CROZIER GEOTECHNICAL CONSULTANTS

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

REPORT ON GEOTECHNICAL ASSESSMENT

for

PROPOSED SUBDIVISION and DEVELOPMENT

at

2 WYADRA AVENUE, CURL CURL

Prepared For

Mark Aubrey

Project: 2020-229

Document Revision Record

Issue No	Date	Details of Revisions
0	12th November 2020	Original issue

CROZIER GEOTECHNICAL CONSULTANTS

Crozier Geotechnical Consultants *ABN: 96 113 453 624*
Unit 12/ 42-46 Wattle Road *Phone: (02) 9939 1882*
Brookvale NSW 2100 *Email: info@croziergeotech.com.au*
Crozier Geotechnical Consultants is a division of PJC Geo-Engineering Pty Ltd

Date: 12th November 2020
No. Pages: 1 of 15
Project No.: 2020 - 229

GEOTECHNICAL REPORT FOR PROPOSED SUBDIVISION AND DEVELOPMENT 2 WYADRA AVENUE, CURL CURL, NSW.

1. INTRODUCTION:

This report details the results of a geotechnical assessment carried out for the proposed subdivision including boundary re-alignment to the rear of No. 14 and No. 16 Ellen Street, Freshwater to form new enlarged property boundaries for No. 2 Wyadra Avenue, Curl Curl. Following this a new residential development is proposed. The assessment was undertaken by Crozier Geotechnical at the request of the client Mark Aubrey.

It is understood that the proposed works involve subdividing the rear of No. 14 and realignment of the rear boundary of No. 16 to increase the size of the property No. 2 Wyadra Avenue. This will result in new Lot 201 (No. 16), Lot 203 (No. 14) and Lot 202 (No. 2) dimensions with No. 16 extending further west and No. 2 extending across the rear of No. 14.

Development works are then proposed within the new No. 2 Wyadra Avenue which involve a parking platform and carport accessed off the existing driveway and then a residential house located adjacent to the western boundary across the southern half of the site. The house works appear to require a bulk excavation of up to approximately 3.0m depth for an isolated OSD tank that will reduce to nil towards the east due to the natural slope.

Reference to the Northern Beaches Council ï Warringah Local Environmental Plan 2011 and Landslip Risk Map (Map Sheet_010), identified that the site is located within land classified as Class ócBô detailed as ñFlanking Slopes 5° to 25°ò and also Class ócÔ ñSlopes >25°ò. The majority of No. 2 will be located within Class ócÔ land.

Crozier Geotechnical Consultants previously supplied a report for DA submission related to the initial sub - division of No. 2 Wyadra Ave from the rear of No. 16 Ellen St and the construction of a new residential house (Geotechnical Site Investigation for Proposed New House at 16 Ellen Street, Freshwater, Project No. 2015-174, Dated: 25th September 2015)

This recent assessment involved:

- Review of previous investigation data from No. 16 Ellen St. and No. 2 Wyadra Ave. related to the previous sub-division and development proposal
- Geotechnical inspection to assess the rear of No. 14 and to confirm conditions within No. 2 and No. 16.

The following plans and diagrams were supplied by the architect for the work;

- Subdivision Plan by David Stutchbury, Reference No. 10358/19, Dated: 22/06/2020
- Site survey by Stutchbury Jaques Pty Ltd, Reference No. 10358/19, Dated 22/06/2020
- Architectural Design drawings by Peter Stutchbury Architecture, Drawing No.: DA1 Amend 1 ï 001, 301, 302, Issue: 4, Dated 22/09/2020

2. SITE FEATURES:

2.1. Description:

The property No. 2 Wyadra Avenue is a rear battle-axe style block with concrete access driveway passing down the northern side of No. 25 Loch Street to the main portion of the block, which extends east and south across the rear of No. 16. The main portion of the block is gently to moderately east dipping down to the crest of an up to 8.0m high cliff line that strikes north-south through the rear edge of the site and also through the neighbouring properties either side, including No. 14 Ellen. Below the cliff base the narrow remainder of the site is gently sloping extending into No. 16.

No. 16 Ellen Street to the east is a near rectangular shaped block with diagonal rear boundary, as formed during the previous sub-division to create No. 2 Wyadra Avenue. This property contains a three storey rendered masonry residential house on the front half with open lawn backyard and gardens that extend to near the base of the cliff line.

No. 14 Ellen Street contains a three storey residential house on the front half of the block with a small garden and lawn at the rear before the continuation of the cliff line crosses the block to the south. Above the cliff the property is gently sloping and contains a raised, single level residential secondary dwelling, adjacent to the boundary with No. 23 Loch Street upslope.

2.2 Geology:

Reference to the Sydney 1: 100,000 Geological Series sheet (9130) indicates that the site is underlain by Hawkesbury Sandstone (Rh) which is of Triassic age. The rock unit typically comprises medium to coarse grained quartz sandstone with minor lenses of shale and laminite. This rock unit was identified in outcrops within the site.

Morphological features often associated with the weathering of Hawkesbury Sandstone are the formation of near flat ridge tops with steep angular side slopes. These slopes often consist of sandstone terraces and cliffs with steep colluvial slopes below. The terraced areas above these cliffs often contain thin sandy (low plasticity) soil profiles with intervening rock (ledge) outcrops. The outline of the cliff areas are often rectilinear in plan view, controlled by large bed thickness and wide spaced near vertical joint pattern, many cliff areas are undercut by differential weathering. Slopes below these cliffs are often steep 15 to 23° with moderately thick sandy colluvial soil profile that are randomly covered by sandstone boulders.

3. FIELD WORK

3.1 Methods:

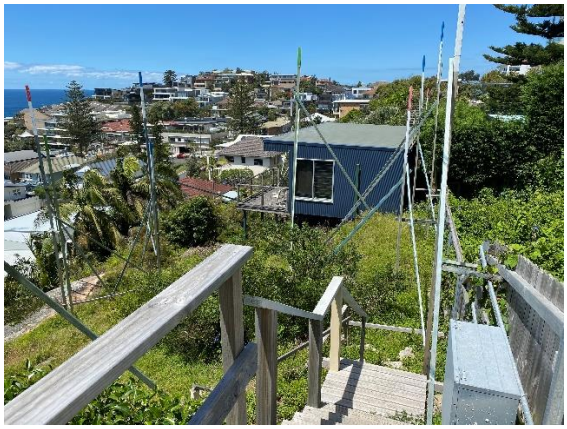
Previous field investigation comprised a walk over inspection and mapping of the No. 16 and adjacent properties on the 28th August 2015 by a Geotechnical Engineer with photographic record of conditions and the drilling of two auger boreholes (BH1 ï 2) using a hand auger to investigate sub-surface geology in areas of soil cover within the rear of the property. Dynamic Cone Penetrometer (DCP) testing was carried out adjacent to the boreholes and in other areas, in accordance with AS1289.6.3.3 ï 1997, ñDetermination of the penetration resistance of a soil ï 9kg dynamic cone penetrometerò to estimate near surface soil conditions and confirm depths to bedrock.

The more recent assessment includes and inspection of the rear of No. 14 and the site (No. 2) by a Senior Engineering Geologist on the 10th November 2020.

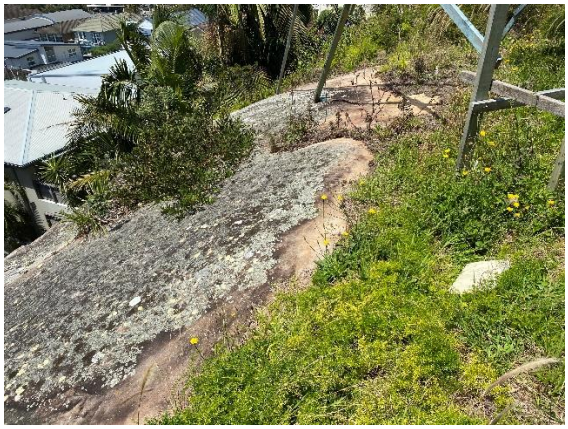
3.2. Field Observations:

The site (No. 2) is located on the low east side of Wyadra Avenue, at mid-slope level with the majority of the property formed down slope to the rear of No. 25 Loch Street, which extends to the ridge crest. Access to the property is formed via a suspended concrete driveway with kerbs and drains that extends from the eastern end of Wyadra Ave and ends at the rear eastern boundary of No. 25.

Timber stairs provide access from the driveway down to the block, which is gently to moderately east dipping with soil slopes covered in low weed vegetation and numerous low (<1.0m) sandstone outcrops considered to be generally bedrock. The rear eastern side of the property is formed with outcropping medium strength sandstone that is considered to be bedrock that forms the crest of the cliff that extends across the site near the rear boundary. Adjacent to the western side of the outcrop is a shallow elongated depression that appears to define a defect within the bedrock below.

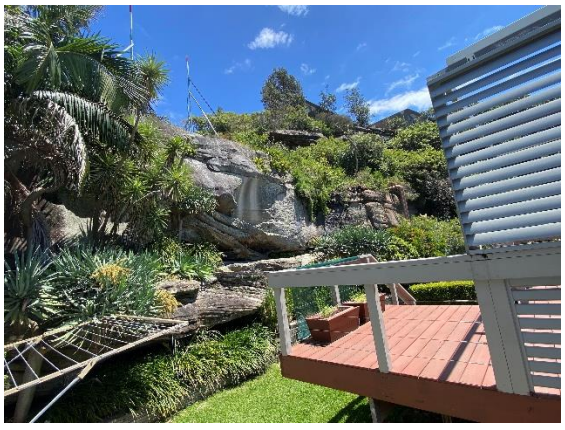


View of site (No. 2) from access driveway

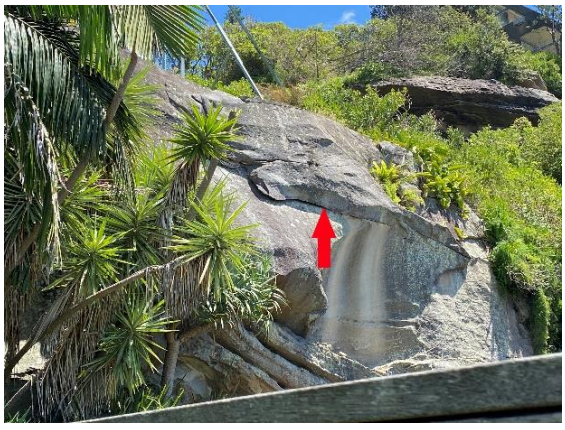


Outcrop along eastern side of block

The cliff is up to 8.0m in height and formed through generally massive sandstone with few bedding or joint defects in the upper portion and with more bedding defects in the lower 3.0m. An undercut is formed at the base of the upper cliff, that extends up to 4.0m laterally into the cliff face towards the east. Some spalling at face of the cliff has also separated some small sections of rock.



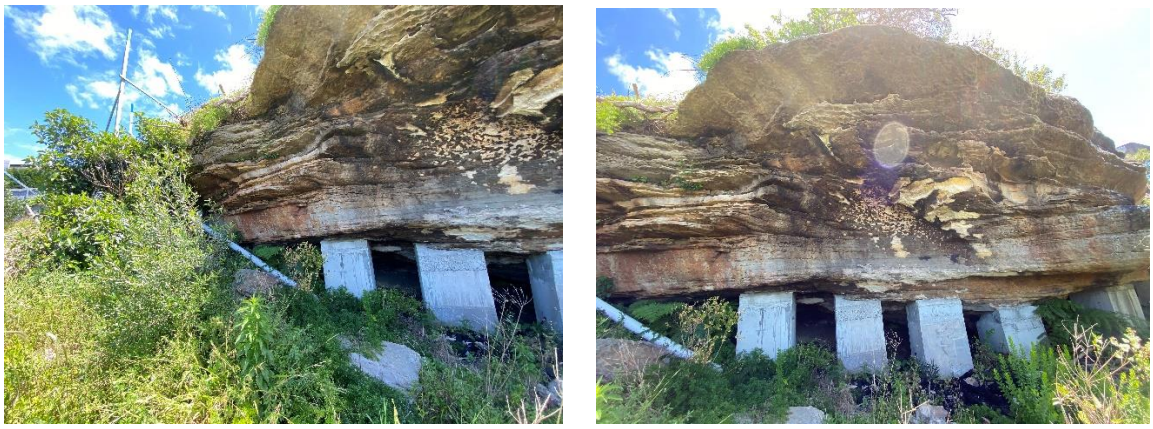
Rear of No. 16 showing cliff line at rear of No. 2



Spalling and fractured rock near cliff crest.

At the rear north-west corner of the property there is another 4.0 ï 5.0m high cliff line that extends from the northern neighbouring property to the sites north-west corner. This cliff contains a large overhang in the corner of the site which has been previously underpinned via several large mass concrete underpinning

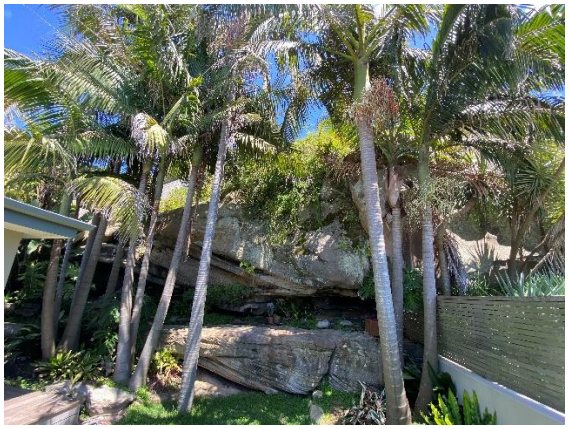
blocks. From this overhang the cliff curves to strike west and reduces in height with low cliffs and terraces stepping down in a southerly direction into the site.



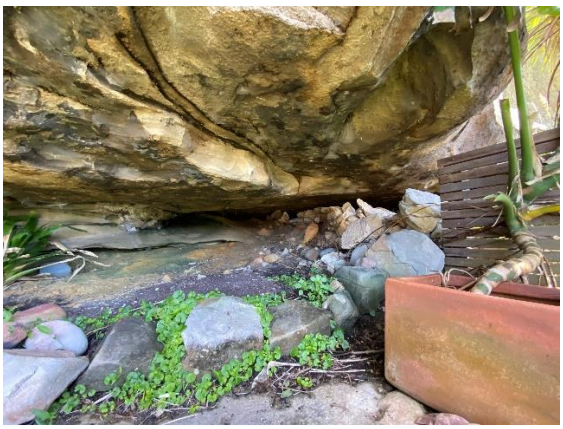
Outcrop cliff and underpinning at north-wets corner of No. 2

No. 16 Ellen Street is located down slope within moderate east dipping topography from below the base of the lower cliff within No. 2. The property consists of a gently east sloping front half containing a three storey cement rendered residence with lawn and driveway at front. To the rear of the house, at upper level, there are a series of rock walls supporting terraced garden beds and lawns along with a timber decking.

The property No. 14 Ellen St contains a three storey cement rendered house structure on the front half within a gentle slope with a garden and lawn at upper level to the rear. The cliff line that cuts across No. 2 extends through this property and is generally near vertical on the north side and becomes partially fragmented and covered in vegetation to the south. Above the cliff this property is also gently to moderately sloping and contains a single storey raised cottage structure adjacent to the rear upslope western boundary. Below this cottage outcropping bedrock as a low (1.0m) cliff with terrace above was mapped which also continues across into No. 2.



Cliff to rear of No. 14



Undercut below cliff face as viewed from No. 14

The neighbouring property to the north and north-west contains a multi-level concrete structure related to Stewart House. This structure is located above the cliff line that enters the north-west corner of the site with the building located approximately 10m from the site boundary.

The neighbouring properties upslope (No. 23 and No. 25 Loch Street) both contain residential houses on the front halves of the blocks with a secondary dwelling and swimming pool at the rear of No. 23 and an undeveloped slope within the rear of No. 25.

4. COMMENTS:

4.1. Geotechnical Assessment:

The inspections identified shallow sandstone bedrock across most of No. 2 with extensive outcrops that also extend across the rear of No. 14 and No. 16.

The outcrop to the north-west of the site has been underpinned where it is undercut and is considered stable. The large sandstone cliff that extends across the rear edge of the site and extends through No. 14 to the south appears generally stable. However, the depression as seen to the rear of the outcrop in No. 2 along with the increased undercut dimension as seen from No. 14 warrant the installation of support systems to ensure long term stability. This could be undertaken following a more detailed geotechnical inspection/investigation via the installation of a blade wall along the boundary alignment between No. 14 and No. 16 or via two separate underpinning blocks, as seen within the overhang in the north-west corner of the site. This work should be engineer designed and installed by an experienced contractor.

The spalling within the cliff crest adjacent to No. 16 has deteriorated since the previous inspection and it is now recommended that this section of rock be removed prior to its natural failure. This is likely to require rope access and should also be undertaken by an experienced contractor. It is recommended that the area below the spalled section of rock be cordoned off to prevent access until this section of rock is removed.

The proposed works involve alterations to existing property boundaries within the site (No. 2 Wyadra) and also No. 14 and No. 16 Ellen Street to create a new enlarged dimension to the site. They also include the construction of a new raised parking platform and carport in the north-west of the block and then a new residential house in the south-west. The house will require a bulk excavation of up to 3.0m depth for an OSD tank.

The proposed development works are located to the west of any potential instability in the existing cliff line therefore they will not be affected even if the instability occurs. The development will involve an excavation, however based on site conditions the excavation will extend generally through outcropping sandstone bedrock of at least low to medium strength, therefore the potential to create instability is limited. The risk associated with the excavation can be managed and maintained within óAcceptableô levels with negligible impact to adjacent properties or structures through geotechnical inspection during excavation and installation of support measures if determined as necessary by those inspections.

The management of ground vibrations will also be a critical aspect of the development works however through the use of suitable excavation equipment, which is anticipated due to the access limitations, the potential for creation of ground vibrations of detrimental level at adjacent structures is óVery Lowô.

As such there are no geotechnical reasons for the proposed boundary alignment or development amendment not to be approved.

4.2. Site Specific Risk Assessment:

Based on our assessment we have identified two geological/geotechnical hazards which need to be considered in relation to the existing site. The hazards are:

A. Landslip (rock topple 20m^3) from cliff due to undercut with rotation of cliff crest
B. Landslip (rock fall <1m^3) due to natural detachment of spalled section of rock on cliff
C. Landslip (rock slide/topple <5m^3) within bedrock due to excavation for house

A qualitative assessment of risk to life and property related to these hazards is presented in Table A and B, Appendix: 2, and is based on methods outlined in Appendix: C of the Australian Geomechanics Society Guidelines for Landslide Risk Management 2007. AGS terms and their descriptions are provided in Appendix: 3.

The **Risk to Life** from the hazards was estimated at up to **8.33 x 10^{-6}** whilst the **Risk to Property** was considered to be up to **'Moderate'**. The hazards were therefore considered to be marginally óAcceptableô when assessed against the criteria of the AGS 2007. However, these hazards are considered without the implementation of the recommendations of this report. Therefore, where geotechnical inspection and installation of support systems along with the removal of the spalled rock occur, the risk levels will reduce significantly.

4.3. Design & Construction Recommendations:

4.3.1. New Footings:

The results of the investigations suggest that the site is underlain by sandy soil of variable but generally shallow depth overlying generally medium strength sandstone bedrock which also outcrops. The new house will be founded at the base of an excavation into bedrock which is expected to expose at least medium strength sandstone whilst the parking platform and carport will also be located over outcrop but this part of the site may also contain detached sections and boulders. Therefore care will be required to ensure all footings are supported off insitu bedrock.

Footings founded in medium to high strength bedrock may be designed for a maximum allowable bearing capacity of 2000kPa, which is expected to be more than sufficient for the proposed works. Inspection by a geotechnical engineer of the base of the excavation and excavated footings is recommended to confirm bearing capacity and the insitu nature of the foundation. All footings should be founded off similar strength bedrock to prevent differential settlement, and this is expected to be achieved via strip/pad footings.

As footings are all expected to be founded within the bedrock it is considered a Class óAô site as per the Australian Standard for Residential Slabs and Footings AS2870 ï 2011.

Under the Australian Standard Structural design actions AS1170.4 ï 2007, Part 4: Earthquake actions in Australia the site Sub-soil classification would be B_e ï rock site.

4.3.2. Excavation:

It is understood that the proposed works for the development include excavation to 3.0m depth, which will extend within 1.0m of the western rear boundary but will be well away from any other boundary. The excavation will therefore extend to within approximately 5.0m of the swimming pools within No. 23 Loch Street but will be very narrow and isolated. The excavation will be up to 3.0m depth in its western side however the depth will reduce quickly to nil in the east due to the natural ground surface slope.

The excavation will intersect shallow sand/fill underlain by low to medium strength sandstone with high strength rock expected in the excavation along with very high strength ironstone layers. Isolated low strength weathered or shale layers may also be present.

The excavation of soil and any extremely low strength, extremely weathered bedrock may be readily achieved using conventional earth moving equipment or hydraulic excavators with the assistance of ripping

for the very low strength bedrock and thin ironstone bands. This method of excavation through soils and weathered bedrock will not create excessive vibrations provided it is undertaken with medium scale (<20 tonne excavator) excavation equipment in a sensible manner.

The majority of the excavation will extend through medium strength sandstone bedrock with the possibility of high strength ironstone bands and occasional low strength shale and siltstone horizons. It will therefore require the use of rock excavation equipment (i.e. rock hammer / breaker / saw / grinder).

The selection of excavation machinery must take into account the following information: Vibration levels from rock breakers can be excessive (Peak Particle Velocities (PPV) greater than 50mm per second) and cause damage to adjacent structures, particularly if high to very high strength iron cemented sandstone bands or major south-east to north-east sub-vertical joints are encountered.

The Australian Standard (AS2187.2) makes reference to several standards used by British and United States authorities to assess damage as a result of ground vibrations from explosions, which produce transient vibration events. From these standards it can be seen that the values to create cosmetic damage, which is defined as hairline cracks (<0.1mm width) in AS2870-2011, Table: C1, are significantly higher than those at which humans find ground vibrations disturbing (>5mm/s). However, rock hammering produces intermittent vibrations which are more continuous than transient events, therefore lower damage thresholds would be expected.

Humans perceive ground vibrations at very low levels (0.5mm/s particle velocities) whilst steady state vibrations, as created by continuous uninterrupted rock hammering, are disturbing to persons above a value of 5mm/s PPV (Wiss 1981). This is especially the case where good relations with neighbours are not held.

It is therefore recommended that a **vibration limit (Maximum Peak Particle Velocity, PPV) of 5mm/s** be set at the founding level of all occupied neighbouring structures for all excavation work on this site with 8mm/s PPV recommended for un-occupied structures (i.e. swimming pools).

Vibration characteristics are site and equipment specific therefore vibration characterisation tests for any rock breaker/hammer will need to be undertaken using vibration monitoring equipment by a geotechnical specialist where a rock hammer >250kg ódead-weightô is proposed for use. These tests are conducted prior to rock excavation work being carried out to define the equipmentôs characteristics, confirm appropriate buffer distances and site vibration characteristics.

Full time vibration monitoring may be required pending the results of the calibration testing. The geotechnical engineer should be notified of the proposed excavation equipment and methodology prior to excavation commencement. Visual monitoring at the commencement of the excavation and during vibration calibration of the equipment should take place via site inspection (Senior Engineering Geologist) to ensure that excavation techniques used by the operator keep vibration levels down to an acceptable level.

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

Maximum Hammer Weight	Required Buffer Distance from Structure
300kg	2.5m
400kg	4.0m
600kg	7.0m
900kg	10.0m

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 and the saw cuts will provide a slight increase in buffer distance for use of rock hammers.

Upper horizons in the bedrock may be detached along bedding and joint defects. Where these sections are impacted via rock hammering the opposite end, potentially located below neighbouring structures, will deflect more than expected. The rock sawing of the excavation perimeter prior to rock hammering will significantly reduce the risk of this hazard.

It is recommended that dilapidation surveys be undertaken 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.

Care will be required to ensure that excavated sections of rock are not allowed to travel down slope from the excavation and may require the placement of a catch fence or similar.

4.3.3. Excavation Support:

Recommended maximum batter slopes for excavation through fill and natural soils/rock on this site are presented below in Table: 1. Where these batters cannot be implemented then the excavation will require temporary support until permanent retaining walls can be completed. If suitable measures are not implemented then the stability of this excavation until permanent retaining walls are completed cannot be guaranteed. It is expected that these batters will be achieved through most of the site due to limited soil and shallow bedrock present.

Table 1 - Batter Slopes

Material	Safe Batter Slope (H:V)	
	Short Term/ Temporary	Long Term/ Permanent
Fill and natural soils	1:1	2:1
Low strength or fractured sandstone	0.75:1	0.75:1
Medium strength, defect free sandstone	vertical	vertical

Vertical batters can be used where the excavation extends through medium to high strength sandstone bedrock which will generally remain self-supporting, though this will be dependent on weathering, the orientation of joints/defects and bedding. As such geotechnical inspection of excavated rock faces is required and may determine the need for installation of support systems, though this appears very unlikely based on site observations.

Based on the proximity of the cut to the rear boundary, any rock bolts may need to extend across into the neighbouring properties, therefore this option is not preferred. Design for the support structures will be on an individual basis as identified during inspections and should be undertaken by a geotechnical engineer to limit potential exposure at property boundaries.

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. Should boulders be identified near the crest of the excavation then these may need to be slightly over excavated, possibly underpinned and supported to ensure that no long term movement occurs that could create point loads on walls or rock face instability.

During excavation works, regular inspections should be undertaken by an appropriately qualified geotechnical professional to assess the subsurface conditions and advise on underpinning works, excavation batter slopes or rock face support requirements. It is recommended that these inspections be undertaken upon clearing of all soils from the bedrock surface and then once the rock excavation extends to its mid-level and then when it reaches its base.

4.3.4. Retaining Structures:

Whilst the medium strength bedrock will be self supporting, new retaining walls may be required as part of the proposed works. Where defects are identified in the geotechnical inspections then rock support may be required however this is considered very unlikely based on the scale of the proposed excavation. Backfilled retaining walls utilizing the coefficient for low strength sandstone may be implemented throughout as permanent support.

These structures will need to be "engineer designed" retaining wall systems designed in accordance with Australian Standard AS 4678-2002 Earth Retaining Structures. Pressures acting on retaining walls can be calculated based on the parameters listed in Table: 2 for the materials likely to be retained.

Table: 2 - Retaining Structures Design Parameters

Material	Unit Weight (kN/m^3)	Long Term (Drained)	Earth Pressure Coefficients		Passive Earth Pressure Coefficient *
			Active (Ka)	At Rest (Ko)	
Fill (sandy) (loose to medium dense)	18	$\phi' = 29°$	0.35	0.52	2.85
Low strength rock (jointed)	22	$\phi' = 38°$	0.10	0.20	600 kPa

* Ultimate design values

In suggesting these parameters it is assumed that the retaining walls will be fully drained and it is envisaged that suitable subsoil drains would be 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 the 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.

Medium strength bedrock is suitable for the use of vertical galvanized steel dowels for lateral/rotation restraint for retaining wall systems. Medium strength bedrock is suitable for a grout/rock adhesion of 600kPa for fully grouted steel dowels and a footing bearing pressure of 2000kPa. The location of individual dowels should be assessed by the geotechnical engineer, they should generally extend a minimum of 600mm depth. However final design will be determined by the structural engineer.

4.3.5. Drainage and Hydrogeology:

The site is situated at mid-slope level within moderate sloping topography which contains extensive sandstone bedrock outcrops and cliff line. Minor groundwater seepage was identified over the bedrock surface however no groundwater table will be intersected in the proposed development works therefore it is not expected to result in any significant impact to local hydrogeology.

Groundwater seepage can be expected at the soil rock interface and on geological defects within the bedrock. This seepage may be under slight artesian pressures due to water head from joints in the rock mass further upslope. 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. Drainage trenches/collection should also be placed in/over open defects in the bedrock exposed in the excavation. This may require some excavation in the joints. Trenches, as well as all new building gutters, down pipes and stormwater intercept trenches should be connected to an engineered stormwater system and discharged to the Councilôs stormwater system off site.

Due to the shallow depth to bedrock onsite disposal is likely unsuitable, however a dispersion system may be suitable if combined with onsite detention or an alternative system designed by a Hydraulics Engineer.

4.4. Conditions Relating to Design and Construction Monitoring:

To allow Crozier Geotechnical Consultants to provide certification as part of construction, building and post-construction activity, it will be necessary for Crozier Geotechnical Consultants to;

1. Review and approve the structural drawings and new stormwater disposal design for compliance with the recommendations of this report,
2. Conduct inspection of cliff overhang and installation of support systems as determined necessary along with confirmation of removal of spalled rock from cliff face.
3. Inspect all new footings and earthworks to confirm compliance to design assumptions with respect to allowable bearing pressure, basal cleanness and the stability prior to the placement of steel or concrete, as per Section 4.3,

5. CONCLUSION:

The site and adjacent properties are underlain by generally shallow layers of sandy soil overlying sandstone bedrock from Ò0.70m depth with outcropping sandstone bedrock of at least medium strength visible in numerous locations.

The proposed works involve alteration to existing property boundaries for No. 14 and No. 16 Ellen Street to result in an increased size to No. 2 Wyadra Avenue. Development works are then proposed to construct a new residential house, which is amended from a previous design. The house involves an OSD tank that will require an excavation of up to 3.0m depth, however it is extremely isolated and expected to extend generally through medium strength bedrock therefore the potential for instability is anticipated to be ówery lowô.

The inspections identified two natural landslip hazards related to the existing site and one potential hazard related to the proposed residential development.

Whilst the risk assessment identified some of the risk levels as being marginally ñAcceptableô when compared to the AGS criteria, it is recommended that an underpinning system be implemented to the overhang based on future detailed geotechnical inspection whilst the spalled section/s of rock on the cliff face adjacent to No. 16 should be removed as soon as possible. Provided this occurs and the excavation/construction inspections detailed within this report the risk from all hazards will be well within the ñAcceptableò risk level for the life span of the proposed development, taken as 100 years.

Prepared by:

Troy Crozier
Principal
RPGeo.: Geotechnical and Engineering

6. REFERENCES:

1. Australian Geomechanics Society 2007, ñLandslide Risk Assessment and Managementò, Australian Geomechanics Journal Vol 42, No 1, March 2007.

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 (rock topple 50m³) from rotation of cliff edge due to overhang		Overhang of dimension when to potentially result in rotation	a) impact rear eastern 1/4 of property b) lawn and rear gardens, impact 20%		a) Person in rear edge of property following future development 1hrs/day avge. b) Person in lawn/garden 2hr/day avge.	a) Possible to not evacuate b) Possible to not evacuate	a) Person in open space, possible crush b) Person in open space, crushed	
			Possible	**Prob. of Impact**	**Impacted**				
		a) No. 2 Wyadra	0.001	1.00	0.25	0.0833	0.5	0.8	**8.33E-06**
		b) Rear Lawn No. 16 or No. 14	0.001	1.00	0.20	0.0417	0.5	1	**4.17E-06**
B	Landslip (rock fall <1m³) spall failure from cliff crest		Spalling is seperating sections of rock with weathering increasing potential for failure	a) rear lawn and garden at base of cliff, impact 0.5%		a) Person in garden 1hrs/day avge	a) Almost Certain to not evacuate	a) Person impacted	
			Likely	**Prob. of Impact**	**Impacted**				
		a) Rear Lawn No. 16	0.01	1.00	0.005	0.0417	1	1.00	**2.08E-06**
C	Landslip (rock slide/topple <5m³) due to excavation		Medium strength bedrock outcropping, shows no potentially de-stabilising defects	a) pool located approx. 5.00m from excavation, impact 5% b) rear garden slope located 1.0m from excavation, impact 1% c) house located at base of excavation, impact 5%		a) Person in pool 1hrs/day avge b) Person in garden 1hrs/day avge c) Person in house 20hrs/day	a) Almost Certain to not evacuate b) Possible to not evacuate c) Almost Certain to not evacuate	a) Structure minor impact only b) person in open space, unlikely buried c) person in structure, minor impact	
			Unlikely	**Prob. of Impact**	**Impacted**				
		a) Rear pool of No. 23 Loch St	0.0001	0.01	0.050	0.0417	1	0.01	**2.08E-11**
		b) Rear of No. 25 Loch St	0.0001	0.20	0.010	0.0417	0.5	0.05	**2.08E-10**
		c) New Site Development	0.0001	1.00	0.050	0.8333	1	0.10	**4.17E-07**

* hazards considered in current condition and/or without remedial/stabilisation measures or poor support systems
* likelihood of occurrence for design life of 100 years
* Spatial Impact - Probability of Impact refers to slide impacting structure/area expressed as a % (i.e. 1.00 = 100% probability of slide impacting area if slide occurs).
  Impacted refers to expected % of area/structure damaged if slide impacts (i.e. small, slow earth slide will damage small portion of house structure such as 1 bedroom (5%), where as large boulder roll may damage/destroy >50%)
* neighbouring houses considered for impact of slide to bedroom unless specified, due to high occupancy and lower potential for evacuation.
* considered for person most at risk, where multiple people occupy area then increased risk levels
* for excavation induced landslip then considered for adjacent premises/buildings founded off shallow footings, unless indicated
* evacuation scale from Almost Certain to<u>not</u> evacuate (1.0), Likely (0.75), Possible (0.5), Unlikely (0.25), Rare to not evacuate (0.01). Based on likelihood of person knowing 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 (rock topple 50m³) from rotation of cliff edge due to overhang	a) No. 2 Wyadra	Possible	The event could occur under adverse conditions over the design life.	Medium	Moderate damage to some of structure or significant part of site or MINOR damage to neighbouring property, requires large stabilising works .	Moderate
		b) Rear Lawn No. 16 or No. 14	Possible	The event could occur under adverse conditions over the design life.	Medium	Moderate damage to some of structure or significant part of site or MINOR damage to neighbouring property, requires large stabilising works .	Moderate
B	Landslip (rock fall <1m³) spall failure from cliff crest	a) Rear Lawn No. 16	Likely	Event will probably occur under adverse circumstances over the design life.	Insignificant	Little Damageor no impact to neighbouring properties, no significant stabilising required .	Low
C	Landslip (rock slide/topple <5m³) due to excavation	a) Rear pool of No. 23 Loch St	Rare	The event is conceivable but only under exceptional circumstances over the design life.	Minor	Limited Damage to part of structure or site or INSIGNIFICANT damage to neighbouring properties, requires some stabilisation .	Low
		b) Rear of No. 25 Loch St	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site or INSIGNIFICANT damage to neighbouring properties, requires some stabilisation .	Low
		c) New Site Development	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site or INSIGNIFICANT damage to neighbouring properties, requires some stabilisation .	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%.
* Cost of site development estimated at