > *(b) The geotechnical engineer shall provide details on important subsurface conditions and suitable guidance to the structural design for excavation retention and for suitable and necessary engineering controls that must be implemented to ensure stable excavation.*
> >
> > *(c) A Construction Methodology Statement (CMS) is to be produced, incorporating an Excavation Management Plan (EMP), and controls/hold points are to be confirmed.*

This report is an update of the original report and provides information from the initial and secondary investigation, it includes a landslide risk assessment of the site, a description of site and sub-surface conditions, in-situ test results, site mapping/plan, geological sections/models, a geotechnical assessment of the proposed works, provides recommendations for construction ensuring stability is maintained for a preferred design life of 100 years and a Construction Methodology Statement (CMS).

The site is also located within Acid Sulphate Soils Class 5 (ASS_015), however due to the topography and location of the site there will be no possibility of intersecting these soils.

The site assessment and reporting were undertaken as per the Proposal No.: P20-451.1, Dated: 5th November 2020 and P21-391, Dated: 12th August 2021.

The initial investigation and reporting (Phase 1) were undertaken as per Proposal No. P20-451.1, Dated: 5th November 2020. The investigation comprised:

a) A detailed geotechnical inspection and mapping of the site and adjacent properties by a Geotechnical Engineer and Principal Engineering Geologist.
b) Dynamic Cone Penetrometer (DCP) testing at four locations to investigate the subsurface conditions.
c) All fieldwork was conducted under the full-time supervision of an experienced Geotechnical Professional.

The recent investigation and reporting (Phase 2) were undertaken as per Proposal No.: P21-391, Dated: 12th August 2021. The investigation comprised:

a) Drilling of three boreholes to a maximum of 7.90m depth using a man portable setup with initial augering through soils then coring of the bedrock.
b) Drilling of five boreholes using hand tools along with seven Dynamic Cone Penetrometer (DCP) tests to investigate the subsurface conditions and depth to bedrock.
c) Further geotechnical inspection and mapping of current site conditions and adjacent properties by a Geotechnical Engineer.
d) Point Load testing of rock core samples for strength analysis along with core photography.
e) All fieldwork was conducted under the full-time supervision of an experienced Geotechnical Professional.

The following plans were supplied and relied upon in the preparation of the investigation and this report:

- Architectural Drawings - Jorge Hrdina Architects Pty Ltd, Project No.: 2004, Drawing No.: DA1000 – DA1001, DA2000 – DA2005, DA2220 – DA2222, DA3000 – DA3004, DA3100 – DA3102, DA4000 – DA4002, Dated: 22/02/2021 & 15/06/2021

- Survey Drawing - Adam Clerke Surveyors Pty Ltd, Reference No.: 20688S, Dated: 23/11/2020
- Geotechnical Review Report - Davies Geotechnical, Project No.: 21-019.A, Dated: 05/07/2021

2. PROPOSED DEVELOPMENT

The proposed works involve the construction of a multi-level residential dwelling house along with a secondary single storey structure. The main structure will consist of four levels, with the ground floor level containing a basement garage to be formed with a FFL of RL12.27m. Maximum bulk excavation will be required along the rear eastern edge of the proposed ground floor level inclusive of the elevator shaft to approximately 6.0m depth.

The upper living levels of the proposed development are to step up the steep west dipping terrain of the site towards the rear property boundary. A swimming pool and spa are to be constructed at the first-floor level (RL20.10m) and are to extend southward from the main structure. It is understood that the swimming pool and surrounds are to be largely constructed out of ground, with only potential for eastern portions of the swimming pool to intersect existing boulder(s). The second and third levels of development are to consist of living levels which appear to be largely designed around the significant boulders of the site. Bulk excavation is anticipated to ≤2.0m depth for the upper living levels. Construction and excavation within the upper north-eastern zone of the site will require boulder removal and/or stabilisation.

The existing block retaining wall within the front of the site is to be largely removed and replaced, with bulk excavation required into the soil embankment for the ground floor level and secondary structure. Bulk excavation appears to be required to approximately 3.2m depth and extends to within 0.9m of the southern boundary to provide an approximate 1.2m side setback for the dwellings south wall. It also appears that the excavation will intersect a large sandstone boulder which will likely require removal. A palm tree is positioned directly to the east of this boulder, which also likely requires removal.

The main structure is to have a 2.5m south side setback, a 0.6m to 1.3m north side setback, an 8.5m rear setback and an approximate 9.0m front boundary setback. The proposed secondary structure is to have an approximate 1.2m south side setback and a 1.2m front boundary setback.

3. SITE FEATURES

3.1. Description:

The site (Lot 3) is an irregularly shaped block at the southern end of No.1110 Barrenjoey Road, with Lot 1 and Lot 2 to the north. The site is situated on the high east side of Barrenjoey Road, located mid slope on the steep western side of a north-south striking ridge line which contains numerous sandstone boulders of varying size.

The site contains a levelled, partially concrete paved terrace within the western portion of the site where a storage container, caravan and shed are located. The tree line located to the west of the near level grassed lawn marks approximately the west site boundary. The rear eastern portion of the site contains steep west dipping natural terrain with large boulders and trees. An aerial photograph of the site (Lot 3) and its surrounds is provided below (Photograph 1), as sourced from NSW Government Six Map spatial data system whilst the front of the site is shown in Photograph 2.

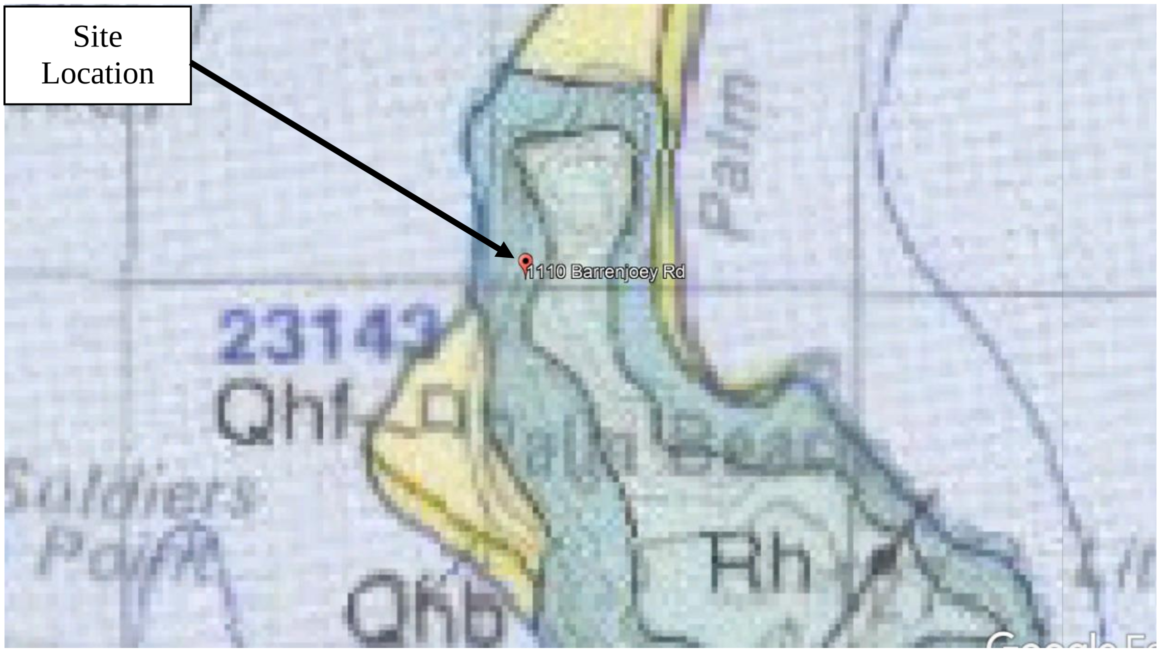
Photograph-1: Aerial photo of site and surrounds

Photograph-2: View of the front of the site, looking south-east from Lot 2

3.2. Geology

Reference to the Sydney 1: 100,000 Geological Series sheet (9130) indicates that the site is underlain by weathered bedrock of the Newport Formation (Upper Narrabeen Group) rock (Rnn) which is of middle Triassic Age. The Newport Formation typically comprises interbedded laminite, shale and quartz to lithic quartz sandstones and pink clay pellet sandstones and has a tendency to weather to significant depths. To the east of the site the Hawkesbury Sandstone (Rh) which is of Triassic Age is defined. This rock unit typically comprises medium to coarse grained quartz sandstone with minor lenses of shale and laminate that forms a capping to the ridge with boulders from this unit scattered over the slopes below. Sandstone boulders were identified throughout the site and neighbouring properties.

Narrabeen Group rocks are dominated by shales and thin siltstone/sandstone beds and often form rounded convex ridge tops with moderate angle (<20°) side slopes. These side slopes can be either concave or convex depending on geology, internally they comprise of interbedded shale and siltstone beds with close spaced bedding partings that have either close spaced vertical joints or in extreme cases large space convex joints. The shale often forms deeply weathered profiles with silty or medium to high plasticity clays and a thin silty colluvial cover. The bedrock may be thinly interbedded with very low to low strength siltstone/shale units and medium to high strength sandstone horizons.



Extract of Sydney (9130 Geology Series Map): 1:100000 - Geology underlying the site

4. FIELD WORK

4.1. Methods:

Phase 1 of the field investigation comprised a walk over inspection, mapping of the site and limited inspection of adjacent properties on the 19th November 2020 by a Geotechnical Engineer and Principal Engineering Geologist. It included a photographic record of site conditions as well as geological/geomorphological mapping of the site and adjacent land with examination of rock outcrops, boulders, existing structures and limited inspection of neighbouring properties.

DCP testing was carried out from the ground surface at four nominated locations in accordance with AS1289.6.3.2 – 1997, “Determination of the penetration resistance of a soil – 9kg Dynamic Cone Penetrometer” to estimate near surface soil conditions and depths to bedrock.

Phase 2 of the field investigation comprised the drilling of three cored boreholes (BH101 – BH103) which was subsequently undertaken on the 29th & 30th November 2021. The cored boreholes were undertaken using a man portable rig setup. The boreholes were undertaken initially by utilizing hand-held solid stem, spiral flight auger drilling techniques through the surface soil prior to installing drilling casing. The boreholes were then extended utilising NMLC triple-tube techniques to acquire rock core samples for logging purposes by a Geotechnical Engineer and for geotechnical laboratory testing.

Further on-site testing including the drilling of five boreholes using hand tools along with seven DCP tests were conducted across the site. Additional mapping of the current site conditions including the examination of boulders embedded into the soil slope, existing structures and inspection of neighbouring properties was also undertaken.

Explanatory notes are included in Appendix: 1. Mapping information and test locations are shown on Figure: 1, along with detailed Cored Borehole Log Sheets, Borehole Log Sheets and Dynamic Penetrometer Test Sheet in Appendix: 2. The geological models/sections are provided as Figure: 2 & 3, Appendix: 2.

4.2. Field Observations:

The site comprises the southern third of a previously vacant block of land. Access to the site is provided via a curved, concrete paved driveway from street level to the western edge of Lot 2. There were no signs of excessive cracking or deformation within the driveway pavement to suggest any movement or underlying geotechnical issues. The slope on the high northern/eastern side of the driveway adjacent to Lot 1 and Lot 2 is retained by a 0.70m to 1.80m high concrete retaining wall which is in good condition with no obvious signs of any cracking or settlement.

The western portion of the site contains a partially paved terrace region with a caravan and shed structure, approximately 2.4m high concrete block and sandstone block retaining walls are located along the eastern side of this front terrace area. These retaining walls appear generally in good condition with no obvious signs of any settlement or movement, except minor cracks within the wall structures. A transition in construction material occurs as the wall extends to the lower face of two large sandstone boulders, where a low concrete block retaining wall (≤0.60m) appears to be supporting the lower sides or soils below these boulders.

The steep slope (≈20°) to the east side of the front terraced area contains an open grassed area with scattered vegetation and large trees. Sandstone boulders to a maximum of approximately 50m^3 are largely embedded into the soil slope across the site, the majority of these boulders appeared to be in a stable condition.

A large palm tree is located approximately 3.0m from the concrete block retaining wall within the front terrace area. The base of this tree shows signs of wash out and erosion, with large sections of the roots exposed. The tree appears to be positioned partially on top of a large sandstone boulder, this is shown in Photograph 3.

A middle-terraced level exists just to the east of the front terraced area at approximately R.L. 16.5m, this region is located between large angular sandstone boulders. A large (≈48m^3) angular, north east – south west striking, west north west dipping (≈65°) sandstone boulder is located on the high east side of this middle-terraced level. A dry stack, subvertical sandstone rock retaining wall is located on the northern side of this boulder. This retaining wall appears to be stable at present, however it is not engineer designed and subject to poor construction methodology and slow degradation from creep pressures. The angular boulder and retaining wall are shown in Photograph 4 and 5.

Photograph-3: Wash out under roots of palm tree, looking east

Photograph-4: Retaining wall to the north of sandstone boulder along the eastern edge of the middle-terraced region, looking east

Photograph-5: Massive, angular sandstone boulder within the middle-terraced region, looking north-east

A series of large sandstone boulders are positioned within the north-eastern corner of the site, with one large boulder extending an approximate 12m into the neighbouring property to the north-east (No.140 Pacific Road), this boulder appeared to be in a stable condition. The lower section of this boulder is detached with a series of stacked prismatic boulders bearing onto a well embedded, stable sandstone boulder. The upper boulders within this section are resting on the large north eastern boulder which continues into the neighbouring property, none of the boulders within this upper section were determined as being unstable at present.

Within this north-eastern section of boulders, another series of four large boulders clustered together were identified, these boulders are shown in Photographs 6 – 9. The northern side of the series includes a detached angular boulder resting on top of another detached unit, both units are orientated down slope bearing onto a largely buried boulder. The upper triangular boulder, lower rectangular boulder and their founding conditions are shown in Photograph 6.

The upper triangular boulder is approximately 2.3m^3, with the lower rectangular boulder approximately 4.0m^3. Both units have become detached along sub-horizontal planes. The upper and possibly lower detached units are interpreted as being susceptible to instability due to sliding or overturning failure. The adjacent boulder to the south has an approximate volume of 35m^3 and weight of approximately 85 tonnes. This boulder has rotated to rest on the adjacent rectangular boulder, with the base of the boulder embedded into the soil slope. It is considered likely that this boulder is also susceptible to instability due to boulder sliding and appears to be an influence on the adjacent boulders to the north.

Photograph-6: Southern view of boulder instability region, including the upper triangle boulder bearing onto the lower rectangular boulder and embedded boulder below.

Photograph-7: Eastern view of boulder instability region, including the stacked boulder section to the left and large southern boulder to the right.

Photograph-8: Northern view of boulder instability region, including the large southern boulder

Photograph-9: Western view of boulder instability region, including the upper triangle boulder to the right and large southern boulder to the left.

A central boulder section is positioned to the east of the large angular sandstone boulder shown in Photograph 5. Loose sandstone cobbles and boulders are positioned throughout this region embedded into the moderate to steep sloping terrain. The majority of these boulders are angular and slender in shape and largely orientated downslope. A number of these boulders are wedged into surrounding trees and vegetation, this is similarly seen in a boulder upslope which is stabilised by a tree positioned on the lower face of the boulder, this is shown in Photograph 10.

Photograph-10: Sandstone boulder stabilised by tree adjacent to eastern boundary of site, facing east

The soil slope of the site is well protected with vegetation cover, with no signs of excessive surface erosion, soil creep or any tension crack/deformations observed over the soil slope to suggest any underlying movement.

A concrete slurry drain from apparent excess concrete connected to the recent construction works within the neighbouring property to the north (Lot 2) extends along the lower northern boundary. The slurry has set within the vegetation cover with excess concrete discharged over the top of the retaining wall, which has set between the eastern side of the shed structure and the retaining wall.

A Sydney Water (SW) sewer asset extends through the eastern portion of the site and along the southern boundary, this pipe is positioned above ground across the site, founded on concrete piles.

The neighbouring property to the west (No.1102 - 1104) contains a currently vacant block of land previously occupied by Palm Beach Fish & Chips, located at Barrenjoey Road street level. A vertical soldier pile retaining wall approximately 4.0m to 5.0m high is positioned along the rear boundary of the property adjacent to the site. The support wall is formed with bored concrete piers (600mm diameter) and intermediate concrete panels with a capping beam on top. This wall appears to be in very good condition with no visible signs of any settlement or rotation. Sub-vertically cut, highly to moderately weathered siltstone/shale bedrock is exposed at the base of the support wall, as shown in Photograph 11.

Photograph-11: Exposed siltstone and shale bedrock at the base of the concrete panel soldier pile wall at the rear excavation face of No.1104 Barrenjoey Road.

A partially suspended sandstone boulder which has been stabilised via shotcrete is positioned in the south-eastern corner of No.1102 -1104 adjacent to the support wall. This sandstone boulder is understood to continue into the neighbouring property to the south (No.1100 Barrenjoey Road). This boulder is exposed along the upper northern face and lower western face, it further appears to underlie a large northern portion of No.1100, with potential for the main structure to be founded on it.

The neighbouring properties to the east (No. 138 – 140 Pacific Road) are located close to the crest of the ridge with their steeply west sloping backyards extending to the common boundaries with the site. The stepped backyards of these properties are densely vegetated and are retained by dry packed stone walls and concrete crib gravity walls of variable heights. Only the site visible sections of these neighbouring properties were inspected with no signs of any obvious geotechnical issues identified.

The neighbouring property to the south (No.1100 Barrenjoey Road) contains a two storey timber house located at street level within the front half of the block. The rear half contains a small, dilapidated timber hut surrounded by dense vegetation and tall trees. An above ground sewer pipe runs below this timber hut and intersects the site within the south eastern corner across an unmarked common boundary and continues into No.138 Pacific Road.

The neighbouring lot to the north (Lot 2, No.1110 Barrenjoey Road) forms the middle portion of No.1110 Barrenjoey Road and is situated within very similar topography as the site. A single storey suspended dwelling supported via wooden piers and concrete piles has recently been constructed. No bulk excavation was required as part of the construction with minor landscaping works within the front and southern side of the property identified. A very large sandstone boulder (≈200m^3) is located within the south-western corner of the lot and extends to the common boundary with the site. Resting on top of this boulder is a smaller detached boulder, which appears to be stable at present, this is shown in Photograph 12.

Photograph-12: Recently constructed dwelling within Lot 2, 1110 Barrenjoey Road, with large sandstone boulder and smaller detached unit on top, facing east

4.3. Ground Conditions:

Phase 1 – DCP & Mapping

Dynamic Cone Penetrometer (DCP) tests were undertaken at specific locations across the site with refusal encountered at depths varying from 0.43m (DCP1) to 2.10m (DCP4) on interpreted bedrock/ boulders. Two of the DCP tests (DCP2 & DCP3) where discontinued at 3.0m depth without encountering refusal. Extensive mapping of the site conditions, boulders and geotechnical hazards was also conducted.

Phase 2 – Coring, Boreholes and DCP

Cored boreholes were drilled at three locations across the site. BH101 was positioned adjacent to the northern boundary in the zone of the proposed garage excavation, this borehole extended to 7.90m depth intersecting fine grained sandstone bedrock from 4.35m depth. BH102 was positioned adjacent to the southern boundary in the zone of the proposed secondary structure excavation, this borehole extended to 5.0m depth, with fine grained sandstone bedrock encountered from 4.25m depth. BH103 was positioned centrally and extended to 3.0m depth with interpreted sandstone bedrock of low strength encountered from 2.15m depth.

Five hand boreholes were drilled across the site to identify near surface soil conditions and depths to bedrock. Colluvium from surface level overlying sandy clay/clayey sand residual soils were encountered at all test locations. Refusal in stiff sandy clay, boulders and extremely low strength sandstone bedrock was encountered between 1.35m (BH1) and 0.20m depth (BH2). DCP tests were conducted adjacent to the borehole locations and at one other nominated location, refusal on interpreted sandstone bedrock of at least very low strength was encountered between 1.60m (DCP11) and 3.40m depth (DCP5).

For a detailed description of the ground conditions encountered underlying the site, the individual borehole and corehole logs should be referred to however, the sub-surface conditions at the project site can be broadly classified as follows:

- **TOPSOIL/COLLUVIUM –** this layer was encountered at all borehole locations and typically comprised dark brown, fine to medium grained, silty/clayey sand. This layer was encountered to depths between 0.30m (BH4) and 0.80m (BH3), with BH2 refusing on sandstone cobbles within this layer at 0.20m depth.
- **SANDY CLAY-** Sandy clay was encountered in BH1, BH4 and all cored borehole locations. The layer consisted of soft grading to interpreted hard, pale brown mottled yellow brown, medium to high plasticity, moist sandy clay. BH1 and BH4 refused within this layer on interpreted sandstone boulders at 0.85m (BH4) and 1.30m depth (BH1). Natural sand was encountered within BH3 underlying topsoil/colluvium layer from 0.80m depth on the high side of a sandstone boulder, it is interpreted that this boulder was intersected at 1.10m depth.
- **SANDSTONE BEDROCK** – Sandstone bedrock of extremely low strength (ELS) with embedded sandstone boulders was identified immediately underlying the residual soils to a maximum of

approximately 4.30m (BH101 & BH102). Fine grained, low strength (LS) sandstone bedrock of the Narrabeen Group was identified from 4.25m, 4.35m and 2.15m respectively (BH101 – BH103). Moderately to slightly weathered, medium strength (MS) sandstone was encountered from 5.60m depth in BH103 to borehole discontinuation at 7.90m depth.

A free standing ground water table or significant water seepage were not identified within any of the boreholes. Moisture was identified on some retrieved DCP rods at depths just above interpreted bedrock of at least extremely low strength.

Table 1: BH101 summary

BH101	Depth (m)	RL(AHD)	
Clay/ Sandstone ELS and Boulders	1.65m – 4.35m	14.85m – 12.15m	Hard clay/extremely weathered, extremely low strength sandstone bedrock grading to extremely low strength, highly weathered pale grey sandstone at 3.70m depth. An ironstone boulder embedded into the soil material was intersected at 2.30m.
Sandstone LS – MS	4.35m – 6.45m	12.15m – 10.05m	Low strength, moderately weathered, fine grained sandstone grading to medium strength, slightly weathered at 5.60m. Sub vertical joint defects encountered at 5.55m and 6.15m.
Sandstone ELS – VLS	6.45m – 6.90m	10.05m – 9.60m	An extremely weathered to highly weathered sandstone band with joint defects encountered above and below this zone.
Sandstone LS - MS	6.90m – 7.90m (END)	9.60m – 8.60m	Low to medium strength, moderately to slightly weathered, fine to medium grained, with joint defects encountered at 7.10m and 7.43m. Coarse grained sandstone interbedded with quartz gravel encountered 0.05m from end of core.

The core photograph of BH101 is shown below

BH101 – 1.64m to 7.95m depth

Table 2: BH102 summary

BH102	Depth (m)	RL(AHD)	
Clay/ Sandstone ELS and Boulders	1.20m – 4.25m	15.20m – 12.15m	Medium to high plasticity clay/extremely weathered, extremely low strength sandstone bedrock. At least one sandstone boulder was intersected between 2.15m and 3.60m with soil material overlying and underlying.
Sandstone LS	4.25m – 5.00m	12.15m – 11.40m	Low strength, highly weathered, fine grained sandstone. Sub vertical joint defects encountered at approximately 0.20m spacing between 4.34m and 4.77m.

The core photograph of BH102 is shown below

BH102 – 1.20m to 5.00m depth

Table 3: BH103 summary

BH103	Depth (m)	RL(AHD)	
Clay/ Sandstone ELS and Boulders	0.20m – 2.15m	21.60m – 19.65m	Topsoil/colluvium from surface with a sandstone boulder encountered at 0.20m, likely medium to high plasticity clay with roots and cobbles/boulders to 2.15m.
Sandstone LS	2.15m – 3.00m	19.65m – 18.80m	Low strength, highly weathered, fine grained, thinly laminated sandstone. Poor core condition recovery due to portable equipment, potential for bedding or joint defects.

The core photograph of BH103 is shown below

BH103 – 0.20m to 3.00m depth

ELS = Extremely low strength, VLS = Very low strength, LS = Low strength, MS = Medium strength, HS = High strength

5. COMMENTS

5.1 Geotechnical Assessment:

The site investigation identified the presence of topsoil/colluvium overlying sandy clay residual soils from a maximum drilled depth of 0.80m (BH3). The sandy clay layer comprised soft grading to hard, medium to high plasticity, moist sandy clay to a maximum drilled depth of 1.30m however it is interpreted to extend to greater depths ≤3.40m (DCP5), with extremely low strength bedrock identified to a maximum depth of 4.35m (BH101). Fine grained sandstone bedrock was encountered underlying the site below the extremely low strength rock, with three cored boreholes identifying sandstone bedrock of low strength between 2.15m (BH103) and 4.35m depth (BH101). The bedrock profile was identified as being deeply weathered from the bedrock surface with extremely low strength sandstone grading to low/medium strength over 1.5m to 3.0m depths, with multiple sub-vertical joint defects identified within deeper portions (4.0m – 7.50m, BH101 and BH102).

It is understood that the proposed works involve the construction of a multi-level residential dwelling house which will step up the steep sloping terrain of the site. The ground floor level of the structure will require excavation into the embankment to a maximum depth of 6.0m at the rear eastern wall. The upper three levels are understood to largely be positioned around the sandstone boulders of the site, with bulk excavation required within portions to a maximum depth of 2.0m. A swimming pool and spa are to be formed on the first floor level of the development with the eastern portion of the pool appearing to intersect a large angular boulder. The development will also include a southern secondary structure which will also require bulk excavation to an anticipated depth of 3.2m within 0.9m from the southern boundary of the site, these works will require the construction of new retaining systems along the front portion of the site. The excavations for the main structure and swimming pool will extend to 1.0m from the northern side boundaries and ≥2.5m from the south boundary, across an estimated area of 113m^2.

The boulders buried across the soil slope are likely creeping with the soil. Excavation adjacent to or into these boulders is likely to disturb and cause instability. Some boulders directly overlie other boulders along unfavourable defects and are considered relatively unstable. Reference has been made (Drawing No.: DA2004) to boulder(s) within the eastern portion of the site; "rock cut back or retained as required". It should be noted that for any rock fall hazards, the preference is removal however this may be difficult to achieve in the current conditions. If this cannot be completed, then stabilising systems are required (i.e. rock bolts/shotcrete). CGC must be consulted prior to any boulder removal or stabilisation works.

The north-eastern zone of sandstone boulders show signs of impending instability, with the boulders shown in Photographs 6 – 9 the main concern. To secure the boulders within this region, a number of stability measures will need to be adopted, as the complex forces acting on the boulders will likely require a complete support system. If removal of boulders is not possible, a combination of rock bolts/anchors, bracing and shotcrete are considered necessary due to the multiple forces acting in different directions on the boulders. It is also recommended that loose, small, unstable boulders be removed in the area of the proposed development prior to any construction work. Unstable boulders within a 1.0V:1.5H influence zone of an excavation base or medium strength bedrock surface are recommended to be removed or secured prior to any excavation on site. All boulder stabilisation works must be completed prior to any construction/excavation associated with the proposed works.

The cored boreholes drilled during Phase 2 of the investigation provided insight into the deeply weathered nature of the underlying bedrock profile. The Narrabeen Group rocks underlie the more resistant Hawkesbury Sandstone, with deep weathering and overall lower strength bedrock associated with the Newport Formation. This was identified in all cored boreholes drilled, as apparent with the amount of core loss (foam) shown in the above core photography. Interpreted sandstone boulders were also encountered within BH101 and BH102 indicating the presence of boulders/detached sections of bedrock embedded within the soil slope, which should be considered as part of excavation methodologies.

The joint defects identified within BH101 and BH102 between 4.37m– 7.43m (BH101) and between 4.34m – 4.77m depth (BH102) indicate potential for localised rock slide/topple failure in the proposed excavations. The likelihood of such failure is dictated by the orientation of the joints (which is impossible to decipher from coring). For example, if the joint is steeply dipping west (downslope) there is a much higher chance of gravity induced sliding failure within the excavation compared to east dipping defects. As a result, all defects identified should be managed with a worst-case scenario approach and therefore dealt with extreme care. Ongoing geotechnical inspections in accordance with Section 5.2.2 will be required as part of the proposed excavation and construction works.

The ground floor level excavation is expected to intersect topsoil/colluvium, clayey residual soils along with embedded sandstone boulders to approximately 4.30m depth from surface level, with sandstone bedrock of low to medium strength below. The ground floor level excavation is to extend to approximately 6.0m depth at the rear of the cut within the steep slope and positioned a minimum of 0.60m from the northern boundary. A very large boulder (≈200m^3) within Lot 2 is positioned a minimum of 2.0m from the proposed excavation footprint. As such safe batter slopes will not be achievable along the southern, eastern or northern faces.

It is envisaged that safe batter slopes will also not be achievable for the secondary structure excavation. Therefore, temporary support systems will need to be installed prior to excavation to ensure stability of the excavation faces including the south boundary and adjacent boulders/trees. Excavation for the secondary structure is anticipated to intersect natural soils with floating sandstone boulders for the majority of the excavation, however there is still potential for ELS – LS sandstone bedrock to be encountered from 1.60m depth (DCP11).

The replacement and upgrade of the existing retaining wall at the front of the site will require careful consideration, including the low concrete block portion supporting a boulder towards the southern end of the wall. Several boulders, including the very large (≈200m^3) boulder largely within Lot 2 along with a boulder to be partly excavated for the secondary structure, are situated on the high side of the wall within proximity.

Where safe batter slopes are not achievable (all lower western excavations), support prior to excavation or robust temporary support systems will need to be installed. Due to the steep topography of the site, piling works will be difficult to implement and will require significant earthworks to provide suitable machinery access across the site. If a piling rig with capability of providing a socket into medium strength bedrock for cantilever support cannot be mobilised on site for pre-excavation support then alternative supported soldier pile wall or similar designs will be required.

This may include a braced or anchored solider pile wall via a staged approach where initial bored piles are drilled to bear onto low to medium strength bedrock only with two rows of anchors providing lateral restraint. Below pile bases a staged anchored shotcrete wall would be required to the base of the excavation level. Alternatively, a staged shotcrete wall could be utilised where excavation into the soils is conducted in 1.0m depth increments with the exposed soils shotcreted and anchored prior to further excavation with depth increment increase to 1.50m in the rock. The joint defects and localised zones of extremely weathered bedrock identified in the cored boreholes indicate that ongoing geotechnical inspection during all stages of the excavation phases will be critical.

An ongoing survey monitoring plan of support crests and mid-points is recommended during the excavation and construction phase to ensure deflection levels in retaining walls match design projections and that any variations can be identified and dealt with in a timely manner.

Due to the steep sloping terrain of the site and nature of the proposed works it is recommended that all footings for the proposed development extend through colluvium/fill and extremely weathered material to bear onto bedrock of at least low strength. Proposed major structures should be supported off pier footings socketed into a minimum of low strength bedrock to prevent differential settlement and provide resistance to creep movement in the slope. A flexible pile system appears to be the most suitable footing option for support of the proposed structures, as a flexible layout could minimise the risk of boulder impact, preventing individual footing drilling or instability with deep pile style footings enabling the development to bear onto competent bedrock.

No groundwater and only indications of minor seepage were encountered during the investigations however, it is likely that minor seepage will be intersected at the soil - rock interface and on defects in the bedrock during excavation, with further surface runoff likely due to the topography of the site. A freestanding water table or Acid Sulfate Soils were not encountered and are not expected within the site due to the elevation and topography of the site within the depths of proposed works and surrounds.

The recommendations and conclusions in this report are based on an investigation utilising only surface observations and boreholes at separate locations. Therefore, some minor variation to the interpreted sub-surface conditions is possible, especially between test locations.

5.2. Stability Risk Assessment:

Based on our site investigation we have identified the following credible geological/geotechnical hazards which need to be considered in relation to the existing site and the proposed works. The hazards are:

A. Landslip (Rockslide/topple <5m^3) of unstable angular boulder within north-east portion of site due to disturbance
B. Landslip (Rockslide/topple <20m^3) of other boulders due to disturbance
C. Landslip (Soil <10m^3) of earth around perimeter of proposed ground floor excavation
D. Landslip (Soil <2m^3) of earth around perimeter of excavation for proposed single storey secondary dwelling
E. Landslip (Rock <10m^3) of bedrock or boulder around perimeter of excavation for proposed single sorey secondary dwelling
F. Landslip (Rock <4m^3) of bedrock around perimeter of ground floor excavation

A qualitative assessment of risk to life and property related to this hazard is presented in Table A and B, Appendix: 3, and is based on methods outlined in Appendix: C of the Australian Geomechanics Society (AGS) Guidelines for Landslide Risk Management 2007. AGS terms and their descriptions are provided in Appendix: 4.

The **Risk to Life** from **Hazard A to F** were estimated to be up to **7.50 x 10^{-5}** for a single person, whilst the **Risk to Property** from the hazards were considered to be up to **‘High’**.

Although the Risk to Life & Property are considered to be ‘Unacceptable’, the assessments were based on excavations with no support or planning. Provided the recommendations of this report are implemented the likelihood of any failure becomes ‘Rare’ and as such the consequences reduce and risk becomes within ‘Acceptable’ levels when assessed against the criteria of the AGS 2007. As such the project is considered suitable for the site provided the recommendations of this report are implemented.

5.3 Design & Construction Recommendations:

Design and the construction recommendations are tabulated below:

5.3.1. New Footings:

Site Classification as per AS2870 – 2011 for new footing design	Class 'P' Due to landslip risk
Type of Footing	Piers, pads or strip dependent on location

Sub-grade material and Maximum Allowable Bearing Capacity & Shaft Adhesion values:

Material	Strength	Maximum Allowable Working Bearing Pressure (kPa) $^{+}$	
		Shaft Adhesion*	End Bearing^{++}
Sandstone	Extremely Low	N/A	600
	Very Low	40	800
	Low	60	1,000
	Medium	150	2,000

Site sub-soil classification as per *Structural design actions AS1170.4 – 2007, Part 4: Earthquake actions in Australia*	B_e – Rock site

Remarks:

*Pells et al, 1998. Where clean socket of roughness category R2 or better then shaft adhesion values can be doubled. Values have been reduced because of smear.

All permanent structure footings should be founded off bedrock of similar strength to reduce the potential for differential settlement unless allowed for in structural design.

All new footings must be inspected by an experienced geotechnical professional before concrete or steel are placed to verify their bearing capacity and the in-situ nature of the founding strata. This is mandatory to allow them to be 'certified' at the end of the project.

5.3.2. Excavation:

Proposed Excavations
Table 1: Property Separation Distances

Boundary	Adjacent Property	Structure	Bulk Excavation Depth (m bgl)	Separation Distances (m)	
				Boundary (m)	Structure
North	Lot 2, 1110 Barrenjoey Road	Single storey dwelling supported via piers with large boulder within south-western corner	≤6.0m depth for proposed ground floor level and lift shaft, with further excavation to ≤2.0m for upper levels	Excavation 0.6m - 1.3m from common boundary	Grassed slope on common boundary, with adjacent sandstone boulder 2.0m further House positioned approximately 5.0m north-east from boundary

South	No.1100 Barrenjoey Road	Two and three storey house at western end with large boulder on northern side	≤3.2m depth for proposed secondary structure	Excavation 0.9m from common boundary	House positioned approximately 12.0m from boundary, boulder appears to be a minimum of 5.0m from boundary
		Single storey cabin at eastern end	Minor excavation into boulder for swimming pool	Excavation 2.5m from common boundary	Cabin a minimum of 0.5m from boundary
West	No.1102 Barrenjoey Road	Vacant block with approximately 4.0m high retaining wall adjacent to rear boundary	≤3.2m depth for proposed secondary structure	Excavation 1.2m from boundary	Retaining wall 6.0m from boundary, downslope
East	No. 138 Pacific Road	House with rear concrete crib retaining wall approximately 3.0m – 4.0m high	≤2.0m for upper living level excavations	Excavation a minimum of 1.5m from boundary	House 16.0m from boundary with retaining wall approximately 10m from boundary
	No.140 Pacific Road	Two storey house with rear retained gardens and large sandstone boulder extending into site		Excavation a minimum of 4.2m from boundary	House 16.0m from boundary, boulder 3.0m from excavation

Main structure ground floor excavation: ≤6.0m depth

Secondary structure excavation and excavation for new proposed retaining walls: ≤3.2m depth

Additional excavation for upper living levels: ≤2.0m depth

Type of Material to be Excavated	Topsoil/colluvium to a maximum drilled depth of 0.80m (BH3).
	Soft to hard sandy clay to a maximum depth of 3.40m (DCP5)
	ELS bedrock from a possible minimum of 1.25m (BH102) to a maximum of approximately 4.35m (BH101)
	VLS to LS bedrock from between 2.15m (BH103) and approximately 4.30m (BH101 & BH102), extending to a maximum recorded depth of 5.60m (BH101).
	MS bedrock encountered from 5.60m depth (BH101).

Guidelines for un-surcharged batter slopes are tabulated below:

Material	Safe Batter Slope (H:V)*	
	Short Term/Temporary	Long Term/Permanent
Colluvium/Topsoil	1.5:1	2:1
Sandy Clay to Extremely low strength bedrock	1:1	1.5:1
Very Low to Low strength or fractured bedrock	0.5:1	0.75:1*
Medium Strength, defect free bedrock	Vertical*	0.25:1.0**

* Dependent on defects and assessment by geotechnical engineer

**Vertical batter slope possible in sandstone, dependent on geotechnical assessment

Remarks:

Seepage through the sandy/clayey soils can reduce the stability of batter slopes and invoke the need to implement additional support measures. Where safe batter slopes are not implemented the stability of the excavation cannot be guaranteed until the installation of permanent support measures. This should also be considered with respect to safe working conditions.

Geotechnical inspection of batters will be required at regular intervals to assess their stability, especially for permanent batters.

Equipment for Excavation	Topsoil/ Natural soils	Excavator with Bucket
	ELS bedrock	Excavator with bucket
	VLS bedrock	Excavator with bucket and ripper
	LS-MS bedrock	Rock hammer (≤250kg) and saw

Remarks:

Based on previous testing of ground vibrations created by various rock excavation equipment within medium strength bedrock, to maintain a vibration level below 5mm/s PPV the below hammer weights and buffer distances are required:

Buffer Distance from Structure	Maximum Hammer Weight
2.0m	200kg
4.0m	500kg
5.0m	800kg
8.0m	1000kg

Onsite calibration will provide accurate vibration levels to the site specific conditions and will generally allow for larger excavation machinery or smaller buffers to be used. Calibration of rock excavation machinery should be carried out prior to commencement of demolition or rock excavation works where >250kg rock hammers are proposed for use.

Rock sawing of the excavation perimeter is recommended as it has several advantages. It often reduces the need for rock bolting as the cut faces generally remain more stable and require a lower level of rock support than hammer cut excavations, ground vibrations from rock saws are minimal, the saw cuts will provide a slight increase in buffer distance for use of rock hammers whilst also reducing deflection of separated rock across boundaries.

Excavation of soils to ELS will not create excessive vibrations provided it is undertaken with medium scale (<20 tonne excavator) excavation equipment in a sensible manner.	
Recommended Vibration Limits (Maximum Peak Particle Velocity (PPV))	Lot 2, No.1110 Barrenjoey Road = 5mm/s No.1100 Barrenjoey Road = 5mm/s No.1102 Barrenjoey Road = 5mm/s No. 138 Pacific Road = 5mm/s No. 140 Pacific Road = 5mm/s DICL Sewer Services = 5mm/s According to the Pittwater Heritage Map (Northern Beaches Council) surrounding areas/properties including No.1108 Barrenjoey Road (Barrenjoey House) and Pittwater Park are heritage items (2270076 & 2270037) = 3mm/s
Vibration Calibration Tests Required	Yes, recommended for any rock hammer >250kg weight
Full time vibration Monitoring Required	Pending proposed equipment and vibration calibration testing results
Geotechnical Inspection Requirement	Yes, recommended that these inspections be undertaken as per below mentioned sequence: ● Install of pre-excavation support systems (including assessment of any new pile wall during drilling) ● For assessment of any unsupported slope batter in soils at 1.0m depth increments ● Where bedrock exposed and in 1.5m intervals of unsupported rock excavation along with at excavation completion ● Where unexpected ground conditions are identified or any other concerns are held. ● Following footing excavations to confirm founding material strength
Dilapidation Surveys Requirement	Recommended on neighbouring structures or parts thereof within 10m of the excavation perimeter prior to site work to allow assessment of the recommended vibration limit and protect the client against spurious claims of damage.
Remarks: Water ingress into exposed excavations can result in erosion and stability concerns in both soil and rock portions. Drainage measures will need to be in place during excavation works to divert any surface flow away from the excavation crest and any batter slope, whilst any groundwater seepage must be controlled within the excavation and prevented from ponding or saturating slopes/batters.	

5.3.3. Retaining Structures:	
Required	New retaining structures will be required as part of the proposed development to support the excavation perimeters. Permanent retaining structures at the front of the site will also be required, to replace the existing retaining wall.
Types	Steel reinforced concrete/concrete block walls post excavation where safe batters can be formed. Pre-excavation support (e.g. braced/anchored soldier pile wall or staged shotcrete wall) will be required where insufficient space exists to form temporary safe batter slopes, or a socketed cantilever soldier pile wall is not feasible. Designed in accordance with Australian Standards AS4678-2002 Earth Retaining Structures.

Parameters for calculating pressures acting on retaining walls for the materials likely to be retained:

Material Strength Properties

Material	**Strength**	**Undrained Analysis**		**Drained Analysis***	
		Cohesion (c_u) (kPa)	**Friction (φ_u) Degrees**	**Cohesion (c’) (kPa)**	**Friction (φ’) Degrees**
Fill	NA	0	0	0	25
Clay/Sandy Clay	stiff	50		5	26
	very stiff	100			
	hard	200			
Bedrock (Sandstone)	very low (Class IV)	350 – 450	29	50	28
	low (Class III)	-	33	100	35
	medium/hard (Class II-I)	-	35	200	42

Material Strength Properties-Trapezoidal Pressure Distribution

Material	**Strength**	**Unit Weight (kN/m^3)**	**Earth Pressure Coefficients**		**Passive Earth Coefficients /Lateral Pressures**
			Active (Ka)	**At rest (Ko)**	
Fill	NA	18	0.45	0.50	N/A
Clay/Sandy Clay	Stiff	20	0.55	1.00*	N/A
	Very Stiff	20			
	Hard	22			
Bedrock (Sandstone)	Very Low (Class IV)	24	0.25	0.45	200kPa
	Low (Class III)	24	0.05	0.15	400kPa
	Medium/High (Class II-I)	24	0.10	0.10	600kPa

*To account for sloping soil surface and creep pressures within colluvium/surficial soils

Material Stiffness Properties

Material	Strength	Young's Modulus E – Mpa[1]
Sandy/Silty Clay	Stiff	30
	Very Stiff	
	Hard	40
Bedrock (Sandstone)	Class V	100
	Very low (Class IV)	250
	Low (Class III)	1000
	Medium/High (Class II-I)	2000

Any (building/construction etc.) surcharge loads/pressures must be added to the above distribution.

Remarks:

In suggesting the support parameters it is assumed that the retaining walls will be fully drained with suitable subsoil drains provided at the rear of the wall footings. If this is not done, then the walls should be designed to support full hydrostatic pressure in addition to pressures due to the soil backfill. It is suggested that post excavation retaining walls should be back filled with free-draining granular material (preferably not recycled concrete) which is only lightly compacted in order to minimize horizontal stresses.

Retaining structures near site boundaries or existing structures should be designed with the use of at rest (K_0) earth pressure coefficients to reduce the risk of movement in the excavation support and resulting surface movement in adjoining areas. Backfilled retaining walls within the site, away from site boundaries or existing structures, that may deflect can utilize active earth pressure coefficients (Ka).

5.3.4. Drainage and Hydrogeology

Groundwater Table or Seepage identified in Investigation		Yes, moisture identified on retrieved DCP rods indicating minor seepage within residual soils
Excavation likely to intersect	Water Table	No
	Seepage	Minor (<0.50L/min), within sandy/clayey soils at bedrock surface or along defects in the bedrock
Site Location and Topography		High east side of Barrenjoey Road, within steep west dipping topography
Impact of development on local hydrogeology		Negligible
Onsite Stormwater Disposal		Not recommended

Remarks:

As the excavation faces are expected to encounter some seepage, an excavation trench should be installed at the base of excavation cuts to below floor slab levels to reduce the risk of resulting dampness issues. Trenches, as well as all new building gutters, down pipes and stormwater intercept trenches should be connected to a stormwater system designed by a Hydraulic Engineer which discharges to the Council's stormwater system off site, or downslope.

5.4 Vibration Monitoring Plan:

Driven support or footings are not recommended at the site due to the potential for excessive vibration generation.

Rock excavation is anticipated within the ground floor excavation and potentially within the secondary structure excavation, along with excavation of boulders embedded within the soil slope across the site. A vibration limit of 5mm/s PPV has been recommended for protection of nearby building structures.

Vibration Calibration testing will be required where large (>250kg) rock hammers are proposed for use for low to high strength bedrock excavation. Pending proposed equipment and vibration calibration testing results, full-time vibration monitoring may be required.

5.5 Construction Monitoring Statement:

This construction monitoring statement provides a preliminary guideline for excavation and construction works of the proposed residential dwelling house. This statement is focused on the geotechnical aspects of the proposed works and the associated hold/stop points.

- Site Establishment
  - Secure site
  - Mark out excavation outlines
- Boulder register
  - List all boulders on site and which are to be intersected, at risk of instability according to this report or are positioned within a 45° influence zone of the proposed excavation bases

Hold Point – Geotechnical Engineer to confirm via inspection which boulders are to be removed or stabilised (stabilisation designs to be provided) according to onsite mark outs of proposed excavations and boulder register collated by builder

- Stabilisation or removal of at-risk boulders specified by the Geotechnical Engineer by an experienced contractor

Hold Point – Geotechnical Engineer to inspect boulder stabilisation works during anchor drilling/underpinning works and upon completion

- Earthworks
  - Clearing of vegetation, trees and loose cobbles/small boulders
  - Mobilisation of machinery on site, necessary minor earthworks to be completed
  - Excavation commencement
    - Batter slope feasibility assessment in accordance with Section 5.3.2
    - Clearing of topsoil/colluvium
    - Installation of pre-excavation support systems

Hold Point – Geotechnical Engineer to supervise installation of support systems

        - Excavation of residual soils and extremely low strength to very low strength sandstone

Hold Point – Dependent on excavation support design (anchored bored pile wall or staged shotcrete wall) Geotechnical Engineer to conduct necessary inspections at 1.5m excavation depths, if defects within the bedrock are identified by builder, where unexpected conditions are encountered and at excavation completion

        - Clearing of bedrock surface

Hold Point – Rock breaking equipment to be calibrated for rock hammers >250kg weight, vibration monitoring to be installed on site pending rock hammer size

        - Excavation of bedrock to excavation bases

- Construction
    - Permanent retaining walls

Hold Point – All new retaining walls to be inspected once footings have been excavated and prior to placement of steel and concrete

    - Excavation for footings of main structure and secondary structure

Hold Point –All new footings must be inspected by the Geotechnical Engineer before concrete or steel are placed to verify their bearing capacity and the in-situ nature of the founding strata

    - Placement of reinforcement
    - Pouring of concrete
    - Superstructure
        - Excavation into large angular boulder for swimming pool

5.6. Design Life of Structure:

We have interpreted the design life requirements specified within Councils Risk Management Policy to refer to structural elements designed to support the house etc, the adjacent slope, control stormwater and maintain the risk of instability within “Acceptable” limits. Specific structures and features that may affect the maintenance and stability of the site in relation to the proposed and existing development are considered to comprise:

- stormwater and subsoil drainage systems,
- retaining walls and soil slope erosion and instability,
- maintenance of trees/vegetation on this and adjacent properties.

Man-made features should be designed and maintained for a design life consistent with surrounding structures (as per AS2870 – 2011 (100 years)). It will be necessary for the structural and geotechnical engineers to incorporate appropriate design and inspection procedures during the construction period. Additionally the property owner should adopt and implement a maintenance and inspection program.

If this maintenance and inspection schedule are not maintained the “Acceptable” risk management criteria for the design life of the property cannot be attained. A recommended program is given in Table: C in Appendix: 3 and should also include the following guidelines.

- The conditions on the block don’t change from those present at the time this report was prepared, except for the changes due to this development.
- There is no change to the property due to an extraordinary event external to this site
- The property is maintained in good order and in accordance with the guidelines set out in;
  a) CSIRO sheet BTF 18
  b) Australian Geomechanics “Landslide Risk Management” Volume 42, March 2007.
  c) AS 2870 – 2011, Australian Standard for Residential Slabs and Footings

Where changes to site conditions are identified during the maintenance and inspection program, reference should be made to relevant professionals (e.g. structural engineer, geotechnical engineer or Council). Where the property owner has any lack of understanding or concerns about the implementation of any component of the maintenance and inspection program the relevant engineer should be contacted for advice or to complete the component.

It is assumed that Council will control development on neighbouring properties, carry out regular inspections and maintenance of the road verge, stormwater systems and large trees on public land adjacent to the site so as to ensure that stability conditions do not deteriorate with potential increase in risk level to the site. Also individual Government Departments will maintain public utilities in the form of power lines, water and sewer mains to ensure they don’t leak and increase either the local groundwater level or landslide potential. Recommendations for construction within hill slopes are also provided in Appendix: 5.

5.7. Conditions Relating to Design and Construction Monitoring:

To allow certification at the completion of the project it will be necessary for Crozier Geotechnical Consultants to:

1. Review and approve structural design drawings, including all retaining wall designs for compliance with current and future recommendations prior to construction,
2. Inspect excavation and construction perimeters at initial mark out,
3. Conduct inspections of works as per Section 5.5 of this report, including during installation of all retention systems,
4. Inspect all new footings to confirm compliance to design assumptions with respect to allowable bearing pressure, basal cleanness and stability prior to the placement of steel or concrete.

Crozier Geotechnical Consultants can <u>not</u> provide certification for the Occupation Certificate if it has not been called to site to undertake the required inspections.

6. CONCLUSION

The investigation identified that the site is situated within steep west dipping topography with several boulders embedded into the colluvial soil slope. It is considered that the detached boulders are generally stable within the soil slopes, however some have potential for instability. Therefore, stabilising measures (i.e. rock bolts/shotcrete) or the removal of unstable boulders is recommended to ensure stability during and after excavation/construction.

It is understood that the proposed works involve the construction of a multi-level residential development with a swimming pool and detached secondary dwelling. The new house will be constructed partially into the existing slope which will require excavations up to 6.0m depth for the garage and elevator shaft. Bulk excavation will be required to an anticipated maximum depth of 3.2m for the construction of the secondary dwelling, with further bulk excavation required up to 2.0m depth for the upper living levels of the main structure.

The subsurface geology of the site consists of colluvial soils, underlain by sandy clay residual soils. Sandstone bedrock of extremely low strength grading to low/medium strength was identified at all cored borehole locations, with low strength sandstone encountered between 2.15m (BH103) and 4.35m depth (BH101). Sandstone boulders were encountered in the cored boreholes at varying depths and are interpreted to be embedded within the soil slope across the site.

Careful consideration and extreme caution will be required during the excavation phase of the proposed works as the steep sloping terrain of the site in combination with boulders embedded into and within the soils and deeply weathered underlying bedrock will likely make for a difficult excavation/construction process. Therefore, ongoing geotechnical inspections as per Section 5.6 of this report must be implemented.

Based on the separation distance between the proposed excavations and boundaries, support measures will be required, in particularly for significant excavation locations, such as the garage and elevator shaft excavation and for the secondary structure.

All footings are recommended to extend through colluvium and residual soils to socket into bedrock of low to medium strength to avoid settlement and/or creep movement. All footings should be inspected by an experienced geotechnical professional before concrete or steel are placed to verify their bearing capacity and the in-situ nature of the founding strata.

Provided the recommendations of this report are implemented in the design and construction phases of the development, it is considered that the works can be carried out with negligible impact to the site and neighbouring properties and as such are considered suitable for the site.

It is considered that the site will meet the ‘Acceptable’ risk management criteria for the design life of the development taken as 100 years from the proposed works provided the property is maintained as per the recommendations of this report.

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5. V. Gardiner & R. Dackombe 1983, “Geomorphological Field Manual” by George Allen & Unwin.

Appendix 1

CROZIER
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NOTES RELATING TO THIS REPORT

Introduction

These notes have been provided to amplify the geotechnical report in regard to classification methods, specialist field procedures and certain matters relating to the Discussion and Comments section. Not all, of course, are necessarily relevant to all reports.

Geotechnical reports are based on information gained from limited subsurface test boring and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Description and classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, Geotechnical Site Investigation Code. In general, descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions.

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (eg. Sandy clay) on the following bases:

Soil Classification	Particle Size
Clay	less than 0.002 mm
Silt	0.002 to 0.06 mm
Sand	0.06 to 2.00 mm
Gravel	2.00 to 60.00mm

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

Classification	Undrained Shear Strength kPa
Very soft	Less than 12
Soft	12 - 25
Firm	25 – 50
Stiff	50 – 100
Very stiff	100 - 200
Hard	Greater than 200

Non-cohesive soils are classified on the basis of relative density, generally from the results of standard penetration tests (SPT) or Dutch cone penetrometer tests (CPT) as below:

Relative Density	SPT "N" Value (blows/300mm)	CPT Cone Value (Qc – MPa)
Very loose	less than 5	less than 2
Loose	5 – 10	2 – 5
Medium dense	10 – 30	5 -15
Dense	30 – 50	15 – 25
Very dense	greater than 50	greater than 25

Rock types are classified by their geological names. Where relevant, further information regarding rock classification is given on the following sheet.

Sampling

Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling to allow information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Drilling Methods

The following is a brief summary of drilling methods currently adopted by the company and some comments on their use and application.

Test Pits – these are excavated with a backhoe or a tracked excavator, allowing close examination of the insitu soils if it is safe to descent into the pit. The depth of penetration is limited to about 3m for a backhoe and up to 6m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (eg. Pengo) – the hole is advanced by a rotating plate or short spiral auger, generally 300mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling – the hole is advanced by pushing a 100mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling soils, since moisture content is unchanged and soil structure, strength, etc. is only marginally affected.

Continuous Spiral Flight Augers – the hole is advanced using 90 – 115mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or insitu testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPT's or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling - the hole is advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

Rotary Mud Drilling – similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. From SPT).

Continuous Core Drilling – a continuous core sample is obtained using a diamond-tipped core barrel, usually 50mm internal diameter. Provided full core recovery is achieved (which is not always possible in very weak rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

Standard Penetration Tests

Standard penetration tests (abbreviated as SPT) are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample. The test procedures is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" – Test 6.3.1.

The test is carried out in a borehole by driving a 50mm diameter split sample tube under the impact of a 63kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150mm of say 4, 6 and 7
  as 4, 6, 7 then N = 13
- In the case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm then as 15, 30/40mm.

The results of the test can be related empirically to the engineering properties of the soil. Occasionally, the test method is used to obtain samples in 50mm diameter thin wall sample tubes in clay. In such circumstances, the test results are shown on the borelogs in brackets.

Cone Penetrometer Testing and Interpretation

Cone penetrometer testing (sometimes referred to as Dutch Cone – abbreviated as CPT) described in this report has been carried out using an electrical friction cone penetrometer. The test is described in Australia Standard 1289, Test 6.4.1.

In tests, a 35mm diameter rod with a cone-tipped end is pushed continually into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on a separte 130mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected buy electrical wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20mm per second) their information is plotted on a computer screen and at the end of the test is stored on the computer for later plotting of the results.

The information provided on the plotted results comprises: -

- Cone resistance – the actual end bearing force divided by the cross-sectional area of the cone – expressed in MPa.
- Sleeve friction – the frictional force on the sleeve divided by the surface area – expressed in kPa.
- Friction ratio - the ratio of sleeve friction to cone resistance, expressed in percent.

There are two scales available for measurement of cone resistance. The lower scale (0 – 5 MPa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main scale (0 – 50 MPa) is less sensitive and is shown as a full line. The ratios of the sleeve friction to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios 1% - 2% are commonly encountered in sands and very soft clays rising to 4% - 10% in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range: -
Qc (MPa) = (0.4 to 0.6) N blows (blows per 300mm)
In clays, the relationship between undrained shear strength and cone resistance is commonly in the range: -
Qc = (12 to 18) Cu

Interpretation of CPT values can also be made to allow estimation of modulus or compressibility values to allow calculations of foundation settlements.

Inferred stratification as shown on the attached reports is assessed from the cone and friction traces and from experience and information from nearby boreholes, etc. This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties, and where precise information on soil classification is required, direct drilling and sampling may be preferable.

Dynamic Penetrometers

Dynamic penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 150mm increments of penetration. Normally, there is a depth limitation of 1.2m but this may be extended in certain conditions by the use of extension rods.

Two relatively similar tests are used.

- Perth sand penetrometer – a 16mm diameter flattened rod is driven with a 9kg hammer, dropping 600mm (AS1289, Test 6.3.3). The test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.
- Cone penetrometer (sometimes known as Scala Penetrometer) – a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS 1289, Test 6.3.2). The test was developed initially for pavement sub-grade investigations, and published correlations of the test results with California bearing ratio have been published by various Road Authorities.

Laboratory Testing

Laboratory testing is generally carried out in accordance with Australian Standard 1289 "Methods of Testing Soil for Engineering Purposes". Details of the test procedure used are given on the individual report forms.

Borehole Logs

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

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes, the frequency of sampling and the possibility of other than 'straight line' variations between the boreholes.

Details of the type and method of sampling are given in the report and the following sample codes are on the borehole logs where applicable:

D	Disturbed Sample	E	Environmental sample	DT	Diatube
B	Bulk Sample	PP	Pocket Penetrometer Test		
U50	50mm Undisturbed Tube Sample	SPT	Standard Penetration Test		
U63	63mm " " " " "	C	Core		

Ground Water

Where ground water levels are measured in boreholes there are several potential problems:

- In low permeability soils, ground water although present, may enter the hole slowly or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report.
- The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made. More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be interference from a perched water table.

Engineering Reports

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. A three-storey building), the information and interpretation may not be relevant if the design proposal is changed (eg. to a twenty-storey building). If this happens, the Company will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface condition, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- unexpected variations in ground conditions – the potential for this will depend partly on bore spacing and sampling frequency,
- changes in policy or interpretation of policy by statutory authorities,
- the actions of contractors responding to commercial pressures,

If these occur, the Company will be pleased to assist with investigation or advice to resolve the matter.

Site Anomalies

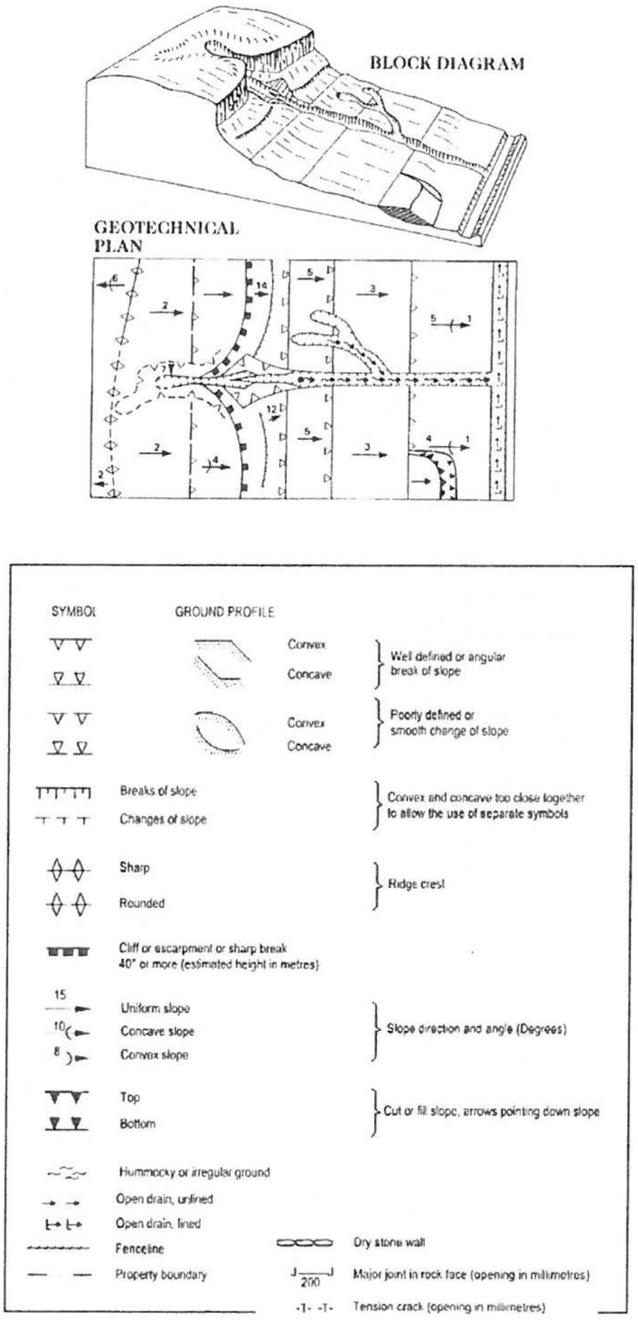
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some later stage, well after the event.

Reproduction of Information for Contractual Purposes

Attention is drawn to the document "Guidelines for the Provision of Geotechnical Information in Tender Documents", published by the Institution of Engineers Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a special ally edited document. The Company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

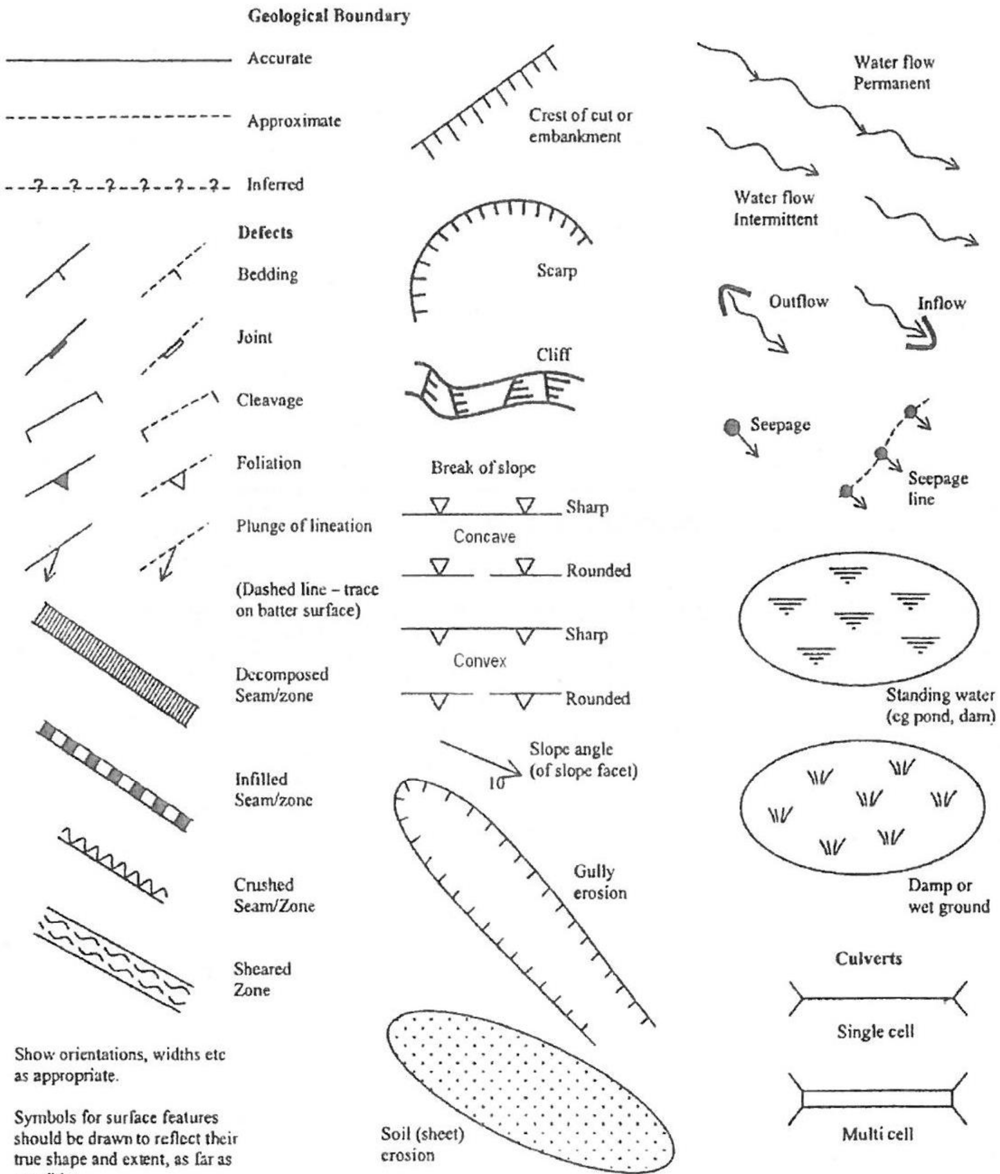
Site Inspection

The Company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.



Example of Mapping Symbols
(after V Gardiner & R V Dackombe (1983).Geomorphological Field Manual. George Allen & Unwin).

APPENDIX E - GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING SYMBOLS AND TERMINOLOGY

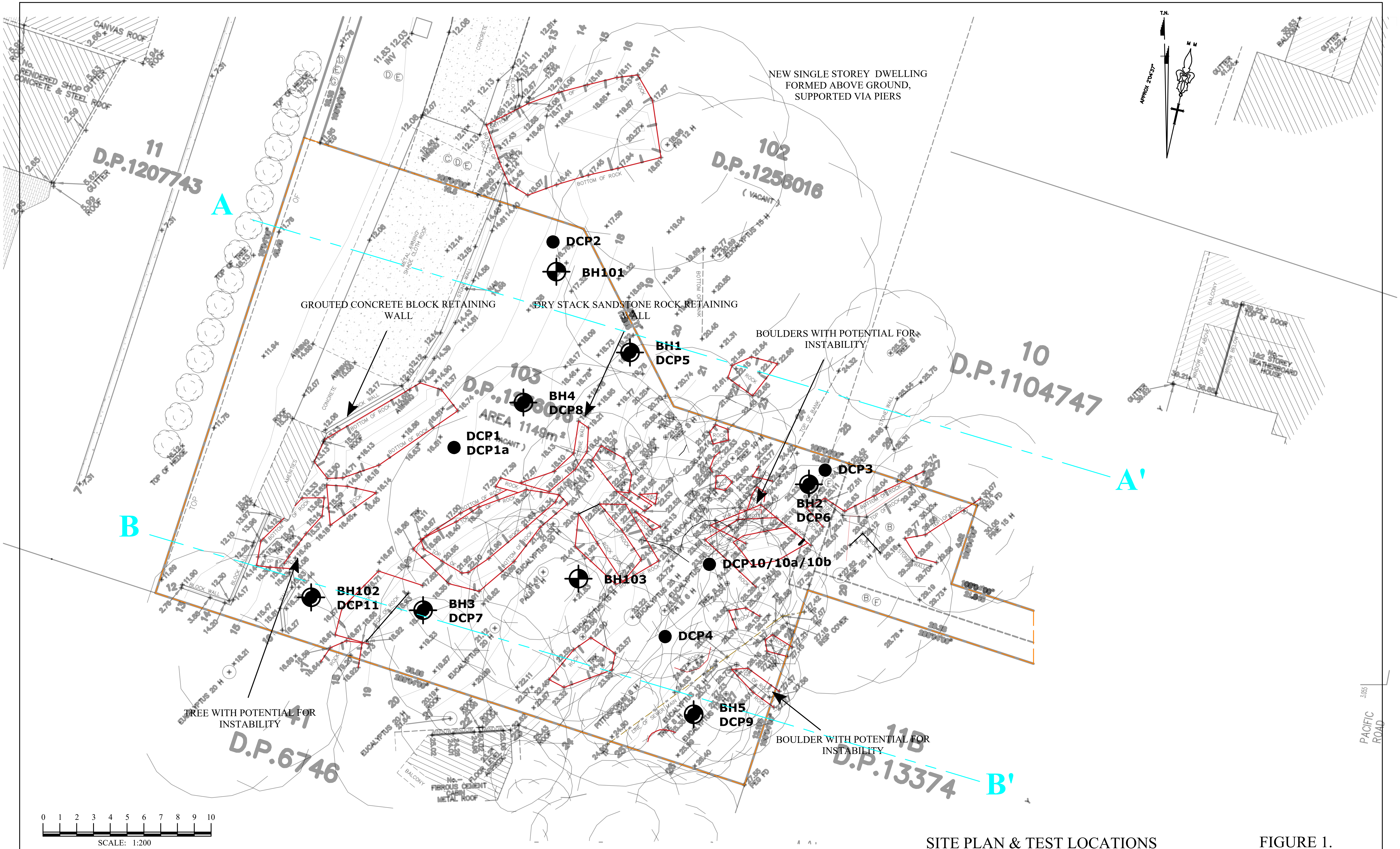


Show orientations, widths etc as appropriate.

Symbols for surface features should be drawn to reflect their true shape and extent, as far as possible.

Examples of Mapping Symbols (after Guide to Slope Risk Analysis Version 3.1 November 2001, Roads and Traffic Authority of New South Wales).

Appendix 2



SITE PLAN & TEST LOCATIONS

FIGURE 1.

CROZIER
GEOTECHNICAL CONSULTANTS

Crozier Geotechnical
Unit 12, 42-46 Wattle Road
Brookvale NSW 2100

ABN: 96 113 453 624
Phone: (02) 9939 1882
Fax: (02) 9939 1883

Crozier Geotechnical is a division of PJC Geo-Engineering Pty Ltd

LEGEND

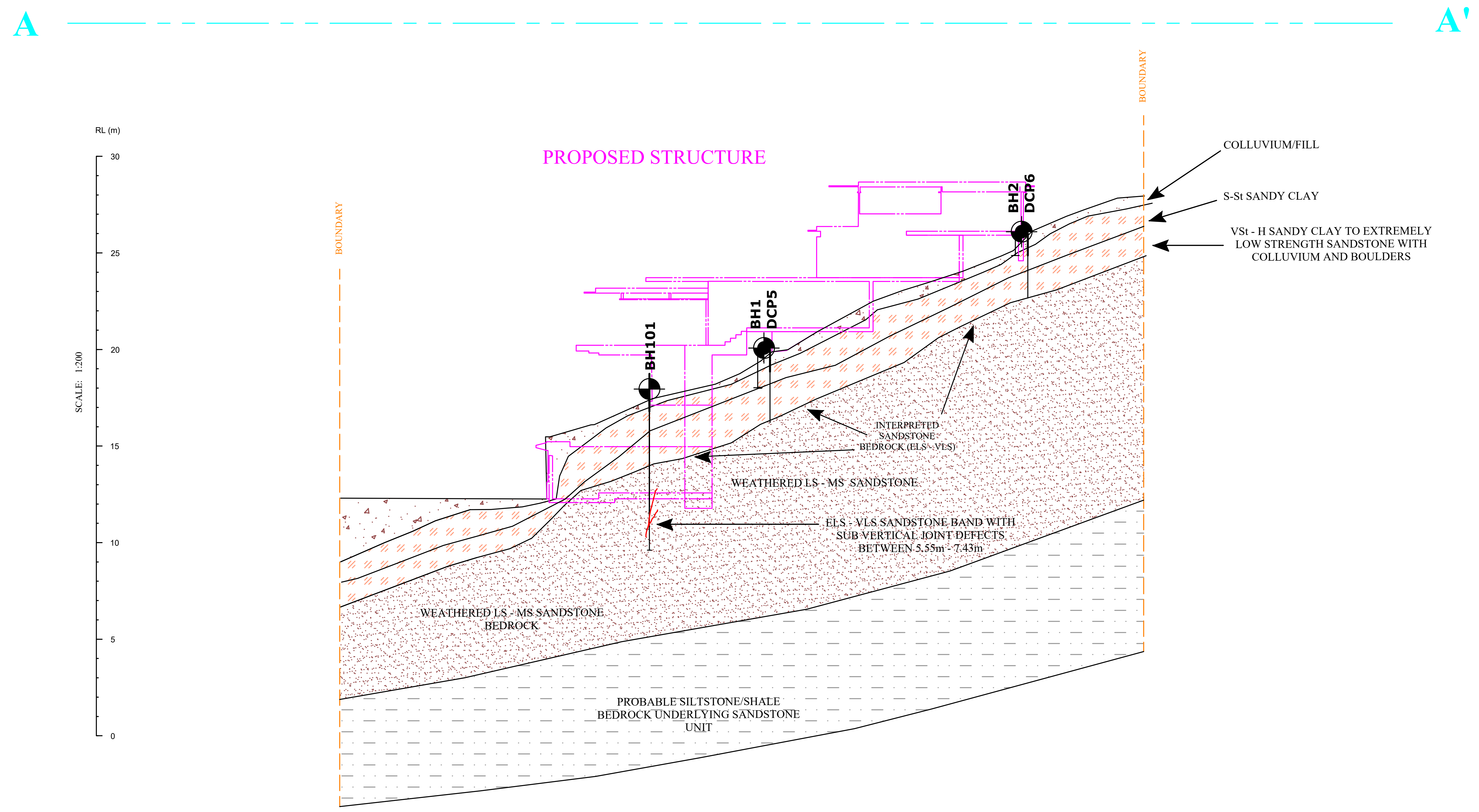
● DCP	DYNAMIC CONE PENETROMETER
⊕ BH	AUGER LOCATIONS
⊕ BH DCP	AUGER / DYNAMIC CONE PENETROMETER LOCATION
A —— A'	CROSS-SECTION REFERENCE LINE
🟥	BOULDERS
🟧	PROPERTY BOUNDARY

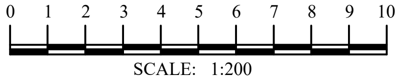
SCALE: 1:200 @ A3
DRAWING: FIGURE 1
DATE: 3/12/2021

APPROVED BY: TMC
DRAWN BY: JC
PROJECT: 2020-232

PREPARED FOR:
ADAM RYTENSKILD

ADDRESS:
LOT 3, 1110 BARRENJOEY ROAD, PALM BEACH





SCALE: 1:200

VL - Very Loose	VS - Very Soft	ELS - Extremely Low Strength	EW - Extremely Weathered	fg - Fine Grained
L - Loose	S - Soft	VLS - Very Low Strength	HW - Highly Weathered	mg - Medium Grained
MD - Medium Dense	F - Firm	LS - Low Strength	DW - Distinctly Weathered	cg - Coarse Grained
D - Dense	St - Stiff	MS - Medium Strength	MW - Moderately Weathered	MAS - Massive
VD - Very Dense	VSt - Very Stiff	HS - High Strength	SW - Slightly Weathered	BD - Bedded
	H - Hard	VHS - Very High Strength	FR - Fresh	OC - Outcrop

NB. FOR LOCATION OF SECTION A-A', PLEASE REFER TO FIGURE 1. SITE PLAN AND TEST LOCATIONS

GEOLOGICAL MODEL FIGURE 2.

CROZIER
GEOTECHNICAL CONSULTANTS

Crozier Geotechnical
Unit 12, 42-46 Wattle Road
Brookvale NSW 2100

ABN: 96 113 453 624
Phone: (02) 9939 1882
Fax: (02) 9939 1883

Crozier Geotechnical is a division of PJC Geo-Engineering Pty Ltd

LEGEND

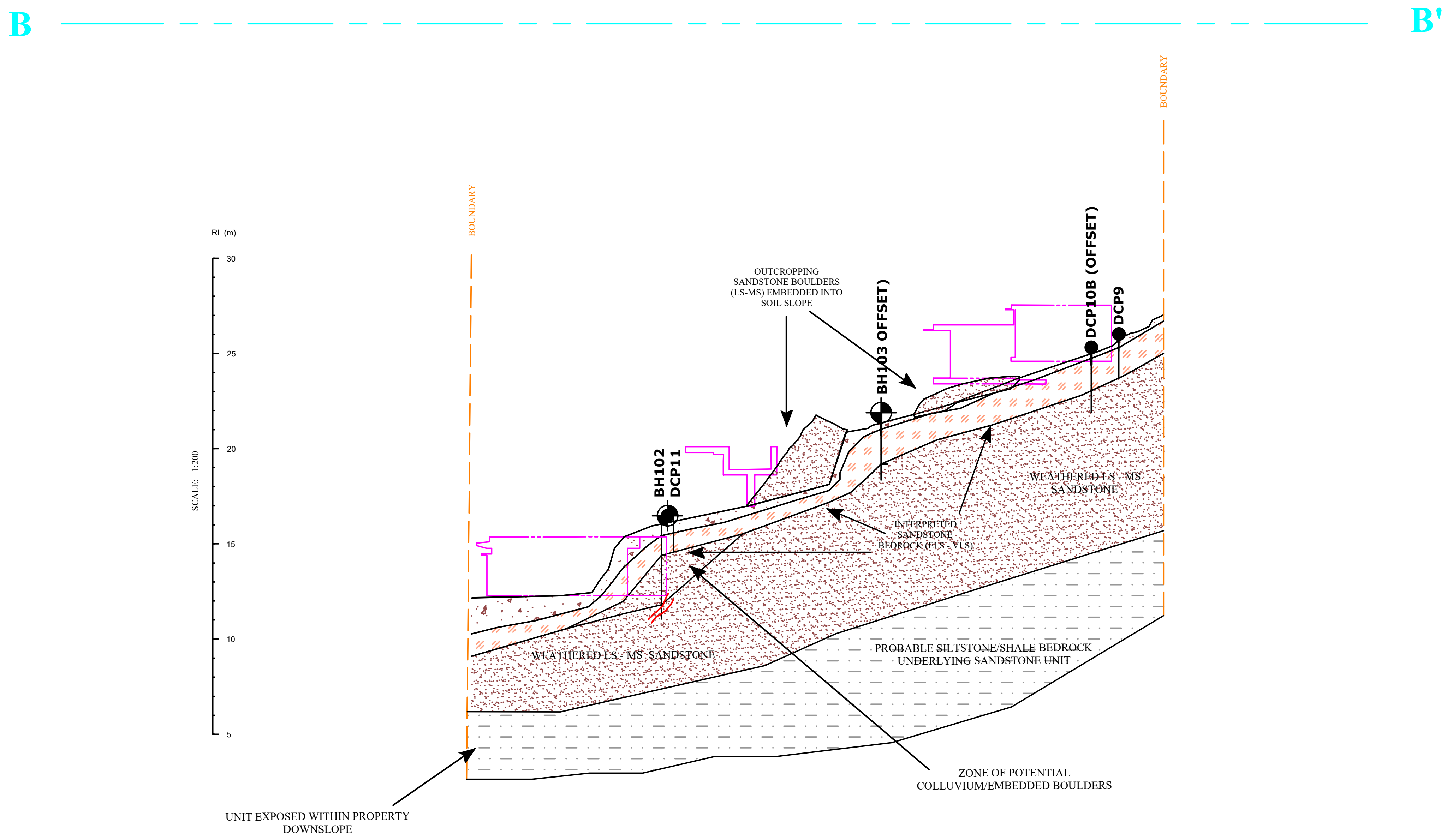
● DCP DYNAMIC CONE PENETROMETER
A — A' CROSS-SECTION REFERENCE LINE
PROPOSED STRUCTURES
PROPERTY BOUNDARY
JOINT DEFECT
☐ COLLUVIUM/FILL
▨ SANDY CLAY TO EXTREMELY LOW STRENGTH SANDSTONE
▨ VLS - LS/MS SANDSTONE BEDROCK
☐ SILTSTONE/SHALE BEDROCK

SCALE: 1:200 @ A3
DRAWING: FIGURE 2
DATE: 9/12/2021

APPROVED BY: TMC
DRAWN BY: JC
PROJECT: 2020-232

PREPARED FOR:
ADAM RYTENSKILD

ADDRESS:
LOT 3, 1110 BARRENJOEY
ROAD, PALM BEACH



0 1 2 3 4 5 6 7 8 9 10

SCALE: 1:200

VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard

ELS - Extremely Low Strength
VLS - Very Low Strength
LS - Low Strength
MS - Medium Strength
HS - High Strength
VHS - Very High Strength

EW - Extremely Weathered
HW - Highly Weathered
DW - Distinctly Weathered
MW - Moderately Weathered
SW - Slightly Weathered
FR - Fresh

fg - Fine Grained
mg - Medium Grained
cg - Coarse Grained
MAS - Massive
BD - Bedded
OC - Outcrop

NB. FOR LOCATION OF SECTION B-B', PLEASE REFER TO FIGURE 1. SITE PLAN AND TEST LOCATIONS

GEOLOGICAL MODEL FIGURE 3.

CROZIER
GEOTECHNICAL CONSULTANTS

Crozier Geotechnical
Unit 12, 42-46 Wattle Road
Brookvale NSW 2100
ABN: 96 113 453 624
Phone: (02) 9939 1882
Fax: (02) 9939 1883
Crozier Geotechnical is a division of PJC Geo-Engineering Pty Ltd

LEGEND

● DCP DYNAMIC CONE PENETROMETER

A — A' CROSS-SECTION REFERENCE LINE

PROPOSED STRUCTURES

PROPERTY BOUNDARY

JOINT DEFECT

COLLUVIUM/FILL

SANDY CLAY TO EXTREMELY LOW STRENGTH SANDSTONE

VLS - LS/MS SANDSTONE BEDROCK

SILTSTONE/SHALE BEDROCK

SCALE:	1:200 @ A3
DRAWING:	FIGURE 3
DATE:	9/12/2021
APPROVED BY:	TMC
DRAWN BY:	JC
PROJECT:	2020-232

PREPARED FOR:
ADAM RYTENSKILD

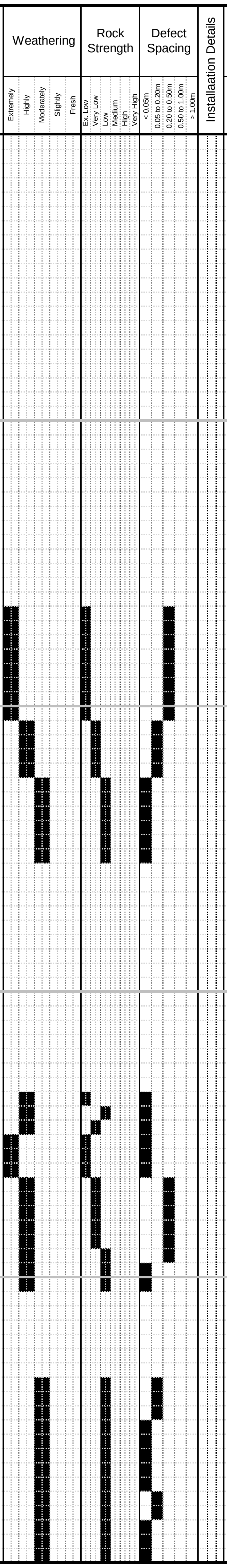
ADDRESS:
LOT 3, 1110 BARRENJOEY
ROAD, PALM BEACH

CROZIER
GEOTECHNICAL CONSULTANTS

Client: Adam Rytenskild
Date: 29/11/2021
Borehole: 101

Project: Construction of multi-level residence with swimming pool
Project No.: 2020-232
Sheet No.: 1 of 2

Location: Lot 3, 1110 Barrenjoey Road, Palm Beach
Surface Level: RL 16.50m



Depth (m)	Description of Strata Soil/rock name, grainsize, texture/fabric, colour	Discontinuities	Type	Depth (m)	Core Rec. %	RQD %	Test Results
	TOPSOIL/COLLUVIUM: Dark brown, fine to medium grained, moist, silty sand with gravel						
0.30	Sandy CLAY: Brown and pale brown, medium plasticity, moist, sandy clay						
0.80	…medium to high plasticty						
	CORE LOSS BETWEEN 1.0m - 1.64m depth	*Start coring at 1.0m depth					
1.64	SANDSTONE (EW/ELS): Light brown, medium to coarse grained, possible colluvium				54	42	
2.10	…highly weathered, very low strength						
2.30	…red, coarse grained, moderately weathered, low strength, possible sandstone/ironstone boulder	*2.39m, JT, 20mm, 45˚, RO, PL, Fe					
2.56	CORE LOSS BETWEEN 2.56m - 3.37m depth				44	26	
3.37	SANDSTONE (EW/ELS): Pale red, medium grained						
3.45	…highly weathered, low strength						
3.50	… very low strength						
3.55	…extremely weathered, extremely low strength						
3.70	…pale grey, highly weathered, very low strength						
3.95	…becoming red, low strength						
4.05	CORE LOSS BETWEEN 4.05m - 4.30m depth						
4.35	SANDSTONE (MW/LS): Pale red, fine grained	*4.37m, JT, 20mm, 45˚, SO, PL, Fe					
4.40	…becoming pale red brown	*4.60m, B, 2mm, 5˚, SO, PL, Fe			82	7	4.65m - 4.76m: Is(50) = 0.13MPa (Diametral), Is(50) = 0.19MPa (Axial)
4.90	…pale brown						

Rig: Man Portable Coring Drill Rig
Driller: BG Drilling

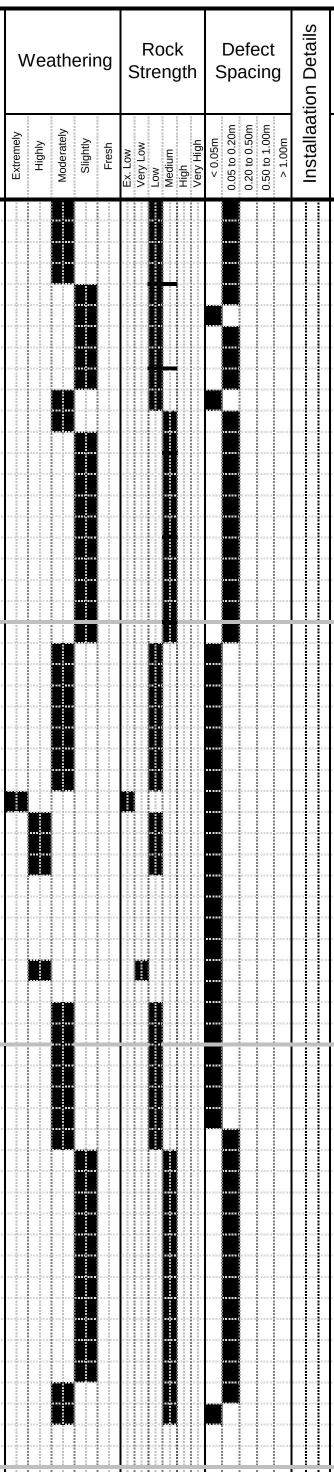
Type of Boring: Auger to 1.00m, NMLC coring to 7.90m depth
Logged By: JC

Water Observations: Water loss throughout coring
Casing: 1.00m

Comments:

CROZIER
GEOTECHNICAL CONSULTANTS

Client: Adam Rytenskild
Date: 29/11/2021
Borehole: 101
Project: Construction of multi-level residence with swimming pool
Project No.: 2020-232
Sheet No.: 2 of 2
Location: Lot 3, 1110 Barrenjoey Road, Palm Beach
Surface Level: RL 16.50m



Depth (m)	**Description of Strata** Soil/rock name, grainsize, texture/fabric, colour	Discontinuities	Type	Depth (m)	Core Rec. %	RQD %	Test Results
5.25	…pale grey, slightly weathered						
							5.42m - 5.52m Is(50) = 0.20MPa (Diametral), Is(50) = 0.28MPa (Axial)
5.50	…yellow brown, moderately weathered						
		*5.55m, JT, 25mm, 60˚, RO, ST, Fe					
5.60	…pale grey, slightly weathered, medium strength						
							5.82m - 5.95m Is(50) = 0.39MPa (Diametral), Is(50) = 0.40MPa (Axial)
6.10	…yellow brown and dark red, moderately weathered, low strength						
		*6.15m, JT, 450mm, 90˚, RO, PL, Fe					
6.45	…extremely weathered, extremely low strength						
6.50	…highly weathered, low strength						
6.60							
	CORE LOSS BETWEEN 6.60m - 6.80m depth						
6.80							
	SANDSTONE: Pale grey and brown, medium grained, highly weathered, very low strength						
	CORE LOSS BETWEEN 6.87m - 6.92m depth						
	SANDSTONE: Brown, fien to medium grained, moderately weathered, low strength						
		*7.10m, JT, 230mm, 80˚, RO, PL, Fe					
7.15	…grey brown						
7.30	…grey, slightly weathered, medium strength						7.30m - 7.40m Is(50) = 0.51MPa (Diametral), Is(50) = 0.39MPa (Axial)
		*7.43m, JT, 40mm, 50˚, SO, PL, Clean					
7.85	…coarse grained with interbedded quartz gravel, moderately weathered						
7.90							
	END OF BOREHOLE at 7.90m depth						

Rig: Man Portable Coring Drill Rig
Driller: BG Drilling
Type of Boring: Auger to 1.00m, NMLC coring to 7.90m depth
Logged By: JC
Water Observations: Water loss throughout coring
Casing: 1.00m
Comments:

CROZIER
GEOTECHNICAL CONSULTANTS

Client: Adam Rytenskild
Date: 29/11/2021
Borehole: 102

Project: Construction of multi-level residence with swimming pool
Project No.: 2020-232
Sheet No.: 1 of 1

Location: Lot 3, 1110 Barrenjoey Road, Palm Beach
Surface Level: RL 16.40m

Depth (m)	**Description of Strata** Soil/rock name, grainsize, texture/fabric, colour	Discontinuities	Weathering					Rock Strength						Defect Spacing					Installaation Details	Sampling and In Situ Testing				
			Extremely	Highly	Moderately	Slightly	Fresh	Ex. Low	Very Low	Low	Medium	High	Very High	< 0.05m	0.05 to 0.20m	0.20 to 0.50m	0.50 to 1.00m	> 1.00m		Type	Depth (m)	Core Rec. %	RQD %	Test Results
	TOPSOIL/COLLUVIUM: Dark brown, medium grained, moist, silty sand with cobbles																							
0.30	…clayey sand																							
0.45		start coring @ 0.45m																						
	CORE LOSS BETWEEN 0.45m - 1.20m depth																				30	19		
1.20	Clayey SAND: Brown, medium grained, clayey sand, possible extremely weathered sandstone																							
1.25	SANDSTONE: Light brown, fine grained, extremely weathered, extremely low strength, possible residual soil		■					■							■									
1.45	…highly weathered, very low strength			■					■						■									
1.55	…red and brown, extremely low strength			■				■						■	■									
	CORE LOSS BETWEEN 1.60m - 2.15m depth																				27	0		
2.15	SANDSTONE: Brown, medium grained, highly weathered, low strength, possible sandstone boulder			■					■					■										
2.25	…very low strength			■					■					■										
2.30	CORE LOSS BETWEEN 2.30m - 3.17m depth																							
3.17	SANDSTONE: Pale grey and red, medium grained, moderately weathered, medium strength, sandstone boulder				■						■				■	■					50	14		3.30m - 3.41m Is(50) = 0.39MPa (Diametral), Is(50) = 0.40MPa (Axial)
3.50	…becoming pale red				■						■					■								
3.60	…grey brown, extremely weathered, extremely low strength		■					■						■										
3.95	CORE LOSS BETWEEN 3.95m - 4.25m depth																							
4.25	SANDSTONE: Yellow brown, fine to medium grained, highly weathered, low strength	*4.34m, JT, 75˚, 40mm, RO, UN, Fe *4.60m, JT, 60˚, 70mm, RO, PL, Clay *4.77m, JT, 85˚, 30mm, ST, RO, Clay		■						■				■	■						80	0		4.50m - 4.58m Is(50) = 0.27MPa (Diametral), Is(50) = 0.31MPa (Axial)
5.00	END OF BOREHOLE at 5.0m depth																							

Rig: Man Portable Coring Drill Rig
Driller: BG Drilling

Type of Boring: Auger to 0.45m, NMLC coring to 5.00m depth
Logged By: JC

Water Observations: Water loss throughout coring
Casing: 0.45m

Comments:

CROZIER
GEOTECHNICAL CONSULTANTS

Client: Adam Rytenskild

Date: 30/11/2021

Borehole: 103

Project: Construction of multi-level residence with swimming pool

Project No.: 2020-232

Sheet No.: 1 of 1

Location: Lot 3, 1110 Barrenjoey Road, Palm Beach

Surface Level: RL 21.80m

Depth (m)	**Description of Strata** Soil/rock name, grainsize, texture/fabric, colour	Discontinuities	Weathering					Rock Strength						Defect Spacing					Installation Details	Sampling and In Situ Testing				
			Extremely	Highly	Moderately	Slightly	Fresh	Ex. Low	Very Low	Low	Medium	High	Very High	< 0.05m	0.05 to 0.20m	0.20 to 0.50m	0.50 to 1.00m	> 1.00m		Type	Depth (m)	Core Rec. %	RQD %	Test Results
	TOPSOIL/COLLUVIUM: Dark brown, medium grained, moist, silty sand with sandstone cobbles																							
0.20	SANDSTONE: Dark grey, medium grained, moderately weathered, low strength, sandstone boulder	start coring @ 0.20m			■					■				■										
0.35	CORE LOSS BETWEEN 0.35m - 1.35m depth																					21	0	
1.35	...roots																							
1.45	SANDSTONE: Yellow brown, fine grained, extremely weathered, extremely low strength, possible colluvium		■					■						■										
1.55	...highly weathered, low strength, possible sandstone boulder			■						■				■										
1.60	CORE LOSS BETWEEN 1.60m - 2.15m depth																							
2.15	SANDSTONE: Red brown, fine to medium grained, highly weathered, low strength			■						■				■										
2.30	...pale grey with yellow brown laminations			■						■				■								61	0	
2.40	...yellow brown			■						■				■										
3.00	END OF BOREHOLE @ 3.0m depth																							

Rig: Man Portable Coring Drill Rig

Driller: BG Drilling

Type of Boring: Auger to 0.20m, NMLC coring to 3.00m depth

Logged By: JC

Water Observations: Water loss throughout coring

Casing: 0.45m

Comments:

BOREHOLE LOG

CLIENT: Adam Rytenskild

DATE: 29/11/2021

BORE No.: 1

PROJECT: Construction of new residence

PROJECT No.: 2020-232

SHEET: 1 of 1

LOCATION: Lot 3 1110 Barrenjoey Road, Palm Beach

SURFACE LEVEL: RL= 19.0m

Depth (m)	**Classification**	**Description of Strata** **PRIMARY SOIL** - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	**Sampling**		**In Situ Testing**	
0.00			**Type**	**Tests**	**Type**	**Results**
		TOPSOIL/COLLUVIUM: Dark brown, fine to medium grained, moist, clayey sand with gravel				
0.20		…increasing coarse gravel with red, coarse grained sand zones				
0.45	CH	Sandy CLAY: Soft, grey brown, medium plasticity, moist, sandy clay				
0.50		…pale brown, medium to high plasticity	D	0.50 0.55		
0.65		…firm, pale brown mottled yellow and orange				
1.00		…pale grey mottled light brown				
1.25		…red brown with gravel				
1.30		AUGER REFUSAL @ 1.30m depth within hard sandy clay				
2.00						

RIG: N/A

DRILLER: JC

METHOD: Hand Auger

LOGGED: JC

GROUND WATER OBSERVATIONS: None encountered during auger drilling

REMARKS:

CHECKED: TMC

BOREHOLE LOG

CLIENT: **Adam Rytenskild**

DATE: 29/11/2021

BORE No.: 2

PROJECT: **Construction of new residence**

PROJECT No.: 2020-232

SHEET: 1 of 1

LOCATION: **Lot 3 1110 Barrenjoey Road, Palm Beach**

SURFACE LEVEL: RL= 24.90m

Depth (m)	**Classification**	**Description of Strata** **PRIMARY SOIL** - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	**Sampling**		**In Situ Testing**	
0.00			**Type**	**Tests**	**Type**	**Results**
		TOPSOIL/COLLUVIUM: Dark brown, fine to medium grained, moist, silty sand with sub angular, sandstone cobbles and gravel				
0.20		AUGER REFUSAL @ 0.20m depth on sandstone cobble				
1.00						
2.00						

RIG: N/A

DRILLER: JC

METHOD: Hand Auger

LOGGED: JC

GROUND WATER OBSERVATIONS: None encountered during auger drilling

REMARKS: Borehole attempted in four locations all refused at shallow depth on sandstone cobbles

CHECKED: TMC

BOREHOLE LOG

CLIENT: **Adam Rytenskild**
DATE: 30/12/2021
BORE No.: 3

PROJECT: **Construction of new residence**
PROJECT No.: 2020-232
SHEET: 1 of 1

LOCATION: **Lot 3 1110 Barrenjoey Road, Palm Beach**
SURFACE LEVEL: RL= 16.50m

Depth (m)	Classification	Description of Strata **PRIMARY SOIL** - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00		TOPSOIL/COLLUVIUM: Dark brown, fine to medium grained, moist, silty sand with gravel and cobbles				
0.70		…sub angular, medium, ironstone gravel				
0.80	SW	SAND: Very loose, brown, medium grained, moist, sand trace silt and gravel				
1.00		…sandstone and ironstone gravel				
1.10		AUGER REFUSAL @ 1.1m depth on interpreted sandstone boulder				
2.00						

RIG: N/A
DRILLER: JC
METHOD: Hand Auger
LOGGED: JC
GROUND WATER OBSERVATIONS: None encountered during auger drilling
REMARKS:
CHECKED: TMC

BOREHOLE LOG

CLIENT: Adam Rytenskild
DATE: 30/11/2021
BORE No.: 4

PROJECT: Construction of new residence
PROJECT No.: 2020-232
SHEET: 1 of 1

LOCATION: Lot 3 1110 Barrenjoey Road, Palm Beach
SURFACE LEVEL: RL= 17.0m

Depth (m)	Classification	**Description of Strata** **PRIMARY SOIL** - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00		TOPSOILO/FILL: Dark brown, medium plasticity, moist to wet, sandy clay with coarse grained sand and ironstone gravel				
0.25		…wet				
0.30	CH	Sandy CLAY: Soft, pale brown, medium to high plasticity, moist, sandy clay				
				0.60		
			D			
				0.70		
0.80		…Pale grey mottled yellow brown				
0.85		AUGER REFUSAL @ 0.85m on interpreted boulder				
1.00						
2.00						

RIG: N/A
DRILLER: JC
METHOD: Hand Auger
LOGGED: JC
GROUND WATER OBSERVATIONS: None encountered during auger drilling

REMARKS:
CHECKED: TMC

DYNAMIC PENETROMETER TEST SHEET

CLIENT: Adam Rytenskild

DATE: 19/11/2020

PROJECT: Construction of multi-level residence with swimming pool

PROJECT No.: 2020-232

LOCATION: Lot 3, 1110 Barrenjoey Road, Palm Beach

SHEET: 1 of 1

	Test Location							
Depth (m)	DCP1	DCP1a	DCP2	DCP3	DCP4			
0.00 - 0.15	1	1	1	4	2			
0.15 - 0.30	5	3	3	12	8			
0.30 - 0.45	27*B @ 0.43m	5	4	3	12			
0.45 - 0.60		8	4	4	8			
0.60 - 0.75		5	3	3	7			
0.75 - 0.90		25	4	4	12			
0.90 - 1.05		15	3	5	6			
1.05 - 1.20		7	5	5	7			
1.20 - 1.35		6	5	5	28			
1.35 - 1.50		33*B @ 1.45m	3	8	45			
1.50 - 1.65			4	7	24			
1.65 - 1.80			7	8	20			
1.80 - 1.95			6	6	26			
1.95 - 2.10			12	6	24*disc			
2.10 - 2.25			9	10				
2.25 - 2.40			10	12				
2.40 - 2.55			7	11				
2.55 - 2.70			9	11				
2.70 - 2.85			12	12				
2.85 - 3.00			15	15				
3.00 - 3.15								
3.15 - 3.30								
3.30 - 3.45								
3.45 - 3.60								
3.60 - 3.75								
3.75 - 3.90								
3.90 - 4.05								

TEST METHOD: AS 1289. F3.2, CONE PENETROMETER

REMARKS:

	(B)	Test hammer bouncing upon refusal on solid object
	--	No test undertaken at this level due to prior excavation of soils

DYNAMIC PENETROMETER TEST SHEET

CLIENT: **Adam Rytenskild** **DATE:** 30/11/2021

PROJECT: **Construction of new residence** **PROJECT No.:** 2020-232

LOCATION: **Lot 3 1110 Barrenjoey Road, Palm Beach** **SHEET:** 1 of 1

	Test Location								
Depth (m)	DCP5	DCP6	DCP7	DCP8	DCP9	DCP10	DCP10a	DCP10b	DCP11
0.00 - 0.10	1	1	0	0	0	0	0	0	1
0.10 - 0.20	1	1	1	0	1	1	1	1	1
0.20 - 0.30	2	1	0	0	3	2	2	4	2
0.30 - 0.40	1	3	2	1	3	4	5*B @0.35m	10	3
0.40 - 0.50	2	3	1	1	5	6		7	4
0.50 - 0.60	2	3	0	2	14	6		5	4
0.60 - 0.70	1	5	1	2	5	7		5	4
0.70 - 0.80	1	5	1	2	6	16*HB @0.8m		5	4
0.80 - 0.90	2	6	1	5	9			5	4
0.90 - 1.00	2	8	1	10	6			5	4
1.00 - 1.10	1	6	1	7	7			5	4
1.10 - 1.20	2	4	4	6	12			4	6
1.20 - 1.30	2	3	2	10	8			5	6
1.30 - 1.40	2	3	2	8	11			5	6
1.40 - 1.50	2	5	3	10	10			5	7
1.50 - 1.60	3	12	5	7	13			6	14*B @1.60m
1.60 - 1.70	4	12	5	7	18			6	
1.70 - 1.80	2	11	5	6	END			10	
1.80 - 1.90	2	12	6	9				11	
1.90 - 2.00	2	13	5	23*HB @2.0m				8	
2.00 - 2.10	3	11	8					10	
2.10 - 2.20	3	11	11					9	
2.20 - 2.30	4	7	10					9	
2.30 - 2.40	8	7	11					9	
2.40 - 2.50	11	7	10					8	
2.50 - 2.60	9	7	11					9	
2.60 - 2.70	12	10	9					8	
2.70 - 2.80	13	9	11					8	
2.80 - 2.90	14	15	19*HB @ 2.87m					7	
2.90 - 3.00	13	17						12	
3.00 - 3.10	11	END						24	
3.10 - 3.20	15							END	
3.20 - 3.30	17								
3.30 - 3.40	18								
3.40 - 3.50	END								

TEST METHOD: AS 1289. F3.2, CONE PENETROMETER

REMARKS:

(B)	Test hammer bouncing upon refusal on solid object
(HB)	Test hammer half bouncing upon refusal on solid object
--	No test undertaken at this level due to prior excavation of soils

CROZIER
GEOTECHNICAL CONSULTANTS

POINT LOAD STRENGTH INDEX TEST RESULTS

Client: Adam Rytenskild
Date: 30/11/2021
Date Tested: 3/12/21
Project: Construction of multi-level residence with pool
Project No.: 2020-232
Location: Lot 3,1110 Barrenjoey Road, Palm beach

Borehole No.	Depth (m)	Sample Description (geology)	Test Type	Width (mm)	Platen Seperation (mm)	Failure Load (kN)	Is (MPa)	Is(50) (MPa)	Failure Mode*	Strength (AS1726-2017)
BH102	3.30 - 3.41	Sandstone	Diametral	-	50	0.97	0.39	0.39	1	M
			Axial	50	50	1.22	0.38	0.40	4	M
BH102	4.50 - 4.58	Sandstone	Diametral	-	50	0.67	0.27	0.27	2	L
			Axial	48	50	0.91	0.30	0.31	1	M
BH101	4.65- 4.76	Sandstone	Diametral	-	50	0.33	0.13	0.13	1	L
			Axial	65	50	0.71	0.17	0.19	4	L
BH101	5.42 - 5.52	Sandstone	Diametral	-	50	0.51	0.20	0.20	1	L
			Axial	61	50	0.98	0.25	0.28	4	L
BH101	5.82 - 5.95	Sandstone	Diametral	-	50	0.98	0.39	0.39	1	M
			Axial	56	50	1.33	0.37	0.40	1	M
BH101	7.30 - 7.40	Sandstone	Diametral	-	50	1.28	0.51	0.51	1	M
			Axial	65	50	1.43	0.35	0.39	4	M

AS4133.4.1 - Rock Strength Tests - Determination of a point load strength index

*Failure Modes

1	Fracture through fabric of specimen oblique to bedding, not influenced by weak planes
2	Fracture along bedding
3	Fractrure influenced by pre-existing plane, microfracture, vein or chemical alteration
4	Chip or partial fracture

Appendix 3

TABLE : A

Landslide risk assessment for Risk to life

HAZARD	Description	Impacting	Likelihood of Slide	Spatial Impact of Slide		Occupancy	Evacuation	Vulnerability	Risk to Life
A	Landslip (Rockslide/topple <5m³) of unstable angular boulder within north east portion of site due to distubance		a) Detached upper boulder bearing onto other boulder, situated within 1.0m of proposed third floor excavation	a) Boulder topple situated within 1.0m of proposed third level excavation and boulder slides across site, impact 20% b) Boulder situated >50m upslope from area, impact 25% c) Boulder topple situated within 2.0m of common boundary, but across slope from house, impact 1% d) Boulder topple situated >12m across slope, impact 1%		a) Person in studio 12hrs/day b) Person in construction site 8hrs/day c) Person in house 16hrs/day d) Person in gardens 2hrs/day	a) Likely to not evacuate b) Possible to not evacuate c) Likely to not evacuate d)Possible to not evacuate	a) Person in building, crushed b) Person in open space, crushed c) Person in building, crushed d) Person in open space, crushed	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Future site house	0.001	1.00	0.20	0.5000	0.75	1.00	**7.50E-05**
		b) Neighbouring property to the west under construction works (No.1102 - No.1104 Barrenjoey Rd)	0.001	0.10	0.25	0.3333	0.5	1.00	**4.17E-06**
		c) Neighbouring house to the north (Lot 2, No.1110 Barrenjoey Rd)	0.001	0.05	0.01	0.6667	0.75	1.00	**2.50E-07**
		d) Neighbouring gardens to the south (No.1100 Barrenjoey Rd)	0.001	0.02	0.01	0.0833	0.5	1.00	**8.33E-09**
B	Landslip (Rockslide/topple <20m³) of other boulders due to distubance		b) Boulders embedded into colluvial soil slope across site	a) Boulder slides/topples of any other boulder within the site, impact 50% b) Boulders situated >20m, impact 10% c) Boulders across slope from common boundary, impact 5% d) Boulders situated within 2.5m of common boundary, impact 5%		a) Person in studio 12hrs/day b) Person in open area 8hrs/day c) Person in house 16hrs/day d) Person in house 16hrs/day	a) Likely to not evacuate b) Lkely to not evacuate c) Likely to not evacuate d) Likely to not evacuate	a) Person in building, crushed b) Person in open area, crushed c) Person in building, crushed d) Person in building, crushed	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Future site house	0.001	0.50	0.40	0.5000	0.75	1.00	**7.50E-05**
		b) Neighbouirng property under construction works (No.1102 - No.1104 Barrenjoey Rd)	0.001	0.10	0.10	0.3333	0.75	1.00	**2.50E-06**
		c) House (Lot 2, No.1110 Barrenjoey Rd)	0.001	0.05	0.05	0.6667	0.75	1.00	**1.25E-06**
		d) House (No.1100 Barrenjoey Rd)	0.001	0.05	0.05	0.6667	0.75	1.00	**1.25E-06**
C	Landslip (Soil <10m³) of earth around perimeter of excavation for proposed ground floor excavations		Excavation to 6.0m depth, up to 4.3m depth into soils expected	a) Excavation face within 1.0m off the proposed structure, impact 5% b) House approximately 5.0m from excavation, impact 20% c) Excavation within 1.0m of the boundary, impact 1% d) House 4.0m from 2.0m excavation, 5% impacted e) Rear retained gardens a minimum of 15m from excavation, impact 2%		a) Person in house 16hrs/day b) Person in house 16hrs/day c) Person in garden 2hr/day d) Person in dilapidated timber hut 0.5hrs/day e) Person in garden 2hr/day	a) Possible to not evacuate b) Possible to not evacuate c) Possible to not evacuate d) Possible to not evacuate e) Possible to not evacuate	a) Person in building, unlikely buried b) Person in building, minor damage only c) Person in open space, possible buried d) Person in building, minor damage only e) Person in open space, unlikley buried	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Future site house	0.001	0.75	0.05	0.6667	0.5	0.20	**2.50E-06**
		b) House (Lot 2, No.1110 Barrenjoey Rd)	0.001	0.40	0.20	0.6667	0.5	0.05	**1.33E-06**
		c) Rear gardens (No.1100 Barrenjoey Rd)	0.001	0.20	0.01	0.0833	0.5	1.00	**8.33E-08**
		d) Timber hut (No.1100 Barrenjoey Rd)	0.001	0.20	0.05	0.0833	0.5	0.05	**2.08E-08**
		e) Rear gardens (No.140 Pacific Rd)	0.001	0.05	0.02	0.0208	0.5	0.20	**2.08E-09**
D	Landslip (Soil <2m³) of earth around perimeter of excavation for proposed single storey secondary dwelling		Excavation up to 3.2m depth possible through colluvium and residual soils	a) Excavation face within 0.5m off the proposed structure, impact 50% b) Excavation approximately 25m from house, impact 1% c) Excavation within 0.9m of the boundary, impact 25% d) Excavation approximately 10m from timber hut, 10% impacted e) Excavation approximately 12m from house downslope, 1% impacted		a) Person in structure 16hrs/day b) Person in house 16hrs/day c) Person in garden 2hr/day d) Person in dilapidated timber hut 0.5hrs/day e) Person in house 16hrs/day	a) Possible to not evacuate b) Possible to not evacuate c) Possible to not evacuate d) Possible to not evacuate e) Possible to not evacuate	a) Person in building, unlikely buried b) Person in building, minor damage only c) Person in open space, possible buried d) Person in building, unlikley buried e) Person in building, minor damage only	

			Possible	**Prob. of Impact**	**Impacted**				
		a) Future site secondary dwelling	0.001	0.75	0.5	0.6667	0.5	0.20	**2.50E-05**
		b) Neighbouring house (Lot 2, No.1110 Barrenjoey Rd)	0.001	0.01	0.01	0.6667	0.5	0.05	**1.67E-09**
		c) Rear gardens (No.1100 Barrenjoey Rd)	0.001	0.50	0.25	0.0833	0.5	1.00	**5.21E-06**
		d) Timber hut (No.1100 Barrenjoey Rd)	0.001	0.10	0.10	0.0208	0.5	0.20	**2.08E-08**
		e) House (No.1100 Barrenjoey Rd)	0.001	0.02	0.01	0.6667	0.5	0.05	**3.33E-09**
E	Landslip (Rock <10m³) of bedrock or boulder around perimeter of excavation for proposed single storey secondary dwelling		Excavation up to 3.2m depth possible, with intersection of sandstone boulder and potential for bedrock	a) Excavation face within 0.5m off the proposed structure, impact 40% b) Excavation approximately 25m from house, impact 1% c) Excavation within 1.2m of the boundary, impact 20% d) Excavation approximately 10m from timber hut, 5% impacted e) Excavation approximately 7m from house, 5% impacted f) Excavation approximately 35m downslope from retaining wall, 2% impacted		a) Person in structure 16hrs/day b) Person in house 16hrs/day c) Person in garden 2hr/day d) Person in dilapidated timber hut 0.5hrs/day e) Person in house 16hrs/day f) Person in garden 2hrs/day	a) Likely to not evacuate b) Likely to not evacuate c) Possible to not evacuate d) Likely to not evacuate e) Likely to not evacuate f) Likely to not evacuate	a) Person in building, unlikely buried b) Person in building, minor damage only c) Person in open space, possible buried d) Person in building, minor damage only e) Person in building, minor damage only f) Person in open space, unlikley fall to serious injury	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Future site secondary dwelling	0.001	0.5	0.4	0.6667	0.75	0.20	**2.00E-05**
		b) House (Lot 2, No.1110 Barrenjoey Rd)	0.001	0.01	0.01	0.6667	0.75	0.05	**2.50E-09**
		c) Rear gardens (No.1100 Barrenjoey Road)	0.001	0.30	0.20	0.0833	0.75	1.00	**3.75E-06**
		d) Timber hut (No.1100 Barrenjoey Rd)	0.001	0.01	0.05	0.0208	0.75	0.05	**3.91E-10**
		e) House (No.1100 Barrenjoey Rd)	0.001	0.03	0.05	0.6667	0.75	0.05	**3.75E-08**
		f) Rear concrete crib retaining wall (No.138 Pacific Rd)	0.001	0.01	0.02	0.0833	0.75	0.20	**2.50E-09**
F	Landslip (Rock <4m³) of bedrock around perimeter of ground floor excavation		Excavation up to 6.0m depth, with likely intersection of boulders. Bedrock anticipated from approximately 4.3m depth	a) Excavation face within 1.0m of the proposed structure, impact 10% b) Excavation within 5.0m of house, impact 20% c) Excavation within 15m of the boundary, impact 2% d) Timber hut within 15m of excavation, 2% impacted e) Excavation approximately 15m downslope from rear of property, impact 2% f) Excavation approximately 20m downslope from retaining wall, impact 2%		a) Person in house 16hrs/day b) Person in house 16hrs/day c) Person in garden 2hr/day d) Person in dilapidated timber hut 0.5hrs/day e) Person in garden 2hrs/day f) Person in garden 2hrs/day	a) Likely to not evacuate b) Likely to not evacuate c) Possible to not evacuate d) Likely to not evacuate e) Likely to not evacuate f) Likely to not evacuate	a) Person in building, minor damage only b) Person in building, minor damage only c) Person in open space, unlikley buried d) Person in building, minor damage only e) Person in open space, unlikley buried f) Person in open space, unlikley fall to serious injury	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Future site structures	0.001	0.5	0.1	0.6667	0.75	0.05	**1.25E-06**
		b) House (Lot 2, No.1110 Barrenjoey Rd)	0.001	0.20	0.20	0.6667	0.75	0.05	**1.00E-06**
		c) Rear gardens (No.1100 Barrenjoey Rd)	0.001	0.10	0.02	0.0833	0.5	0.50	**4.17E-08**
		d) House (Timber hut No.1100 Barrenjoey Rd)	0.001	0.10	0.20	0.0208	0.75	0.05	**1.56E-08**
		e) Rear retained gardens (No.140 Pacific Rd)	0.001	0.02	0.01	0.0833	0.75	0.50	**6.25E-09**
		f) Rear concrete crib retaining wall (No.138 Pacific Rd)	0.001	0.02	0.02	0.0833	0.75	0.50	**1.25E-08**

* hazards considered in current condition and/or without remedial/stabilisation measures or retention
* likelihood of occurrence for design life of 100 years
* Spatial Impact - Probaility of Impact referes to slide impacting structure/area expressed as a % (1.00 = 100% probability of slide impacting area if it occurs), Imapcted refers to % of area/strucure impacted if slide occurred
* neighbouring houses considered for bedroom impact unless specified
* considered for person most at risk
* considered for adjacent premises/buildings founded via shallow footings unless indicated
* evacuation scale from Almost Certain to not evacuate (1.0), Likely (0.75), Possible (0.5), Unlikely (0.25), Rare to not evacuate (0.01). Based on likelihood of person knwoing of landslide and completely evacuating area prior to landslide impact.
* vulnerability assessed using Appendix F - AGS Practice Note Guidelines for Landslide Risk Management 2007

TABLE : B

Landslide risk assessment for Risk to Property

HAZARD	Description	Impacting	Likelihood		Consequences		Risk to Property
A	Landslip (Rockslide/topple <20m³) of unstable angular boulder within north east portion of site due to distubance	a) Future site house	Possible	The event could occur under adverse conditions over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Moderate
		b) Neighbouring property to the west under construction works (No.1102 - No.1104 Barrenjoey Rd)	Unlikely	The event might occur under very adverse circumstances over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Low
		c) Neighbouring house to the north (Lot 2, No.1110 Barrenjoey Rd)	Unlikely	The event might occur under very adverse circumstances over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Low
		d) Neighbouring gardens to the south (No.1100 Barrenjoey Rd)	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
B	Landslip (Rockslide/topple <50m³) of other boulders due to distubance	a) Future site house	Possible	The event could occur under adverse conditions over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Moderate
		b) Neighbouirng property under construction works (No.1102 - No.1104 Barrenjoey Rd)	Possible	The event could occur under adverse conditions over the design life.	Major	Extensive damage to most of site/structures with significant stabilising to support site or MEDIUM damage to neighbouring properties.	High
		c) House (Lot 2, No.1110 Barrenjoey Rd)	Unlikely	The event might occur under very adverse circumstances over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Low
		d) House (No.1100 Barrenjoey Rd)	Unlikely	The event might occur under very adverse circumstances over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Low
C	Landslip (Soil <4m³) of earth around perimeter of excavation for proposed house and garage excavations	a) Future site house	Possible	The event could occur under adverse conditions over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Moderate
		b) House (Lot 2, No.1110 Barrenjoey Rd)	Possible	The event could occur under adverse conditions over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Moderate
		c) Rear gardens (No.1100 Barrenjoey Rd)	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
		d) Timber hut (No.1100 Barrenjoey Rd)	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
		e) Rear gardens (No.140 Pacific Rd)	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
D	Landslip (Soil <2m³) of earth around perimeter of excavation for proposed excavation of secondary dwelling excavation	a) Future site secondary dwelling	Possible	The event could occur under adverse conditions over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Moderate
		b) Neighbouring house (Lot 2, No.1110 Barrenjoey Rd)	Unlikely	The event might occur under very adverse circumstances over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Low

		c) Rear gardens (No.1100 Barrenjoey Rd)	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
		d) Timber hut (No.1100 Barrenjoey Rd)	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
		e) House (No.1100 Barrenjoey Rd)	Unlikely	The event might occur under very adverse circumstances over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Low
E	Landslip (Rock <10m^3) of bedrock or boulder around perimeter of excavation for proposed single storey secondary dwelling	a) Future site secondary dwelling	Possible	The event could occur under adverse conditions over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Moderate
		b) House (Lot 2, No.1110 Barrenjoey Rd)	Unlikely	The event might occur under very adverse circumstances over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Low
		c) Rear gardens (No.1100 Barrenjoey Road)	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
		d) Timber hut (No.1100 Barrenjoey Rd)	Unlikely	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
		e) House (No.1100 Barrenjoey Rd)	Unlikely	The event might occur under very adverse circumstances over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Low
		f) Rear concrete crib retaining wall (No.138 Pacific Rd)	Unlikely	The event might occur under very adverse circumstances over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Low
F	Landslip (Rock <3m^3) of bedrock around perimeter of excavation for proposed basement garage and elevator excavation	a) Future site structures	Possible	The event could occur under adverse conditions over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Moderate
		b) House (Lot 2, No.1110 Barrenjoey Rd)	Possible	The event could occur under adverse conditions over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Moderate
		c) Rear gardens (No.1100 Barrenjoey Rd)	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
		d) House (Timber hut No.1100 Barrenjoey Rd)	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
		e) Rear retained gardens (No.140 Pacific Rd)	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
		f) Rear concrete crib retaining wall (No.138 Pacific Rd)	Unlikely	The event might occur under very adverse circumstances over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Low

* hazards considered in current condition, without remedial/stabilisation measures and during construction works.

* qualitative expression of likelihood incorporates both frequency analysis estimate and spatial impact probability estimate as per AGS guidelines.

* qualitative measures of consequences to property assessed per Appendix C in AGS Guidelines for Landslide Risk Management.

* Indicative cost of damage expressed as cost of site development with respect to consequence values: Catastrophic : 200%, Major: 60%, Medium: 20%, Minor: 5%, Insignificant: 0.5%.

TABLE: C

Recommended Maintenance and Inspection Program

Structure	Maintenance/ Inspection Item	Frequency
Stormwater drains.	Owner to inspect to ensure that the open drains, and pipes are free of debris & sediment build-up. Clear surface grates and litter. Owner to check and flush retaining wall drainage pipes/systems	Every year or following each major rainfall event. Every 7 years or where dampness/moisture
Retaining Walls. or remedial measures	Owner to inspect walls for deveation from as constructed condition and repair/replace. Replace non engineered rock/timber walls prior to collapse	Every two years or following major rainfall event. As soon as practicable
Large Trees on or adjacent to site	Arborist to check condition of trees and remove as required. Where tree within steep slopes (>18°) or adjacent to structures requires geotechincal inspection prior to removal	Every five years
Slope Stability	Geotechnical Engineering Consultant to check on site stability and maintenance	Five years after construction is completed.

N.B. Provided the above shedule is maintained the design life of the property should conform with Councils Risk Management Policy.

Appendix 4

APPENDIX A

DEFINITION OF TERMS

INTERNATIONAL UNION OF GEOLOGICAL SCIENCES WORKING GROUP ON LANDSLIDES, COMMITTEE ON RISK ASSESSMENT

Risk – A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability x consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.

Hazard – A condition with the potential for causing an undesirable consequence (*the landslide*). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the likelihood of their occurrence within a given period of time.

Elements at Risk – Meaning the population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.

Probability – The likelihood of a specific outcome, measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between 0 and 1, with 0 indicating an impossible outcome, and 1 indicating that an outcome is certain.

Frequency – A measure of likelihood expressed as the number of occurrences of an event in a given time. See also Likelihood and Probability.

Likelihood – used as a qualitative description of probability or frequency.

Temporal Probability – The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.

Vulnerability – The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.

Consequence – The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.

Risk Analysis – The use of available information to estimate the risk to individuals or populations, property, or the environment, from hazards. Risk analyses generally contain the following steps: scope definition, hazard identification, and risk estimation.

Risk Estimation – The process used to produce a measure of the level of health, property, or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis, and their integration.

Risk Evaluation – The stage at which values and judgements enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental, and economic consequences, in order to identify a range of alternatives for managing the risks.

Risk Assessment – The process of risk analysis and risk evaluation.

Risk Control or Risk Treatment – The process of decision making for managing risk, and the implementation, or enforcement of risk mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.

Risk Management – The complete process of risk assessment and risk control (*or risk treatment*).

Individual Risk – The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.

Societal Risk – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental, and other losses.

Acceptable Risk – A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.

Tolerable Risk – A risk that society is willing to live with so as to secure certain net benefits in the confidence that it is being properly controlled, kept under review and further reduced as and when possible.

In some situations risk may be tolerated because the individuals at risk cannot afford to reduce risk even though they recognise it is not properly controlled.

Landslide Intensity – A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, kinetic energy per unit area.

Note: Reference should also be made to Figure 1 which shows the inter-relationship of many of these terms and the relevant portion of Landslide Risk Management.

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.

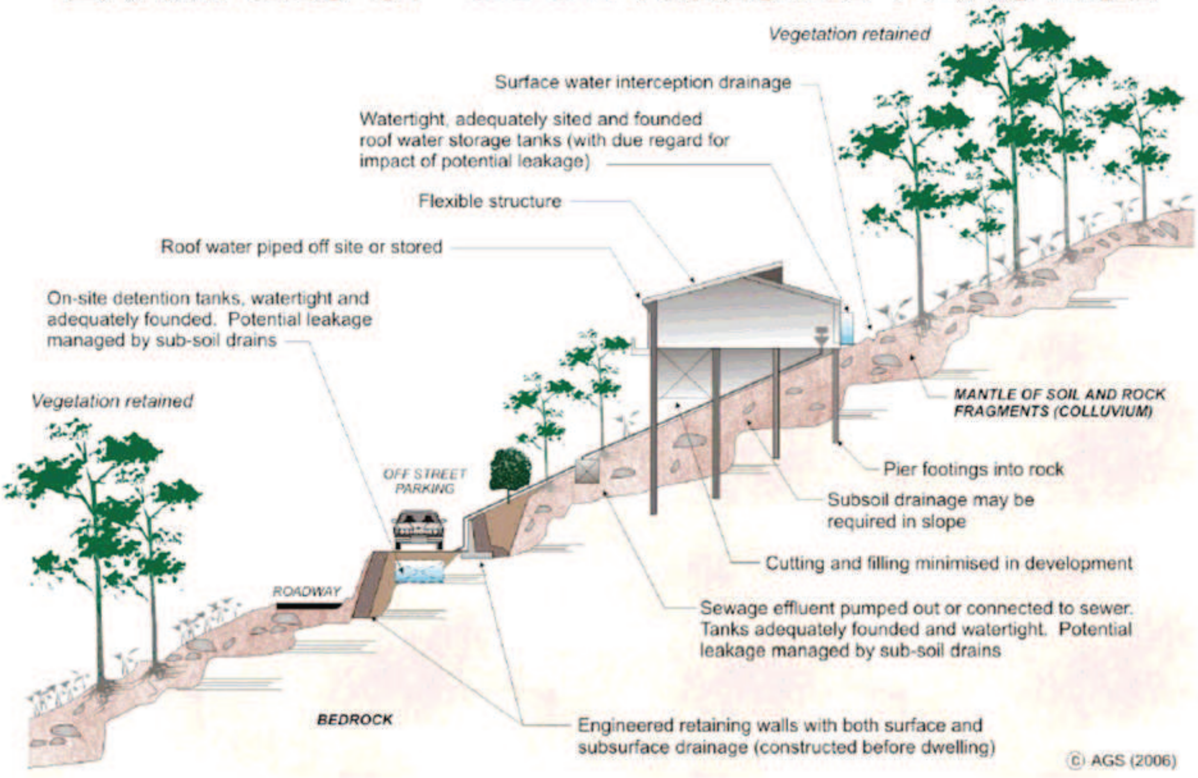
Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

Appendix 5

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
Cuts	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
Fills	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
Rock Outcrops & Boulders	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
Surface	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
Subsurface	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
Septic & Sullage	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	

EXAMPLES OF GOOD HILLSIDE PRACTICE



EXAMPLES OF POOR HILLSIDE PRACTICE