Geotechnical Consultants Australia

Granny Flat Solutions

Geotechnical Investigation and Site Lot Classification Report

Proposed Development at:
25 Carpenter Crescent
Warriewood NSW 2102

G19360-1

27th November 2019

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Report Distribution

Geotechnical Investigation and Site Lot Classification Report

Address: 25 Carpenter Crescent Warriewood NSW 2102

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1. INTRODUCTION AND SITE DESCRIPTION

1.1 Background

This report presents the results of a geotechnical investigation undertaken by Geotechnical Consultants Australia Pty Ltd (GCA) for a proposed development at No. 25 Carpenter Crescent Warriewood NSW 2102 (the site). The investigation was commissioned by Mr. Wally Gebrael of Granny Flat Solutions (the client), and was carried out on the 26th November 2019.

The purpose of the investigation was to assess the subsurface conditions over the proposed development area (where accessible and feasible), and provide necessary recommendations from a geotechnical perspective for the proposed development.

The findings presented in this report are based on our subsurface investigation and our experience with subsurface conditions in the area. This report presents our assessment of the geotechnical conditions, and has been prepared to provide advice and recommendations to assist in the preparation of designs and construction of the ground structures for the proposed development.

For your review, **Attachment 1** contains a document prepared by GCA entitled "Important Information About Your Geotechnical Report", which summarises the general limitations, responsibilities, and use of geotechnical reports.

1.2 Provided Information

The following relevant information was provided to GCA prior to the site investigation and during preparation of this report:

- Architectural drawing prepared by Granny Flat Solutions, titled "Proposed 2 Bedroom Granny Flat 25 Carpenter Crescent, Warriewood", referenced job No. 193466, and included sheet nos. CDC 01 to CDC 05 inclusive.
- Site survey plan prepared by CC Surveying, titled "25 Carpenter Crescent Warriewood", referenced project No. 5251, page 1 of 1, and dated 1st May 2019.

1.3 Geotechnical Assessment Objectives

The objective of the geotechnical investigation was to assess the site surface and subsurface conditions at the borehole and testing locations (where accessible and feasible), and to provide professional geotechnical advice and recommendations on the following based on requirements provided to GCA by the client:

- Excavation conditions and recommendations on excavation methods in soils and rocks.
- Recommendations on suitable foundation types and design for the site.
- End bearing capacities and shaft adhesion for shallow and deep foundations based on the ground conditions within the site (for ultimate limit state and serviceability loads.
- Groundwater levels which may be determined during the site investigation.
- Preliminary site lot classification in accordance with Australian Standards (AS) 2870-2011.
- Preliminary wind classification in accordance with AS/New Zealand Standards (NZS) 1170.2-2011.
- General geotechnical advice on site preparation, filling and subgrade preparation.

1.4 Scope of Works

Fieldwork for the geotechnical investigation was undertaken by an experienced geotechnical engineer, following in general the guidelines outlined in AS 1726-2017. The scope of works included:

- Service locating carried out using electromagnetic detection equipment to ensure the area is free of any underground services at the selected boreholes and testing locations.
- Review of site plans and drawings to determine appropriate testing locations (where accessible and feasible), and identify any relevant features of the site.
- Hand augering of one (1) borehole within the proposed development area (where accessible and feasible), identified as borehole BH1, using hand operated equipment to a practical refusal depth of approximately 1.1m below the existing ground level (bgl) within the site.
- Dynamic Cone Penetrometer (DCP) testing immediately adjacent to borehole BH1, and at selected locations within the proposed development area (where accessible and feasible), identified as DCP1 and DCP2, and carried out to practical terminated and refusal depths of approximately 1.75m and 1.7m bgl.
    - The approximate locations of the hand augered borehole and DCP tests are shown on **Figure 1, Attachment 2** of this report.
- Collection of soil samples during augering for any laboratory testing which may be required.
- Reinstatement of the borehole with available soil displaced during augering.
- Preparation of this brief geotechnical engineering report.

1.5 Proposed Development and Site Description

Table 1 outlines a general description of the proposed development gathered from information provided by the client, along with the overall site description and its surroundings.

Table 1. Proposed Development, Overall Site Description and Site Surroundings

Information	Details
Proposed Development	Information provided by the client indicates the proposed development comprises construction of a secondary dwelling (granny flat) within the rear portion of the site. The Finished Floor Level (FFL) of the proposed developments ground floor level is set to be at Reduced Level (RL) 21.215m to RL21.300m Australian Height Datum (AHD). Based on this information and the existing site topography, cut and fill are expected to be required for construction of the proposed development, with locally deeper excavations for the proposed footings and services trenches.
Approximate Site Area[1]	714.5m^2
Local Government Authority	Northern Beaches Council
Site and Investigation Area Description	The site is located within a residential area along Carpenter Crescent carriageway. At the time of the investigation, a residential dwelling was present within the site, accompanied by associated concrete pavements and a detached garage. The remaining site area was predominately covered in grass, vegetation and a number of mature trees scattered throughout. It is noted that a Sydney Water main pipeline intersects the rear portion of the site, heading from the eastern to western site boundaries.
Approximate Distances to Nearest Watercourses (i.e. rivers, lakes, etc.)	• South Pacific Ocean/Tasman Sea – 340m east of the site.
Site Surroundings	The site is located within a residential area, and is bounded by: • Carpenter Crescent carriageway to the north. • Residential properties to the east, south and west.
Topography[3]	The local topography surrounding the site, as well as the site topography generally falls towards the south to south-east, and towards the east.
Regional Geology[2]	The site is located within a geological region generally underlain by Triassic Aged Newport and Garie Formation (Rnn).

[1]Site area is approximate and based off the site survey plan referenced in Section 1.2.
[2]Information obtained on the local regional subsurface conditions, referenced from the Department of Mineral Resources, Sydney 1:100,000 Geological Series Sheet 9130 First Edition, dated 1983, by the Geological Survey of New South Wales.
[3]It should be noted that the site topography, levels and slopes are approximate and based off observations made during the site investigation. The site and local topography and levels are expected to vary from those outlined in this report.

2. SUBSURFACE CONDITIONS AND ASSESSMENT RESULTS

2.1 Stratigraphy

A summary of the surface and subsurface conditions within the investigation area of the proposed development are summarised in the detailed engineering borehole logs presented in **Attachment 4**, and should be read in conjunction with the geotechnical explanatory notes detailed in **Attachment 3**. Rock description has been based on Pells P.J.N, Mostyn G. & Walker B.F. Foundations on Sandstone and Shale in the Sydney Region, Australian Geomechanics Journal, December 1998.

It should be noted that estimated soil consistency/strength assessed by during DCP testing in the site during the geotechnical investigation are approximate and variances should be expected throughout. Due to the variable ground conditions throughout the site, it is recommended that confirmation of the subsurface materials be carried out during construction by inspection, or by additional boreholes and testing. It should also be noted that ground conditions within the site are expected to differ from those encountered and inferred in this report, since no geotechnical or geological exploration program, no matter how comprehensive, can reveal and identify all subsurface conditions underlying the site.

From the borehole (BH1) carried out within the site, the subsurface conditions at the test location generally comprised:

- FILL material predominately comprising Silty CLAY, medium plasticity clay, gravel and sand inclusions, from the existing ground level within the site to a depth of approximately 0.4m (varying throughout), overlying:
- RESIDUAL Silty CLAY, medium to high plasticity, estimated firm to stiff, extending to depths of approximately (at least) 1.1m (varying throughout).

Based on the geotechnical investigation, along with our experience and observations made within the site and local region, it is inferred that bedrock of variable composition, strength and weathering is underlying the majority of the proposed development area at varying depths of approximately 1.7m to 1.8m, and is expected to vary throughout. Variable composition and consistency/strength natural soils are also likely to be present throughout the site, predominately at locations and depths not assessed during the geotechnical investigation.

Experience within the local region indicates the possibility of the presence of a hard, well-consolidated clayey layer, which may be inferred to be bedrock from the DCP test results (i.e. higher blow counts, "bouncing" at the DCP anvil, etc.). It is therefore recommended that this layer not be precluded during construction, and confirmation be carried out by a geotechnical engineer.

A summary of the inferred subsurface conditions encountered and inferred during DCP testing are summarised in Table 2 below, with the DCP testing results attached in **Attachment 5**. Ground conditions depicted in Table 2 below are inferred based on the DCP testing results, and confirmation should be carried out by additional testing or during construction by inspection. It should also be noted that the underlying subsurface conditions should be confirmed during construction of the proposed development as site conditions may vary throughout the site.

It should also be noted that DCP tests and higher blow counts encountered may be affected by factors such as gravels, ironstone bands, well consolidated soils and highly cemented sands, and other deleterious materials which may be present within the underlying soils, along with tree rootlets extending throughout the soils from trees and vegetation within the vicinity. These results should be read in conjunction with the boreholes, and geotechnical confirmation should be carried out during construction by inspection, or by additional borehole drilling and testing as site conditions may vary.

Table 2. Summary of Inferred Subsurface Conditions From DCP Testing

	DCP ID	**DCP1**	**DCP2**
Unit	**Unit Type**	**Depth/Thickness of Unit (m)**	
1	*Inferred* Fill[2]	0.0 – 0.4	0.0 – 0.4
2	Residual Soils[1]	0.4 – 1.75	0.4 – 1.7
3	*Inferred* Bedrock[3, 4]	1.8	1.7

[1]Estimated consistency/strength is based on DCP testing to the maximum refusal depth at the selected testing locations within the site. The potential for weak or softer layers throughout the unit should be considered.
[2]Assumed fill thickness based on DCP blow counts and observations made during the geotechnical investigation. Thickness of the fill layer is expected to vary from those indicated in Table 2.
[3]Inferred bedrock composition, continuity, strength and depth should be confirmed by a geotechnical engineering either prior to construction by additional boreholes and rock strength testing, or during construction by inspection. Bedrock inferred to be present at or shortly below the practical DCP testing refusal depths at the selected testing locations.
[4]The possibility for encountering a hard, well-consolidated clayey layer should not be precluded at these depths, based on our experience within the local region.
Notes:

- Clay seams, defects and fractured and extremely weathered zones are expected to be present throughout the underlying inferred bedrock, predominately at depths and locations unobserved during the geotechnical investigation.
- Ground conditions are expected to vary across the site, and should be confirmed by a geotechnical engineer, predominately in areas unobserved during the geotechnical investigation.

2.2 Groundwater

No groundwater was encountered or observed during the geotechnical investigation at all testing locations to a maximum depth of approximately 1.75m bgl. It is noted that borehole BH1 was immediately backfilled following completion of augering which precluded longer term monitoring of groundwater levels. Although no groundwater was encountered or observed during the investigation, its presence should not be precluded within the site and during construction.

Groundwater which may be present within the site is expected to be in the form of seepage through the voids within the underlying fill material, and through the pore spaces between particles of unconsolidated natural soils, or through networks of fractures and solution openings in consolidated inferred bedrock underlying the site.

It should be noted that groundwater levels have the potential to elevate during daily or seasonal influences such as tidal fluctuations, heavy rainfall, damaged services, flooding, etc., and moisture content within soils may be influenced by events within the site and adjoining properties. Groundwater monitoring should be carried out during construction, to assess any groundwater inflows within the site.

3. GEOTECHNICAL ASSESSMENT AND RECOMMENDATIONS

3.1 General Geotechnical Issues

The following aspects have been considered main geotechnical issues for the proposed development:

- Preliminary site lot classification.
- Excavation conditions.
- Foundations.

Based on results of our assessment, a summary of the geotechnical aspects above and recommendations for construction and designs are presented below.

3.2 Preliminary Site Lot Classification

Based on the geotechnical investigation and observations made during the site investigation, fill and residual soils are expected to be underlain by inferred bedrock at depths across the proposed development area of approximately 1.7m to 1.8m (varying throughout). Due to the site and subsurface conditions, no laboratory testing was carried out on any soils present underlying the proposed development area.

The governing site lot classification in accordance with AS 2870-2011 has been identified as **"Class P" (Problematic Site)** for the overall site, due to the presence of existing infrastructures (including the Sydney Water pipelines) and trees within and adjoining the site, causing abnormal and changing moisture conditions.

Based on the borehole and DCP tests carried out within the proposed development area, AS 2870-2011 indicates the site may be classified as a **"Class H1"** site, for design and construction of the foundation system founded below any topsoil, slopewash, fill or other deleterious material, being entirely on the inferred bedrock underlying the proposed development area (subject to confirmation).

This classification is solely based on assessment of the subsurface conditions are the selected borehole and testing locations within the site, and confirmation should be carried out as outlined in this report.

Foundation design and construction should be carried out as outlined in Section 3.4 below, with reference made to AS 2870-2011. Geotechnical inspections and confirmation of the actual depth of underlying fill material, natural soils and inferred bedrock should be made prior to construction by additional borehole drilling and rock strength testing, or during construction by inspection.

Where ground conditions vary from those outlined at the borehole and testing locations, and confirmation of the actual depth of underlying fill material, natural soils and inferred bedrock has not been carried out by a geotechnical engineer as outlined in this report, and where the building foundations are not proposed to be constructed on the inferred bedrock underlying the site, GCA should be contacted immediately, and the building foundations be designed and constructed as a "Class P" site.

Footing designs should take into consideration the effect of recent removal and planting of trees, along with any future tree removal within the vicinity of the proposed development on soil moisture conditions. Sufficient time should be given for soil moisture to re-equilibrate following any removal or planting of trees within the proposed development area, or specific engineering assessment and design will be required on the foundation design.

Although trees and vegetation are considered to contribute to the stability of the site, we recommend that planting of trees around the development area (i.e. in close proximity to the proposed building foundations) be limited as they can also affect moisture changes within the soil and cause significant displacement/damage within the building foundations by extensive tree root system movement.

Based on the preliminary site lot classification outlined above, it is recommended that reference is made to the recommendations provided by CSIRO "Guide to Home Owners on Foundation Maintenance and Footing Performance", attached as **Attachment 6**.

3.3 Excavation

Cut and fill are expected to be required for construction of the proposed development, with locally deeper excavations also anticipated to be required for the proposed building footings and service trenches across the site.

Based on this information and existing ground conditions as encountered during the geotechnical investigation, it is anticipated that excavation will extend through Unit 1 (fill) to Unit 2 (residual soils) throughout the majority of the site area, as discussed in Section 2.

Consultation should be made with subcontractors to discuss the feasibility and capability of machinery for the proposed development for the existing site conditions.

3.3.1 Excavation Assessment

Excavation through softer soils encountered during the geotechnical investigation should be feasible using conventional earth moving excavators, typically medium to large hydraulic excavators. Smaller sized excavators may encounter difficulty in high strength bands of soils and rocks which may be encountered. Where high strengths bands are encountered, rock breaking or ripping should be allowed for. Removal of the existing pavements and associated infrastructures within the site are also expected to require larger excavators and rock breaking and ripping.

Demolition, excavation and construction activities (or the like) will generate both vibration and noise, whilst being carried out within the site. Vibration control measures should be implemented as part of the construction process. All excavation works should be carried out in accordance with the NSW WorkCover code of practice for excavation work.

3.4 Foundations

Based on the geotechnical investigation and observations made during the geotechnical investigation within the proposed development area, fill and residual soils of variable composition and consistency/strength as discussed in Section 2 above are expected to underlie the majority of the proposed development area, overlying inferred bedrock (possibly hard, well-consolidated clayey layer) at varying depths throughout.

Variable strength residual soils and fill material are likely to result in total and differential settlement under working load, and not adequately support shallow foundations for the proposed development within the site. Removal of the fill material within the proposed development area should be carried out prior to construction of the proposed building foundation system.

It is noted that ground conditions within the site are expected to differ from those encountered and inferred in this report, since no geotechnical or geological exploration program, no matter how comprehensive, can reveal and identify all subsurface conditions underlying the site. It is therefore recommended that confirmation of the underlying ground conditions be confirmed by a geotechnical engineer prior to construction by additional borehole drilling and testing, or during construction by inspection.

3.4.1 Geotechnical Assessment

Based on the proposed development and assessment of the subsurface conditions, it is recommended that a piled foundation system be adopted for the proposed developments within the site, with the building footings supported on piles sufficiently embedded into the inferred bedrock underlying the proposed development area.

Bored piles sufficiently embedded into the underlying inferred bedrock may achieve a preliminary allowable bearing capacity of **500kPa** (extremely low to very low estimated strength), subject to confirmation by a geotechnical engineer. It should be noted that settlement behaviour, and pile and bearing capacities will vary significantly depending on the pile dimensions and actual depth of embedment, along with the method of installation.

Where inferred bedrock is not encountered, and bored piles are sufficiently embedded into estimated very stiff to hard (or better) clayey soils (or possible hard, well-consolidated clayey layer), a preliminary allowable bearing capacity of **300kPa** may be achieved.

Installation of piles should be complemented by inspections carried out by a geotechnical engineer during construction to confirm the allowable bearing capacities have been achieved. The actual depth and embedment of the piles should be assessed by the project structural engineer, with all structural elements also inspected and certified by a suitably qualified structural engineer.

Higher bearing capacities may be justified subject to confirmation by inspection during construction, or by additional borehole drilling and testing. Where higher estimated strength bedrock is encountered during construction, GCA should be contacted to re-assess the preliminary allowable bearing capacities provided in this report. Confirmation of the actual subsurface conditions underlying the proposed development area should also be carried out by a geotechnical engineer during construction, predominately the underlying inferred weathered bedrock.

Due to variable ground conditions and soil reactivity within the site (as discussed in Section 3.3), it is recommended that all foundations are constructed on consistent and competent strength bedrock throughout the proposed development area to provide uniform support and reduce the potential for total and differential settlement. Reference should be made to the estimated levels of the subsurface conditions outlined in this report, and compared to the final bulk excavation levels across the site.

We recommend geotechnical inspections, and additional boreholes and appropriate testing (such as rock strength testing) be carried out during construction to confirm the estimated allowable bearing capacities provided above have been achieved. Where ground conditions vary from those outlined in this report, GCA should be contacted immediately for further advise.

3.4.2 Geotechnical Comments

Bearing capacity and settlement behaviour varies according to foundation depth, shape and dimensions. Consultation should be made with specialist subcontractors to discuss the feasibility of piles for the existing site conditions. It should be noted that higher bearing capacities may be justified for the proposed foundations subject to confirmation by inspection during construction, or by additional borehole drilling and rock strength testing.

Foundations located within the “zone of influence” of any services or sensitive structures (i.e. Sydney Water pipelines) should be supported by a piled foundation. The depths of the piles should extend below the “zone of influence” and should ignore any shaft adhesion. Appropriate measures should be taken to ensure that any services or sensitive structures located within the “zone of influence” of the proposed development are not damaged during and following construction.

Consideration should also be given to the concrete encasement of the existing pipeline within the site. This should be carried out by a suitably qualified, licensed and accredited subcontractor, with assessment and inspections provided by a geotechnical engineer and appropriate asset co-ordinators/stakeholders.

Specific geotechnical advice should also be obtained for footing deigns and end bearing capacities, and design of the foundation system (shallow and pile foundations) should be carried out in accordance with AS 2870-2011 and AS 2159-2009.

It is recommended that suitable drainage and the use of impermeable surfaces be implemented as a precaution as part of the design and construction of the proposed development in order to divert surface water away from the building, and help eliminate or minimise surface water infiltration to minimise moisture within the soils. Although trees and vegetation are considered to contribute to the stability of the site, we recommend that planting of trees around the development area (i.e. in close proximity to the proposed building foundations) be limited as they can also affect moisture changes within the soil and cause significant displacement/damage within the building foundations by extensive tree root system movement.

The design and construction of the foundations should take into consideration the potential of flooding. All foundation excavations should be free of any loose debris and wet soils, and if groundwater seepage or runoff is encountered dewatering should be carried out prior to pouring concrete in the foundations. Due to the possibility of groundwater being encountered, or possible groundwater seepage during installation of bored piles within the site, it is recommended that consideration be given to other piling methods such as Continuous Flight Auger (CFA) piles.

Shaft adhesion may be applied to socketed piles adopted for foundations provided the socketed shaft lengths conform to appropriate classes of bedrock (subject to confirmation) in accordance with Pells et. al, and shaft sidewall cleanliness and roughness are to acceptable levels. Shaft adhesion should be ignored or reduced within socket lengths that are smeared or fail to satisfy cleanliness requirements (i.e. at least 80%). It is recommended that where piles penetrate expansive soils present within the site, which are susceptible to shrink and swell due to daily and seasonal moisture, shaft adhesion be ignored due to the potential of shrinkage cracking. Pile inspections should be complemented by downhole CCTV camera.

We recommend that geotechnical inspections of foundations be completed by an experienced geotechnical engineer to determine that the designed socket materials have been reached and the required bearing capacity has been achieved. The geotechnical engineer should also determine any variations between the boreholes carried out and inspected locations. Inspections should be carried out in dewatered foundations for a more accurate examination, and inspections should be carried out under satisfactory WHS requirements. Geotechnical inspections for verification capacities of the foundations should constitute as a “Hold Point”.

3.5 Preliminary Wind Classification

Selection methods used to identify the wind classification of the site from AS/NZS 1170.2-2011 indicates the site may be classified as **N2.**

3.6 Filling

Where filling is required, the following recommended compaction targets should be considered:

- Place horizontal loose layers not more than 150mm thickness over the prepared subgrade.
- Compact to a minimum dry density ratio not less than 98% of the maximum dry density for the building platforms.
- The moisture content during compaction should be maintained at ±2% of the Optimal Moisture Content (OMC).
- The upper 150mm of the subgrade should be compacted to a dry density ratio not less than 100% of the maximum dry density.

Any soils which are imported onto the site for the purpose of filling and compaction of the excavated areas should be free of deleterious materials and contamination. The imported soils should also include appropriate validation documentation in accordance with current regulatory authority requirements. The design and construction of earthworks should be carried out in accordance with AS 3798-2007 and AS 1289. Inspections of the prepared subgrade should be carried out by a geotechnical engineer, and should include proof rolling as a minimum. These inspections should be established as “Hold Points”.

3.7 Subgrade Preparation

The following are general recommendations on subgrade preparation for earthworks, slab on ground constructions and pavements:

- Remove existing fill and topsoil, including all materials which are unsuitable from the site.
- Excavate natural soils and rock.
  - Excavated material may be used for engineered fill.
  - Rock may be used for subgrade material underlying pavements.
- Any natural soils (predominately clayey soils) exposed at the bulk excavation level should be treated and have a moisture condition of 2% OMC. This should be followed by proof rolling and compaction of the upper 150mm layer.
  - Any soft or loose areas should be removed and replaced with engineered or approved fill material.
- Any rock exposed at the bulk excavation level should be clear of any deleterious materials (and free of loose or softened materials). As a guideline, remove an additional 150mm from the bulk excavation level.
- Ensure the foundations and excavated areas are free of water prior to concrete pouring.
- Areas which show visible heaving under compaction or proof rolling should be excavated at least 300mm and replaced with engineered or approved fill, and compacted to a minimum dry density ratio not less than 98% of the maximum dry density.

4. ADDITIONAL GEOTECHNICAL RECOMMENDATIONS

Following completion of the geotechnical investigation and report, GCA recommends the following additional work to be carried out:

- Dilapidation survey report on adjacent properties and infrastructures.
- Constant monitoring and supervision of any excavations which may be required during construction.
- Subsurface conditions and materials underlying the proposed development area (predominately inferred bedrock) should be confirmed either prior to construction by further borehole drilling and rock strength testing, or during construction by inspection from a geotechnical engineer.
- Geotechnical inspections of foundations (shallow and pile foundations) to confirm the preliminary bearing capacities have been achieved.
- Monitoring of any groundwater inflows during construction within the site.
- Classification of all excavated material transported from the site.
- A meeting to be carried out to discuss any geotechnical issues and inspection requirements.
- Final architectural and structural design drawings are provided to GCA for further assessment.

5. LIMITATIONS

Geotechnical Consultants Australia Pty Ltd (GCA) has based its geotechnical assessment on available information obtained prior and during the site inspection/investigation. The geotechnical assessment and recommendations provided in this report, along with the surface, subsurface and geotechnical conditions are limited to the inspection and test areas during the site inspection/investigation, and then only to the depths investigated at the time the work was carried out. Subsurface conditions can change abruptly, and may occur after GCA's field testing has been completed.

It is recommended that if for any reason, the site surface, subsurface and geotechnical conditions (including groundwater conditions) encountered during the site inspection/investigation vary substantially during construction, and from GCA's recommendations and conclusions, GCA should be contacted immediately for further testing and advice. This may be carried out as necessary, and a review of recommendations and conclusions may be provided at additional fees. GCA's advice and accuracy may be limited by undetected variations in ground conditions between sampling locations.

GCA does not accept any liability for any varying site conditions which have not been observed, and were out of the inspection or test areas, or accessible during the time of the investigation. This report and any associated information and documentations have been prepared solely for **Granny Flat Solutions**, and any misinterpretations or reliances by third parties of this report shall be at their own risk. Any legal or other liabilities resulting from the use of this report by other parties can not be religated to GCA.

This report should be read in full, including all conclusions and recommendations. Consultation should be made to GCA for any misundertandings or misinterpretations of this report.

For and behalf of

Geotechnical Consultants Australia Pty Ltd (GCA)

Joe Nader
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6. REFERENCES

Pells P.J.N, Mostyn, G. & Walker B.F., "Foundations on Sandstone and Shale in the Sydney Region", Australian Geomechanics Journal, 1998.

S 3600-2009 Concrete Structures. Standards Australia.

AS 1726-2017 Geotechnical Site Investigation. Standards Australia.

AS 3798-2007 Guidelines on Earthworks for Commercial and Residential Developments. Standards Australia.

AS 1289 Methods for Testing Soils for Engineering Purposes. Standards Australia.

AS 2870-2011 Residential Slabs and Footings. Standards Australia.

AS 2159-2009 Piling - Design and Installation. Standards Australia.

AS/NZS 1170.2-2011 Structural Design Actions, Part 2: Wind Actions. Standards Australia and New Zealand.

NSW WorkCover "Code of Practice – Excavation Work" (July 2015).

NSW Department of Mineral Resources (1983) Sydney 1:100,000 Geological Series Sheet 9130 (Edition 1) Geological Survey of New South Wales. Department of Mineral Resources.

NSW Planning Portal.

NSW Six Maps.

Enclosed Attachments

1 Important Information About Your Geotechnical Report
2 Site Plan (Figure 1)
3 Geotechnical Explanatory Notes
4 Engineering Borehole Logs
5 Dynamic Cone Penetrometer Test Results
6 Foundation Maintenance and Footing Performance – CSIRO

Important Information About Your
Geotechnical Report

This geotechnical report has been prepared based on the scopes outlined in the project proposal. The works carried out by Geotechnical Consultants Australia Pty Ltd (GCA), have limitations during the site investigation, and may be affected by a number of factors. Please read the geotechnical invesitgation report in conjunction with this "Important Information About Your Geotechnical Report".

Geotechnical Services Are Performed for Specicif Projects, Clients and Purposes.
Due to the fact that each geotechnical investigation is unique and varies from sites, each geotechnical report is unique, and is prepared soley for the client. A geotechnical report may satisfy the needs of structural engineer, where is will not for a civil engineer or construction contractor. No one except the client should rely on the geotechnical report without first conferring with the specific geotechnical consultant who prepared the report. The report is prepared for the contemplated project or original purpose of the investigation. No one should apply this report to any other or similar project.

Reading The Full Report.
Do not read selected elements of the report or tables/figures only. Serious problems have occurred because those relying on the specially prepared geotechnical invesitgation report did not read it all in full context.

The Geotechnical Report is Based on a Unique Set of Project And Specific Factors.
When preparing a geotechnical report, the geotechnical engineering consultant considers a number of unique factors for the specific project. These typially include:

- Clients objectives, goals and risk management preferences;
- The general proposed development or nature of the structure involved (size, location, etc.); and
- Future planned or existing site improvements (parking lots, roads, underground services, etc.);

Care should be taken into identifying the reason of the geotechnical report, where you should not rely on a geotechnical engineering report that was:

- Not prepared for your project;
- Not prepared for the specific site;
- Not prepared for you;
- Does not take into consideration any important changes made to the project; or
- Was carried out prior to any new infrastructure on your subject site.

Typical changes that can affect the reliabiliy if an existing geotechical investigation report include those that affect:

- The function of the proposed structure, where it may change from one basement level to two basement levels, or from a light structure to a heavy loaded structure;
- Location, size, elevation or configuration of the proposed development;
- Changes in the structural design occur; or
- The owner of the proposed development/project has changed.

The geotecnical engineer of the project should always be notified of any changes – even minor – and be asked to evaluate if this has any impact. GCA does not accept responsibility or liability for problems that occur because its report did not consider developments which it was not informed of.

Subsurface Conditions Can Change
This report is based on conditions that existed at the time of the investigation, at the locations of the subsurface tests (i.e. boreholes) carried out during the site investigation. Subfurface conditions can be affected and modified by a number of factores including, but not limited to, the passage of time, man-made influences such as construction on or adjacent to the site, by natural forces such as floods, groundwater fluctuations or earthquakes. GCA should be contacted prior to submitting its report to determine if any further testing may be required. A minor amount of additional testing may prevent any major problems.

Geotechnical Findings Are Professional Opinions
Results of subsurface conditions are limited only to the points where the subsurface tests were carried out, or where samples were collected. The field and laboratory data is analysed and reviewed by a geotechnical engineer, who then applys their professional experience and recommendations about the site's subsurface conditions. Despite investigation, the actual subsurface conditions may differ – in some cases significantly – from the results presented in the geotechnical investigation report, since no subsurface exploration program, no matter how comprehensive, can reveal all subsurface anomalies and details.

Therefore, the recommendations in this report can only be used as preliminary. Retaining GCA as your geotechnical consultants on your project to provide construction observations is the most effective method of managing the risks associated with unanticipated subsurface conditions.

Geotechnical Report's Recommendations Are Not Final
Because geotechnical engineers provide recommendations based on experience and judgement, you should not overrely on the recommendations provided – they are not final. Only by observing the actual subsurface conditions revealed during construction may a geotechnical engineer finalise their recommendations. GCA does not assume responsibility or liability for the report's recommendations if no additional observations or testing is carried out.

Geotechnical Report's Are Subject to Misinterpretations
The project geotechnical engineer should consult with appropriate members of the design team following submission of the report. You should review your design teams plans and drawings, in conjunction with the geotechnical report to ensure they have all be incorporated. Due to many issues arising from misinterpretation of geotechnical reports between design teams and building contractors, GCA should participate in pre-construction meetings, and provide adequate construction observations.

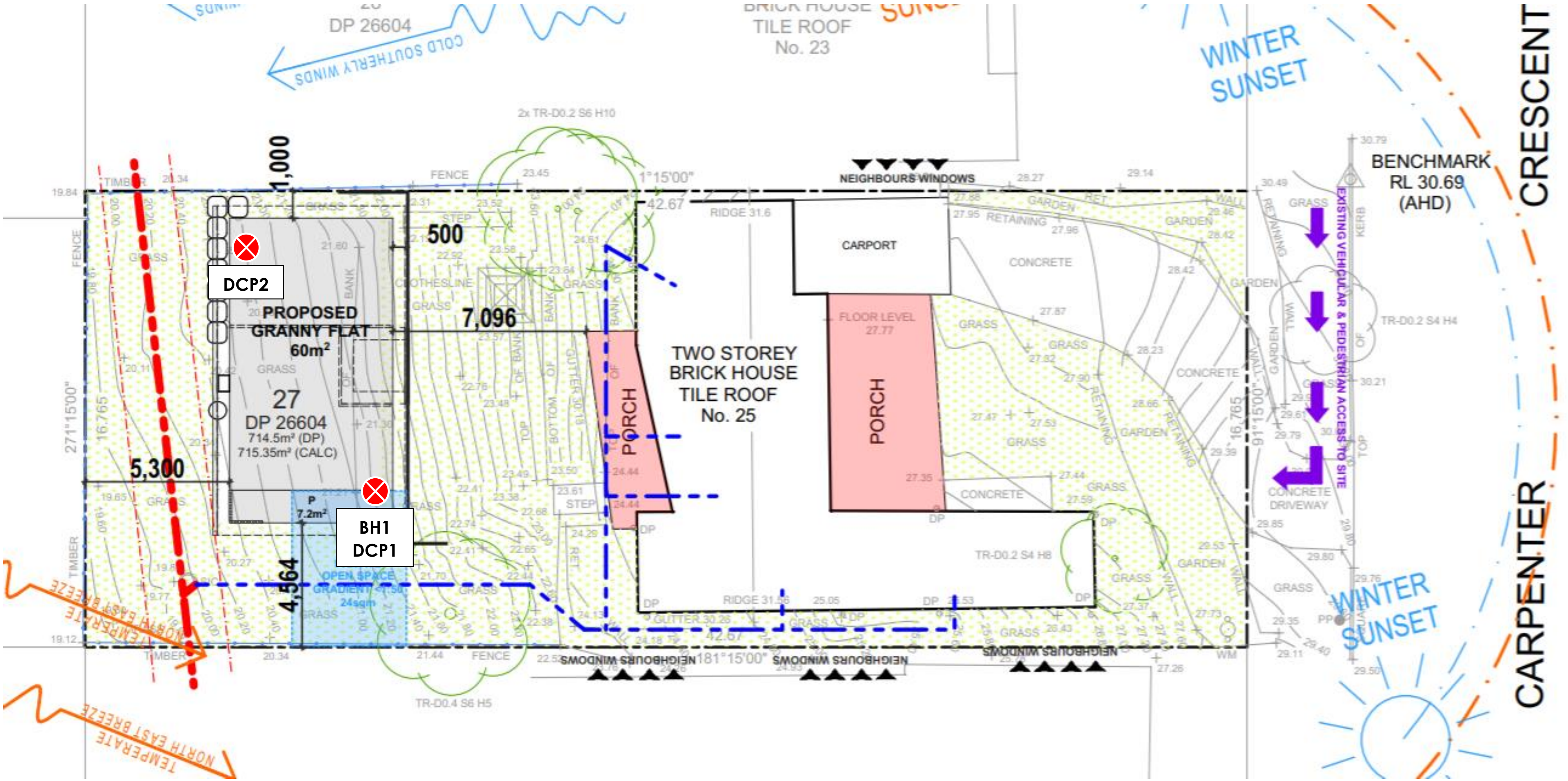
Engineering Borehole Logs And Data Should Not be Redrawn
Geotechnical engineers prepare final borehole and testing logs, figure, etc. based on results and interpretation of field logs and laboratory data following the site investigation. The logs, figure, etc. provided in the geotechnical report should never be redrawn or altered for inclusion in any other documents from this report, includined architectural or other design drawings.

Providing The Full Geotechnical Report For Guidance
The project design teams, subcontactors and building contractors should have a copy of the full geotechnical investigation report to help prevent any costly issues. This should be prefaced with a clearly written letter of transmittal. The letter should clearly advise the aforementioned that the report was prepared for proposed development/project requirements, and the report accuracy is limited. The letter should also encourage them to confer with GCA, and/or carry out further testing as may be required. Providing the report to your project team will help share the financial responsibilities stemming from any unanticipated issues or conditions in the site.

Understanding Limitation Provisions
As some clients, contractors and design professionals do not recognise geotechnical engineering is much broader and less exact than other engineering disciplines, this creates unrealistic expectations that lead to claims, disputs and other disappointments. As part of the geotechnical report, (in most cases) a 'limitations' explanatory provision is included, outlining the geotechnical engineers' limitations for your project – with the geotechnical engineers responsibilites to help other reduce their own. This should be read closely as part of your report.

Other Limitations
GCA will not be liable to revise or update the report to take into account any events or circumstances (seen or unforeseen), or any fact occurring or becoming apparent after the date of the report. This report is the subject of copyright and shall not be reproduced either totally or in part without the express permission of GCA. The report should not be used if there have been changes to the project, without first consulting with GCA to assess if the report's recommendations are still valid. GCA does not accept any responsibility for problems that occur due to project changes which have not been consulted.

Legend: Approximate Borehole/DCP Testing Location



GCA Geotechnical Consultants Australia	Figure 1 Site Plan	**Geotechnical Investigation and Site Lot Classification Report**	Drawn: GN/GA	
		Granny Flat Solutions	Date: 27/11/2019	
	Job No.: G19360-1	25 Carpenter Crescent Warriewood NSW 2102	Scale: NTS	

Image source: Architectural drawing prepared by Granny Flat Solutions, titled "Proposed 2 Bedroom Granny Flat 25 Carpenter Crescent, Warriewood", referenced job No. 193466, and sheet No. CDC 02.

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Explanation of Notes, Abbreviations and Terms Used on Borehole and Test Pit Reports

DRILLING/EXCAVATION METHOD

Method	Description
AS	Auger Screwing
BH	Backhoe
CT	Cable Tool Rig
EE	Existing Excavation/Cutting
EX	Excavator
HA	Hand Auger
HQ	Diamond Core-63mm
JET	Jetting
NMLC	Diamond Core –52mm
NQ	Diamond Core –47mm
PT	Push Tube
RAB	Rotary Air Blast
RB	Rotary Blade
RT	Rotary Tricone Bit
TC	Auger TC Bit
V	Auger V Bit
WB	Washbore
DT	Diatube

PENETRATIION/EXCAVATION RESISTANCE

These assessments are subjective and dependant on many factors including the equipment weight, power, condition of the drilling tools or excavation, and the experience of the operator..

L **Low Resistance.** Rapid penetration possible with little effort from the equipment used.
M **Medium Resistance.** Excavation possible at an acceptable rate with moderate effort required from the equipment used.
H **High Resistance.** Further penetration is possible at a slow rate and required significant effort from the equipment.
R **Refusal or Practical Refusal.** No further progress possible within the risk of damage or excessive wear to the equipment used.

WATER

Water level at date shown — ◁ Partial water loss

▷ Water inflow — ◀ Complete water loss

Groundwater not observed: The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.

Groundwater not encountered: No free-flowing (springs or seepage) was intercepted, although the soil may be moist due to capillary water. Water may be observed in low permeable soils if the test pits/boreholes had been left open for at least 12-24 hours.

MOISTURE CONDITION (AS 1726-1993)

Dry - Cohesive soils are friable or powdery
Cohesionless soil grains are free-running

Moist - Soil feels cool, darkened in colour
Cohesive soils can be moulded
Cohesionless soil grains tend to adhere

Wet - Cohesive soils usually weakened
Free water forms on hands when handling

For cohesive soils the following codes may also be used:

MC>PL Moisture Content greater than the Plastic Limit.
MC~PL Moisture Content near the Plastic Limit.
MC<PL Moisture Content less than the Plastic Limit.

SAMPLING AND TESTING

Sample	Description
B	Bulk Disturbed Sample
DS	Disturbed Sample
Jar	Jar Sample
SPT*	Standard Penetration Test
U50	Undisturbed Sample –50mm
U75	Undisturbed Sample –75mm

*SPT (4, 7, 11 N=18). 4, 7, 11 = Blows per 150mm. N= Blows per 300mm penetration following 150mm sealing.
SPT (30/80mm). Where practical refusal occurs, the blows and penetration for that interval is recorded.

ROCK QUALITY

The fracture spacing is shown where applicable and the Rock Quality Designation (RQD) or Total Core Recovery (TCR) is given where:

$$TCR\ (\%) = \frac{\text{length of core recovered}}{\text{length of core run}}$$

$$RQD\ (\%) = \frac{\text{Sum of Axial lengths of core > 100mm long}}{\text{length of core run}}$$

ROCK STRENGTH TEST RESULTS

● Diametral Point Load Index test

■ Axial Point Load Index test

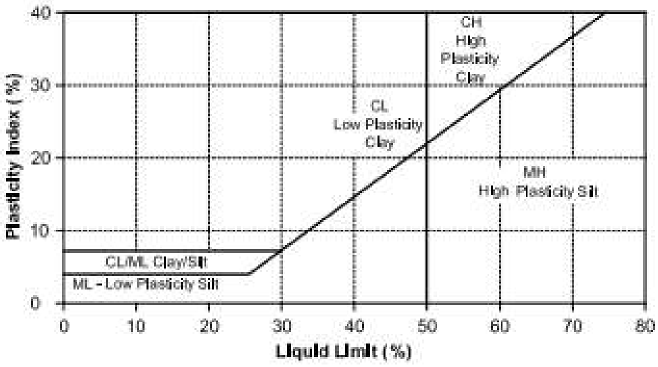
Method and Terms for Soil and Rock Descriptions Used on Borehole and Test Pit Reports

Soil and Rock is classified and described in reports of boreholes and test pits using the preferred method given in AS 1726-1993, Appendix A. The material properties are assessed in the field by visual/tactile methods. The appropriate symbols in the Unified Soil Classification are selected on the result of visual examination, field tests and available laboratory tests, such as, sieve analysis, liquid limit and plasticity index.

COHESIONLESS SOILS PARTICLE SIZE DESCRIPTIVE TERMS

Name	Subdivision	Size
Boulders		>200 mm
Cobbles		63 mm to 200 mm
Gravel	coarse	20 mm to 63 mm
	medium	6 mm to 20 mm
	fine	2.36 mm to 6 mm
Sand	coarse	600 µm to 2.36 mm
	medium	200 µm to 600 µm
	fine	75 µm to 200 µm

PLASTICITY PROPERTIES



COHESIVE SOILS – CONSISTENCY (AS 1726-1993)

Strength	Symbol	Undrained Shear Strength, C_u (kPa)
Very Soft	VS	< 12
Soft	S	12 to 25
Firm	F	25 to 50
Stiff	St	50 to 100
Very Stiff	VSt	100 to 200
Hard	H	> 200

PLASTICITY

Description of Plasticity	LL (%)
Low	<35
Medium	35 to 50
High	>50

COHESIONLESS SOILS - RELATIVE DENSITY

Term	Symbol	Density Index	N Value (blows/0.3 m)
Very Loose	VL	0 to 15	0 to 4
Loose	L	15 to 35	4 to 10
Medium Dense	MD	35 to 65	10 to 30
Dense	D	65 to 85	30 to 50
Very Dense	VD	>85	>50

UNIFIED SOIL CLASSIFICATION

USC Symbol	Description
GW	Well graded gravel
GP	Poorly graded gravel
GM	Silty gravel
GC	Clayey gravel
SW	Well graded sand
SP	Poorly graded sand
SM	Silty sand
SC	Clayey sand
ML	Silt of low plasticity
CL	Clay of low plasticity
OL	Organic soil of low plasticity
MH	Silt of high plasticity
CH	Clay of high plasticity
OH	Organic soil of high plasticity
Pt	Peaty Soil

ROCK MATERIAL WEATHERING

Symbol	Term	Definition
RS	Residual Soil	Soil definition on extremely weathered rock; the mass structure and substance are no longer evident; there is a large change in volume but the soil has not been significantly transported
EW	Extremely Weathered	Rock is weathered to such an extent that it has 'soil' properties, i.e. It either disintegrates or can be remoulded in water
HW } *DW*	Highly Weathered *Distinctly Weathered (as per AS 1726)*	The rock substance is affected by weathering to the extent that limonite staining or bleaching affects the whole rock substance and other signs of chemical or physical decomposition are evident. Porosity and strength is usually decreased compared to the fresh rock. The colour and strength of the fresh rock is no longer recognisable.
MW	Moderately Weathered	The whole of the rock substance is discoloured, usually by iron staining or bleaching, to the extent that the colour of the fresh rock is no longer recognisable
SW	Slightly Weathered	Rock is slightly discoloured but shows little or no change of strength from fresh rock
FR	Fresh	Rock shows no sign of decomposition or staining

ROCK STRENGTH (AS 1726-1993 and ISRM)

Term	Symbol	Point Load Index $Is_{(50)}$ (MPa)
Extremely Low	EL	<0.03
Very Low	VL	0.03 to 0.1
Low	L	0.1 to 0.3
Medium	M	0.3 to 1
High	H	1 to 3
Very High	VH	3 to 10
Extremely High	EH	>10

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ABREVIATIONS FOR DEFECT TYPES AND DECRIPTIONS

Term	Defect Spacing	Bedding
Extremely closely spaced	<6 mm	Thinly Laminated
	6 to 20 mm	Laminated
Very closely spaced	20 to 60 mm	Very Thin
Closely spaced	0.06 to 0.2 m	Thin
Moderately widely spaced	0.2 to 0.6 m	Medium
Widely spaced	0.6 to 2 m	Thick
Very widely spaced	>2 m	Very Thick

Type	Definition
B	Bedding
J	Joint
HJ	Horizontal to Sub-Horizontal Joint
F	Fault
Cle	Cleavage
SZ	Shear Zone
FZ	Fractured Zone
CZ	Crushed Zone
MB	Mechanical Break
HB	Handling Break

Planarity	Roughness
P – Planar	C – Clean
Ir – Irregular	Cl – Clay
St – Stepped	VR – Very Rough
U - Undulating	R – Rough
	S – Smooth
	Sl – Slickensides
	Po – Polished
	Fe – Iron

Coating or Infill	Description
Clean (C)	No visible coating or infilling
Stain	No visible coating or infilling but surfaces are discoloured by mineral staining
Veneer	A visible coating or infilling of soil or mineral substance but usually unable to be measured (<1mm). If discontinuous over the plane, patchy veneer
Coating	A visible coating or infilling of soil or mineral substance, >1mm thick. Describe composition and thickness
Iron (Fe)	Iron Staining or Infill.

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BOREHOLE NUMBER BH1

CLIENT Granny Flat Solutions
PROJECT NAME Geotechnical Investigation
PROJECT NUMBER G19360-1
PROJECT LOCATION 25 Carpenter Crescent Warriewood NSW 2102

DATE STARTED 26/11/19 **COMPLETED** 26/11/19
R.L. SURFACE
DATUM
DRILLING CONTRACTOR Geotechnical Consultants Australia Pty Ltd
SLOPE 90°
BEARING ---
EQUIPMENT Hand Operated Equipment
HOLE LOCATION Refer To Site Plan (Figure 1) For Test Locations
HOLE SIZE 100mm Diameter
LOGGED BY JN
CHECKED BY JN
NOTES RL To The Top Of The Borehole & Depths Of The Subsurface Conditions Are Approximate

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Additional Observations
HA	Not Encountered During Augering					Silty CLAY, medium plasticity, brown to dark brown, brownish orange laminations, some fine grained sand, some fine to medium grained gravel, organics, moist.		FILL
			0.5		CI-CH	Silty CLAY, medium to high plasticity, brown to brownish orange, reddish brown and grey laminations, some fine grained gravel, moist, estimated firm to stiff.		RESIDUAL SOILS
			1.0			some ironstone bands from 1.0m bgl.		
						Practical hand auger refusal at 1.1m bgl. Borehole BH1 terminated at 1.1m		
			1.5					
			2.0					

DYNAMIC CONE PENETOMETER RESULTS

Client:	Granny Flat Solutions	**Test Date:**	26/11/2019
Address:	25 Carpenter Crescent Warriewood NSW 2102	**Job No.:**	G19360-1

Depths (mm bgl)	**DCP No.**				**Depths (mm bgl)**	**DCP No.**			
	1	**2**							
0-100	1	2			0-100				
100-200	1	2			100-200				
200-300	1	7			200-300				
300-400	2	7			300-400				
400-500	2	3			400-500				
500-600	2	2			500-600				
600-700	2	3			600-700				
700-800	3	2			700-800				
800-900	3	4			800-900				
900-1000	5	5			900-1000				
1000-1100	7	7			1000-1100				
1100-1200	12	10			1100-1200				
1200-1300	15	10			1200-1300				
1300-1400	17	10			1300-1400				
1400-1500	16	5			1400-1500				
1500-1600	24	5			1500-1600				
1600-1700	32	20			1600-1700				
1700-1800	20/50mm	**Bouncing**			1700-1800				
1800-1900	**Terminated**				1800-1900				
1900-2000					1900-2000				
2000-2100					2000-2100				
2100-2200					2100-2200				
2200-2300					2200-2300				
2300-2400					2300-2400				
2400-2500					2400-2500				
2500-2600					2500-2600				
2600-2700					2600-2700				
2700-2800					2700-2800				
2800-2900					2800-2900				
2900-3000					2900-3000				
3000-3100					3000-3100				
3100-3200					3100-3200				
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3500-3600					3500-3600				
3600-3700					3600-3700				
3700-3800					3700-3800				
3800-3900					3800-3900				
3900-4000					3900-4000				

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Tested:	GN/GA		**Sheet:**	**1 of 1**

Foundation Maintenance and Footing Performance: A Homeowner's Guide

BTF 18 replaces Information Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

Settlement due to construction

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

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

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

Erosion

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

Saturation

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

Seasonal swelling and shrinkage of soil

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

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

Shear failure

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

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

GENERAL DEFINITIONS OF SITE CLASSES

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

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

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

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

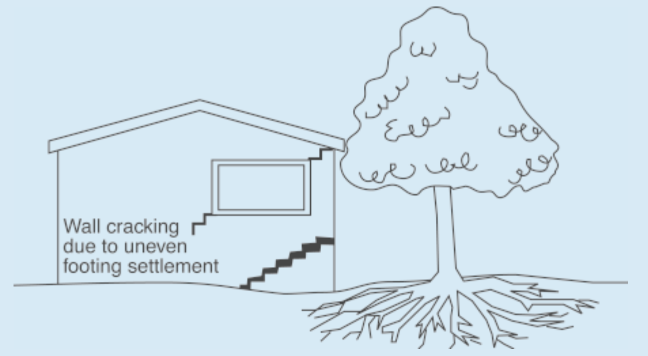
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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

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

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

Trees can cause shrinkage and damage



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

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

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

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

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

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

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

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

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

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

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

Effects on framed structures

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

Effects on brick veneer structures

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

Water Service and Drainage

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

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.

Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

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

Seriousness of Cracking

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

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

Prevention/Cure

Plumbing

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

Ground drainage

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

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

Protection of the building perimeter

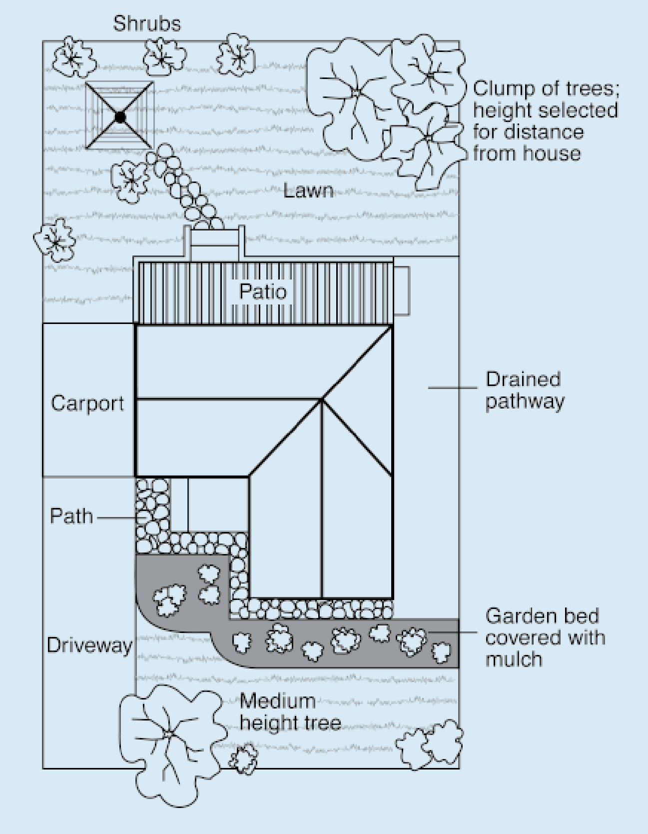
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

Gardens for a reactive site



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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