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Reference: 7787-4-R1 Rev2
25 August 2026

Kosciuszko Thredbo Pty Ltd
By email: chris_byrnes@evt.com

**Attention: Chris Byrnes**

Dear Chris,

# Proposed Installation of Snowmaking Unit No 2, Friday Flat, Thredbo NSW Geotechnical Assessment

## 1 INTRODUCTION

### 1.1 General

This report presents the results of a geotechnical assessment for a Proposed Installation of Snowmaking Unit No 2 at Friday Flat, Thredbo NSW (the Site). The assessment was commissioned by Chloe Chalk of Kosciuszko Thredbo Pty Ltd. This follows on from a geotechnical assessment for Snowmaking Unit No 1 (reference 7604-R1 Rev 3 dated 28 January 2025).

Documents been supplied to us for this assessment are as follows:

- Site Plan prepared by Kosciuszko Thredbo Pty Ltd, project 'Snowmaking All Weather Unit 2', reference 25002-001-r1, edition 1, dated 18 August 2026.
- Cut and Fill Plan.1 by Kosciuszko Thredbo Pty Ltd, project 'Friday Flat Snowmaking Unit 2', reference 25002_002_r1, dated 18 August 2026.
- Cut and Fill Section.1 by Kosciuszko Thredbo Pty Ltd, project 'Friday Flat Snowmaking Unit 2', reference 25002_002.2_r1, dated 18 August 2026.
- Product specifications sheet prepared by KTI-Plersch Kältetechnik GmbH, for model CPSP 360 kpl Doku (SnowPro 400), ref 10067243, dwg 00, dated 26 September 2025.

Based on the supplied drawings, we understand that the project involves installation of a snowmaking unit located approximately 79m northwest and upslope of Unit No 1 in Friday Flat with associated underground snow feeder pipes and distribution pits for purpose of distributing snow. We also understand that the AW snowmaking unit (400 model) will be used, which weighs approximately 35 tonnes and will be supported by a concrete slab on ground, approximately 4m wide by 15m long. Seven new pits are proposed, typically 1.2 x 1.2 x 1.2m precast concrete pits.

Based on the supplied trench detail drawing, it is understood that a total of seven 100mm diameter snow distribution pipes to pits to be installed in four separate snow distribution trenches between 300mm and 450mm wide with minimum 250mm cover, total trench depth nominal 500mm.

A combined water, stormwater, and control cable trench is also proposed, 450mm wide by 600mm depth with approximately 400mm cover.

Also, a retaining wall is required around most of the installation, ranging up to 2.5m height at the western end over a narrow width of less than 5m. The retaining structure is likely to be concrete sleepers slotted into vertically mounted steel U beam. The beam will be concreted in piers with depth equal to wall height.

Whilst the site lies within an area designated as “G” as defined in the maps accompanying DIPNR’s “Geotechnical Policy – Kosciuszko Alpine Resorts”, November 2003, considering the minimal extent required for the development and the low bearing pressure imposed on the ground by the structure, the development is considered ‘minimal impact’ and a full geotechnical report is not required to accompany the development application as per the requirements of the Geotechnical Policy. Notwithstanding, this report provides recommendations for design and construction of the development to ensure that geotechnical impacts remain at ‘minimal’.

## 1.2 Scope of Work

The objective of the Geotechnical Assessment is to provide information on the surface conditions and likely subsurface conditions, and to provide a Site Classification to AS2870-2011 'Residential Slabs and Footings' and a Form 4 certification with design recommendations.

The following scope of work was carried out to achieve the project objectives:

- Review of available reports and maps held within our files, especially focusing on invasive investigations carried out by Asset in the vicinity of the proposed snow factory (ref: 6262-G1; dated: 2 November 2020, and ref: 6751-G1; dated: 6 February 2022).
- Desktop study, engineering assessment, and reporting including Form 4 for minimal impact certification.

Our report describes the surface and subsurface conditions and provides recommendations on:

- Key geotechnical constraints to the development.
- Subgrade preparation and earthworks.
- Suitable foundation options.
- Settlement.
- Site Classification as per AS2870 ‘Residential Slabs and Footings’ (2011).

# 2 SITE DESCRIPTION

The proposed installation site is located about 79m northwest of Unit No 1 in Friday Flats. The Site is located on gently undulating terrain that generally slopes down to the southwest at about 7° to 10° towards Friday Drive. Photo 1 shows a view of the proposed installation. The Site is bounded to the east by Gunbarrel Express Bottom Station and elsewhere by grass land.

Topographically, the Site is situated at the toe of a gentle slope of about 10° to 12° up to the northwest before again increasing to about 22° to 26°. Heavy populated buried services are located to the north- east of the Site.

The 1:250,000 Tallangatta Geological Map indicates the site is underlain by Silurian aged intrusive granite.

# 3 SUBSURFACE CONDITIONS

## 3.1 General

The geotechnical investigation previously conducted by Asset located closest to the proposed installation site is job number 6262 completed in 2020. The invasive investigation included excavation of test pits at eight locations using a Kubota U17–3 excavator. The test pits were terminated at depths ranging from 1 m to 1.5 m. Specifically, results from test pits numbered 4, 5, and 6 are used for the geological assessment due to their proximity to the proposed snowmaking installation site. Test pits 4 and 5 located at about 30 metres to the East of the installation site and test pit 6 located at about 50 metres to the West of the installation site.

Also, results from 4 hand-augered boreholes from job number 6751 (dated 29 Nov 2021) have been assessed. The invasive investigation at this job included drilling of hand auger boreholes and conducting Dynamic Cone Penetrometer (DCP) soundings at four locations. The boreholes were auger drilled to depths of 0.2m to 0.72 below ground level (bgl) and were discontinued at the recorded depths due to reaching refusal on inferred weathered granite and or very stiff to hard clayey fill soil. The DCP soundings were terminated at depths of 0.2m to 1.3m at 'solid' refusal on inferred Granite bedrock or boulder.

A marked-up plan showing these test locations in relation to the proposed installation site is attached.

## 3.2 Stratigraphy

A generalised geotechnical model for the Site has been developed is shown in Table 1 based on log results from test pits 4, 5 and 6 from job number 6262. For a detailed description of the subsurface conditions, refer the attached engineering logs and explanatory notes.

**Table 1 – Generalised Site Geotechnical Model**

| Unit | Origin | Description | Depth to Top of Unit [1] (m) | Unit Thickness [1] (m) |
|---|---|---|---|---|
| 1 | Topsoil | SILT, medium plasticity, dark grey, grass roots | Ground surface | 0.2 |
| 2 | Fill | GRAVEL, fine to medium grained, over geofabric | Ground surface | 0.1 |
| 2a | Fill | Mixture of Clayey SAND and Cobbles and small boulders to 300mm size, tree roots. TP6 only | 0.1 | 1.2 |
| 3 | Colluvium | CLAY, medium plasticity, dark brown to orange-brown, some cobbles to 200mm | 0.1 | 1.4 |
| 4 | Residual | Clayey SAND, medium to coarse grained, light grey/brown. COMPLETELY WEATHERED GRANITE | 1.2 | Not proven beyond a depth of 1.4 |

**Notes:**

1. The depths and layer thicknesses are based only on the test locations, so they might not show the deepest or shallowest points across the whole site.

## 3.3 Groundwater

Groundwater was not observed in the test pits during excavation to depths of 1.4m to 1.6m bgl. It is noted that the groundwater observation may have been made before water levels had stabilised. No long-term groundwater monitoring was carried out.

# 4 DISCUSSIONS & RECOMMENDATIONS

The excavation for the proposed work is expected to range from 0.6m to 1m depth for the strip footing and Snow Distribution Pipe layout, and up to about 2.5m for the retaining wall at the high end of the snowmaking slab and is anticipated to be almost entirely within soils of variable nature including fill and possibly completely weathered granite and cobbles. Rock excavation may be encountered in the lower part of the excavation and possibly some boulders may be encountered above rock. Filling is generally not expected except for trench backfill and minor filling of up to about 0.5m to 1m thickness on the low end of the snowmaking slab.

The proposed works will have 'minimal geotechnical impact' on the site, based on the generally relatively shallow depths of excavation required (and the deepest part of the excavation being relatively narrow (at about 4m to 5m width), the relatively low bearing pressure beneath the footings, and the lack of obvious signs of hillside instability observed or expected. A completed Form 4 – Minimal Impact Certification – is attached to this report. Recommendations for the development are provided in the following sections.

## 4.1 Subgrade Preparation

The following general recommendations are provided for subgrade preparation for earthworks, proposed strip footings, and minor structures:

- Strip existing topsoil.
- Excavate to a suitable subgrade (firm or better clays / medium dense or better sandy soils).

Any waste soils being removed from the Site must be classified in accordance with current regulatory authority requirements to enable appropriate disposal to an appropriately licensed landfill facility.

## 4.2 Filling

Where filling (anticipated to be minor, less than say 0.5m to 1m depth) is required, spread in horizontal layers over the prepared ground and compact it according to the guidelines in Table 2.

**Table 2 – Compaction Specifications**

| Parameter | Cohesive Fill | Non-Cohesive Fill |
|---|---|---|
| Fill layer thickness (loose measurement): | | |
| • Within 1.5m of the rear of retaining walls | 0.2m | 0.2m |
| • Elsewhere | 0.3m | 0.3m |
| Density: | | |
| • Beneath Pavements | ≥ 95% Std | ≥ 70% ID |
| • Beneath Structures | ≥ 98% Std | ≥ 80% ID |
| • Upper 150mm of subgrade | ≥ 100% Std | ≥ 80% ID |
| Moisture content during compaction | ± 2% of optimum | Moist but not wet |

Any soil brought to the site for backfilling must be free from contamination and be provided with documents proving it's suitable for the intended use, in line with current regulations.

### 4.2.1 Batter Slopes

Excavations are anticipated to range from minor (less than about 1m depth) to substantial (up to about 2.5m depth). Temporary batter slopes may be cut vertically up to 1m depth. Recommended maximum slopes for temporary batters greater than 1m and up to 2.5m depth, should they be required, are presented in Table 3.

**Table 3 – Recommended Maximum Temporary Dry Batter Slopes (>1m to 2.5m depth)**

| Unit | Maximum Temporary Dry Batter Slope (H : V) |
|---|---|
| Residual Clay & colluvium & fill | 1 : 1 |
| Completely weathered Granite | 0.75 : 1 |
| Highly weathered Granite | 0.5 : 1 |

## 4.3 Site Classification

Due to the presence of fill, the Site is classified as a Class P (Problem) Site in accordance with AS 2870–2011 "Residential Slabs and Footings". This requires that footings be designed from first principles rather than relying on standard footings in AS2870-2011.

## 4.4 Footings

Based on the structure drawing and information provided in the product specifications sheet, the average bearing pressure beneath the footings is expected to be insignificant. An allowable bearing pressure of 100kPa may be adopted for the firm or better clays / medium dense or better sands below the strip footings. Footing excavations should be inspected to verify that suitable founding material has been reached.

## 4.5 Excavation Support

It is expected that temporary batter slopes as per Section 4.2.1 can be accommodated in the development, and temporary shoring will therefore not be required. Permanent retaining is to be provided by a cantilever retaining wall, which may be designed for the parameters given in Table 4, using a triangular earth pressure distribution with the lateral pressure being determined as follows:

$\sigma_z = K_{o,a,p} \times z \times \gamma$ where $\sigma_z$ = lateral earth pressure (kPa) at depth z
$K_{o,a,p}$ = earth pressure coefficient
o = 'at rest', a = 'active', p = 'passive'
$z$ = depth (m)
$\gamma$ = unit weight of soil / rock (kN/m$^3$)

### Table 4 – Excavation Support Design Parameters

| Material | Moist Unit Weight ($\gamma_m$) kN/m$^3$ | 'Active' Lateral Earth Pressure Coefficient $^{(1)}$ ($K_a$) | 'At Rest' Coefficient $^{(1)}$ ($K_o$) | 'Passive' Coefficient $^{(2)}$ ($K_p$) |
|---|---|---|---|---|
| Residual Clay & Colluvium & Fill | 18.0 | 0.35 | 0.5 | N/A |
| Completely weathered granite | 20.0 | 0.3 | 0.5 | 5 |
| Highly weathered granite | 22.0 | 0.1 | 0.3 | 15 |

**Notes to table:**

1. These values assume that some wall movement and relaxation of horizontal stress will occur due to the excavation. Actual in-situ $K_0$ values may be higher, particularly in the rock units.
2. Includes a reduction factor to the ultimate value of $K_p$ to consider strain incompatibility between active and passive pressure conditions. Parameters assume horizontal backfill and no back of wall friction.

The parameters for the 'at rest' condition ($K_o$) should be used for the design of lateral earth pressures where adjacent footings / structures / services are located within the 'zone of influence' of the wall. The 'zone of influence' may be taken as a line extending upwards and outwards at 45° above horizontal from the base of the wall. Piles for cantilever walls should be socketed below bulk excavation level by a depth at least equal to the retained height. For assessment of passive restraint embedded below excavation level, we recommend a triangular pressure distribution.

Allowance must also be made for surcharge loadings behind the retaining wall.

Where an adequate subsoil drainage system designed by an appropriately qualified and experienced Hydraulic / Stormwater Engineer is provided behind retaining walls, no allowance for hydrostatic pressure would be necessary.

# 5 LIMITATIONS

In addition to the limitations inherent in site investigations (refer to the attached Information Sheets), it must be pointed out that the recommendations in this report are based on assessed subsurface conditions from limited investigations. To confirm the assessed soil and rock properties in this report, further site-specific investigation and / or construction inspections would be required.

This report may have included geotechnical recommendations for design and construction of temporary works (e.g., temporary batter slopes or temporary shoring of excavations). Such temporary works are expected to perform adequately for a relatively short period only, which could range from a few days (for temporary batter slopes) up to six months (for temporary shoring). This period depends on a range of factors including but not limited to: site geology; groundwater conditions; weather conditions; design criteria; and level of care taken during construction. If there are factors which prevent temporary works from being completed and/or which require temporary works to function for periods longer than originally designed, further advice must be sought from the Geotechnical Engineer and Structural Engineer.

Aretas Group accepts no liability where our recommendations are not followed or are only partially followed. The document "Important Information about your Geotechnical Report" in Appendix A provides additional information about the uses and limitations of this report.

❖❖❖

Please do not hesitate to contact the undersigned if you have any questions regarding this report or if you require further assistance.

For and on behalf of
**Aretas Group**

Mark Bartel

**Mark Bartel**
Senior Principal Geotechnical Engineer
FIEAust, CPEng, NER, RPEQ, BE (Civil)

Encl: Site Photos
Figure 1 – Previous Test Locations
Important Information about your Geotechnical Report
CSIRO Foundation Maintenance and Footing Performance
Test Pit Logs
Form 4

# DOCUMENT CONTROL

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## Document Status

| Rev | Revision Details | Date | Author | Reviewer | Approver |
|---|---|---|---|---|---|
| 0 | Initial issue | 26 April 2025 | MAB |  | MAB |
| 1 | Updated plans | 17 August 2026 | MAB |  | MAB |
| 2 | Further updates to plans | 25 August 2026 | MAB |  | MAB |

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ISO 45001:2018

## SITE PHOTOS

**Photo 1 – View of proposed Unit 2 location looking southeast towards Unit 1 location**

APPROXIMATE ONLY.
SOURCE: Site Plan prepared by Kosciuszko Thredbo Pty Ltd; Snowmaking All Weather Snowmaking Unit 2; edition 1; dated 5/8/2026.
THIS DRAWING IS USED TO ILLUSTRATE TEST LOCATIONS ONLY, AND <u>MUST NOT BE USED FOR ANY OTHER PURPOSE</u>.

LEGEND ⌖ 6751–Boreholes ▞ 6262–Test pits

0 1:2,500 A4 100m

N

| | | |
|---|---|---|
| | | |
| | | |
| B | 17.8.26 | Updated Plans |
| A | 26.4.25 | Initial Issue |
| issue | date | description |

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Proposed Snowmaking Unit No 2 Installation
Thredbo, Friday Flats
for
Kosciuszko Thredbo Pty Ltd

Previous Test Locations

**drawn:** MAB
**date:** 17.8.2026
**checked:** MAB
**scale:** 1:2,500 A4

**job no.:** 7787–4
**fig:** 1
**issue:** B

# Important Information

## Geotechnical Report

This document forms part of every geotechnical report issued by Aretas Group Pty Ltd (Aretas) and must be read alongside the report to which it is attached. It sets out the professional and contractual context within which the report was prepared and the conditions under which its findings may be used.

Reading this document in full is not optional. Aretas accepts no responsibility for outcomes arising from selective use of the report or from failure to understand the limitations described here.

## 1. Purpose and Scope

The report was prepared by Aretas for the Client identified in the report, in accordance with the agreed scope of services, for the specific project and site described. The scope of investigation reflects professional judgement about the level of work required, having regard to project requirements, available information, site conditions, access, and budget.

The report is intended solely for the purpose for which it was prepared. Any use beyond that purpose requires prior written confirmation from Aretas.

## 2. Use and Reliance

The report has been prepared for the exclusive use of the Client. No other party is entitled to rely on it, and Aretas does not accept any duty of care to third parties in connection with the report or its contents. Any third party seeking to rely on the report does so at their own risk and should obtain independent advice.

The report must be read in full. Aretas accepts no responsibility for the use of isolated sections, figures, or data extracted from the report without the context of the whole.

## 3. The Nature of Geotechnical Engineering

Geotechnical engineering is an interpretive discipline. Engineering models and recommendations are derived from discrete subsurface data using professional judgement, relevant experience, and accepted methodology. This is standard industry practice.

Subsurface conditions are inherently variable. The report provides an engineering interpretation of site conditions at the time of investigation. It does not represent an exhaustive or exact description of conditions across the site, and should not be treated as one.

## 4. Limitations of Site Investigation

Subsurface investigation is conducted at discrete locations — boreholes, test pits, and in-situ testing points. The data obtained from those locations is used to develop an inferred model of conditions across the site. No investigation program, however thorough, can detect every subsurface feature.

Variations in soil and rock conditions between investigation points should be expected. Features such as lenses, voids, zones of weakness, and groundwater anomalies may not be detected. Accordingly, two things follow:

First, conditions encountered during construction may differ from those described in the report.

Second, recommendations are based on interpreted conditions and must be verified when those conditions are physically exposed during works.

## 5. Time-Dependent Conditions

The report describes conditions as they existed at the time of investigation. Subsurface conditions can change. Natural processes — rainfall, flooding, drought, and groundwater fluctuation — can alter soil behaviour. Adjacent construction activities and site disturbance can do the same.

Aretas does not warrant that conditions will remain unchanged after the date of investigation. Where events occur that may have materially altered site conditions, Aretas should be notified and consulted before construction proceeds or recommendations are relied upon.

## 6. Construction Phase Verification

Verification of geotechnical conditions during construction is essential. Where conditions encountered differ materially from those described in the report — whether due to natural variability or construction activity — Aretas must be notified promptly. This allows timely review of recommendations and, where necessary, provision of revised advice.

Identifying meaningful changes in soil and rock conditions during excavation requires experience. Aretas recommends that a suitably qualified geotechnical engineer be engaged during construction with sufficient frequency to inspect exposed conditions and confirm that the report recommendations remain applicable.

## 7. Information Provided by Others

The report may rely on information provided by the Client or third parties, including survey data, design documentation, existing reports, drawings, and specifications. Unless explicitly stated, Aretas has not independently verified the accuracy or completeness of that information.

Aretas accepts no responsibility for errors, omissions, or consequences arising from inaccurate or incomplete information provided by others.

## 8. Applying the Recommendations

Recommendations are based on the project details, design assumptions, and site conditions understood at the time of preparation. If the design changes, the construction methodology changes, or new information becomes available, the recommendations may no longer be applicable and should be reviewed by Aretas before being acted upon.

Where recommendations are not followed, or are implemented incorrectly, the performance of the works may be adversely affected. Aretas accepts no responsibility for outcomes arising from deviation from the report without prior review and written confirmation.

## 9. Reproduction and Data Integrity

This report is subject to copyright and must not be reproduced, in whole or in part, without the prior written consent of Aretas.

Where the report is referenced in project documentation, it should be included in full. Partial inclusion creates a material risk of misinterpretation.

Geotechnical data — including borehole logs, figures, test results, and drawings — form an integral part of the report and must not be altered, redrawn, or extracted and used independently without the written approval of Aretas.

## 10. Third Party Use

Aretas accepts no responsibility for reliance on this report by any party other than the Client. To the extent permitted by law, Aretas excludes liability to any third party for any loss or damage arising from such reliance.

## 11. No Obligation to Update

Aretas is under no obligation to update or revise the report to reflect changes in site conditions, project scope, or design, or to account for new information arising after the date of the report — unless specifically engaged to do so.

## 12. Governing Agreement and Liability

This document should be read in conjunction with the Aretas Professional Services Agreement (PSA). In the event of any inconsistency between this document and the PSA, the terms of the PSA prevail.

Aretas' liability in connection with this report is limited in accordance with the terms of the PSA and applicable law. Nothing in this document excludes or limits any right or remedy that cannot be excluded under applicable legislation.

# Soil and Rock

## Explanation Sheets

## LOG ABBREVIATIONS & NOTES

### Method

| Code | Borehole Logs | Code | Excavation Logs |
|---|---|---|---|
| **AS** | Auger screw * | **NE** | Natural excavation |
| **AD** | Auger drill * | **HE** | Hand excavation |
| **RR** | Roller / tricone | **BH** | Backhoe bucket |
| **W** | Washbore | **EX** | Excavator bucket |
| **CT** | Cable tool | **DZ** | Dozer blade |
| **HA** | Hand auger | **R** | Ripper tooth |
| **D** | Diatube | | |
| **B** | Blade / blank bit | | |
| **V** | V-bit | | |
| **T** | TC-bit | | |

* Bit type shown by suffix, e.g. ADV.    Coring: NMLC, NQ, PQ, HQ

### Support

| Code | Borehole Logs | Code | Excavation Logs |
|---|---|---|---|
| **N** | Nil | **N** | Nil |
| **M** | Mud | **S** | Shoring |
| **C** | Casing | **B** | Benched |
| **NQ** | NQ rods | | |

### Core lift

| | |
|---|---|
| ⦀ | Casing installed |
| ├─┤ | Barrel withdrawn |

### Water

| | |
|---|---|
| ▼ | Level |
| ▶─ | Inflow |

| | |
|---|---|
| ─◀ | Outflow (complete) |
| ─◁ | Outflow (partial) |

### Notes, Samples, and Tests

| | |
|---|---|
| **D** | Disturbed |
| **B** | Bulk disturbed |
| **U50** | Thin-walled sample, 50mm diameter |
| **HP** | Hand penetrometer (kPa) |
| **SV** | Shear vane test (kPa) |
| **DCP** | Dynamic cone penetrometer (blows per 100mm penetration) |
| **SPT** | Standard penetration test |
| **N*** | SPT value (blows per 300mm) — asterisk denotes sample taken |
| **Nc** | SPT with solid cone |
| **R** | Refusal of DCP or SPT |

### USCS Symbols

| | |
|---|---|
| **GW** | Gravel and gravel-sand mixtures, little or no fines |
| **GP** | Gravel and gravel-sand mixtures, little or no fines, uniform gravels |
| **GM** | Gravel-silt mixtures and gravel-sand-silt mixtures |
| **GC** | Gravel-clay mixtures and gravel-sand-clay mixtures |
| **SW** | Sand and gravel-sand mixtures, little or no fines |
| **SP** | Sand and gravel-sand mixtures, little or no fines |
| **SM** | Sand-silt mixtures |
| **SC** | Sand-clay mixtures |
| **ML** | Inorganic silt and very fine sand, rock flour, silty or clayey fine sand, or silt with low plasticity |
| **CL, CI** | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays |
| **OL** | Organic silts |
| **MH** | Inorganic silts |
| **CH** | Inorganic clays of high plasticity |
| **OH** | Organic clays of medium to high plasticity, organic silt |
| **PT** | Peat, highly organic soils |

### Moisture Condition

| | |
|---|---|
| **D** | Dry |
| **M** | Moist |
| **W** | Wet |
| **Wp** | Plastic limit |
| **Wl** | Liquid limit |

### Soil Consistency and Density Index

| Code | Consistency |
|---|---|
| **VS** | Very soft |
| **S** | Soft |
| **F** | Firm |
| **St** | Stiff |
| **VSt** | Very stiff |
| **H** | Hard |
| **Fb** | Friable |

| Code | Density Index |
|---|---|
| **VL** | Very loose |
| **L** | Loose |
| **MD** | Medium dense |
| **D** | Dense |
| **VD** | Very dense |
| | |
| | |

### Rock Weathering and Strength

| Code | Weathering |
|---|---|
| **XW** | Extremely weathered |
| **HW** | Highly weathered |
| **MW** | Moderately weathered |
| **SW** | Slightly weathered |
| **FR** | Fresh |
| | |

| Code | Strength |
|---|---|
| **VL** | Very low |
| **L** | Low |
| **M** | Medium |
| **H** | High |
| **VH** | Very high |
| **EH** | Extremely high |

### Rock Defects

| Type | | Coating | | Shape / Roughness | |
|---|---|---|---|---|---|
| **JT** | Joint | **cl** | Clean | **pl** | Planar |
| **PT** | Parting | **st** | Stained | **cu** | Curved |
| **SZ** | Shear zone | **ve** | Veneer | **un** | Undulating |
| **SM** | Seam | **co** | Coating | **st** | Stepped |
| | | | | **ir** | Irregular |
| | | | | **po** | Polished |
| | | | | **sl** | Slickensided |
| | | | | **sm** | Smooth |
| | | | | **ro** | Rough |
| | | | | **vr** | Very rough |

Inclination measured above axis and perpendicular to core.

### RQD (%)

RQD = (Sum of intact core pieces > 2 × diameter ÷ Total length of core run drilled) × 100

## AS1726–2017

Soil and rock described in accordance with AS1726–2017.

# SOIL

### Moisture Condition

| Term | Description |
|---|---|
| Dry | Looks and feels dry. Fine-grained and cemented soils are hard, friable or powdery. Uncemented coarse-grained soils run freely through the hand. |
| Moist | Soil feels cool and darkened in colour. Fine-grained soils can be moulded. Coarse soils tend to cohere. |
| Wet | As for moist, but with free water forming on hand. |

Moisture content of cohesive soils may also be described relative to plastic limit (Wp) or liquid limit (Wl): >> much greater than, > greater than, < less than, << much less than.

### Consistency of Fine-Grained Soils

| Term | Su (kPa) |
|---|---|
| Very soft | < 12 |
| Soft | > 12 – ≤ 25 |
| Firm | > 25 – ≤ 50 |
| Stiff | > 50 – ≤ 100 |

| Term | Su (kPa) |
|---|---|
| Very stiff | > 100 – ≤ 200 |
| Hard | > 200 |
| Friable | — |
| | |

### Relative Density of Coarse-Grained Soils

| Term | Density Index (%) |
|---|---|
| Very Loose | < 15 |
| Loose | 15 – 35 |
| Medium Dense | 35 – 65 |

| Term | Density Index (%) |
|---|---|
| Dense | 65 – 85 |
| Very Dense | > 85 |
| | |

### Particle Size

| Name | Subdivision | Size (mm) |
|---|---|---|
| Boulders | | > 200 |
| Cobbles | | 63 – 200 |
| Gravel | Coarse | 19 – 63 |
| | Medium | 6.7 – 19 |
| | Fine | 2.36 – 6.7 |
| Sand | Coarse | 0.6 – 2.36 |
| | Medium | 0.21 – 0.6 |
| | Fine | 0.075 – 0.21 |
| Silt | | 0.002 – 0.075 |
| Clay | | < 0.075 |

### Material Delineation

| Material | Criterion |
|---|---|
| Sand or gravel | >65% above 0.075 mm |
| Clay or silt | >35% below 0.075 mm |

| Term | Coarse-grained (% fines) | Fine-grained (% coarse) |
|---|---|---|
| Trace | ≤ 5% | ≤ 15% |
| With | > 5% to ≤ 12% | > 15% to ≤ 30% |

### Soil Zoning

| | |
|---|---|
| **Layers** | Continuous across exposures or sample |
| **Lenses** | Discontinuous, lenticular shaped zones |
| **Pockets** | Irregular shaped zones of different material |

### Soil Cementing

| | |
|---|---|
| **Weakly** | Easily broken up by hand pressure in water or air |
| **Moderately** | Effort is required to break up by hand in water or air |

### USCS Symbols

| | |
|---|---|
| **GW** | Gravel and gravel-sand mixtures, little or no fines |
| **GP** | Gravel and gravel-sand mixtures, little or no fines, uniform gravels |
| **GM** | Gravel-silt mixtures and gravel-sand-silt mixtures |
| **GC** | Gravel-clay mixtures and gravel-sand-clay mixtures |
| **SW** | Sand and gravel-sand mixtures, little or no fines |
| **SP** | Sand and gravel-sand mixtures, little or no fines |
| **SM** | Sand-silt mixtures |
| **SC** | Sand-clay mixtures |
| **ML** | Inorganic silt and very fine sand, rock flour, silty or clayey fine sand, or silt with low plasticity |
| **CL, CI** | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays |
| **OL** | Organic silts |
| **MH** | Inorganic silts |
| **CH** | Inorganic clays of high plasticity |
| **OH** | Organic clays of medium to high plasticity, organic silt |
| **PT** | Peat, highly organic soils |

# ROCK

### Sedimentary Rock Type Definitions

| Rock Type | Definition (more than 50% of rock consists of …) |
|---|---|
| Conglomerate | Gravel-sized (> 2mm) fragments |
| Sandstone | Sand-sized (0.06 to 2mm) grains |
| Siltstone | Silt-sized (< 0.06mm) particles; rock is not laminated |
| Claystone | Clay; rock is not laminated |
| Shale | Silt or clay-sized particles; rock is laminated |

### Layering

| Term | Description |
|---|---|
| Massive | No layering apparent |
| Poorly Developed | Layering just visible. Little effect on properties |
| Well Developed | Layering distinct. Rock breaks more easily parallel to layering |

### Structure (Bedding Spacing)

| Term | Spacing (mm) |
|---|---|
| Thinly laminated | < 6 |
| Laminated | 6 – 20 |
| Very thinly bedded | 20 – 60 |
| Thinly bedded | 60 – 200 |

| Term | Spacing (mm) |
|---|---|
| Medium bedded | 200 – 600 |
| Thickly bedded | 600 – 2,000 |
| Very thickly bedded | > 2,000 |
| | |

### Strength (Is50 = Point Load Strength Index)

| Term | Is50 (MPa) |
|---|---|
| Very Low | 0.03 – 0.1 |
| Low | 0.1 – 0.3 |
| Medium | 0.3 – 1.0 |

| Term | Is50 (MPa) |
|---|---|
| High | 1.0 – 3.0 |
| Very High | 3.0 – 10.0 |
| Extremely High | > 10.0 |

### Weathering

| Term | Description |
|---|---|
| Residual Soil | Material is weathered to an extent that it has soil properties. Rock structures are no longer visible, but the soil has not been significantly transported. |
| Extremely Weathered | Material is weathered to the extent that it has soil properties. Mass structure, material texture and fabric of original rock is still visible. |
| Highly Weathered | Rock strength is significantly changed by weathering; rock is discoloured, usually by iron staining or bleaching. Some primary minerals have weathered to clay minerals. |
| Moderately Weathered | Rock strength shows little or no change from fresh rock; rock may be discoloured. |
| Slightly Weathered | Rock is partially discoloured but shows little or no change of strength from fresh rock. |
| Fresh | Rock shows no signs of decomposition or staining. |

### Defect Description

| Type / Attribute | Term | Description |
|---|---|---|
| Type | Joint | A surface or crack across which the rock has little or no tensile strength. May be open or closed. |
| | Parting | A surface or crack across which the rock has little or no tensile strength. Parallel or sub-parallel to layering/bedding. May be open or closed. |
| | Sheared Zone | Zone of rock substance with roughly parallel, near-planar, curved or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects. |
| | Seam | Seam with deposited soil (infill), extremely weathered in-situ rock (XW), or disoriented usually angular fragments of the host rock (crushed). |
| Shape | Planar | Consistent orientation. |
| | Curved | Gradual change in orientation. |
| | Undulating | Wavy surface. |
| | Stepped | One or more well-defined steps. |
| | Irregular | Many sharp changes in orientation. |
| Roughness | Polished | Shiny smooth surface. |
| | Slickensided | Grooved or striated surface, usually polished. |
| | Smooth | Smooth to touch. Few or no surface irregularities. |
| | Rough | Many small surface irregularities (amplitude generally < 1mm). Feels like fine to coarse sandpaper. |
| | Very Rough | Many large surface irregularities (amplitude generally > 1mm). Feels like very coarse sandpaper. |
| Coating | Clean | No visible coating or discolouring. |
| | Stained | No visible coating but surfaces are discoloured. |
| | Veneer | A visible coating of soil or mineral, too thin to measure; may be patchy. |
| | Coating | Visible coating ≥ 1mm thick. Thicker soil material described as seam. |

# FOUNDATION MAINTENANCE AND FOOTING PERFORMANCE

## Understanding and preventing soil-related building movement

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

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 home owner 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.

## 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. Table 1 below is a reproduction of Table 2.1 from Australian Standard AS 2870-2011, Residential slabs and footings.

## 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 may be the province of the builder and should be taken into consideration as part of the preparation of the site for construction.

### 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, from AS 2870). 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.

### 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.

TABLE 1. 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, which may experience only slight ground movement from moisture changes |
| M | Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes |
| H1 | Highly reactive clay sites, which may experience high ground movement from moisture changes |
| H2 | Highly reactive clay sites, which may experience very high ground movement from moisture changes |
| E | Extremely reactive sites, which may experience extreme ground movement from moisture changes |

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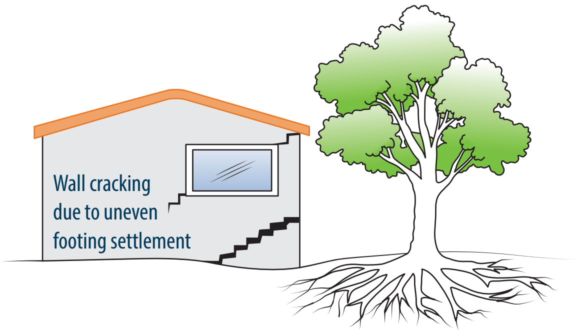

**FIGURE 1** Trees can cause shrinkage and damage.

- 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 through absorption. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Shrinkage usually begins on the side of the building 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.

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 causes 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. Table 2 below is a reproduction of Table C1 of AS 2870-2011.

AS 2870-2011 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 AND 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 may 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 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.

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.

### TABLE 2. CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS.

| Description of typical damage and required repair | Approximate crack width limit | Damage category |
|---|---|---|
| Hairline cracks | <0.1 mm | 0 – Negligible |
| Fine cracks which do not need repair | <1 mm | 1 – Very Slight |
| Cracks noticeable but easily filled. Doors and windows stick slightly. | <5 mm | 2 – Slight |
| 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 – Moderate |
| 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 depends on number of cracks | 4 – Severe |

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Warning: Although this Building Technology Resource 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, and mould.
- 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.

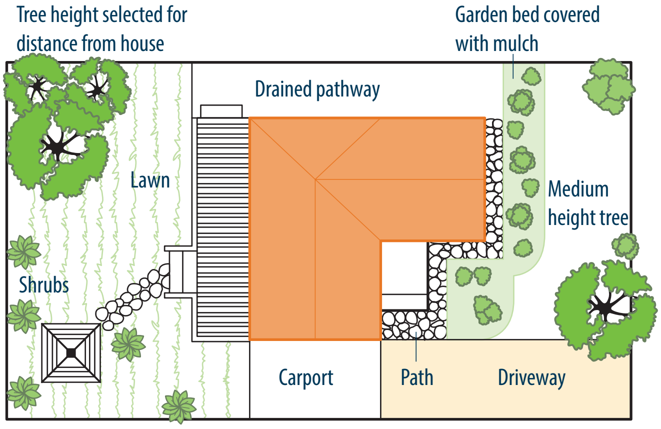

**FIGURE 2** Gardens for a reactive site.

## 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 home owner 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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# Excavation Log

**EX no:** TP1
**sheet:** 1 of 1
**job no.:** 6262

**client:** EVT / Kosciuszko Thredbo Pty Ltd
**principal:**
**project:** Proposed Snowmaking Pipeline Replacement
**location:** Thredbo
**equipment:** Kubota U17-3 Excavator
**dimensions:** 0.9 x 0.9m
**E:**
**N:**

**started:** 4.10.2020
**finished:** 4.10.2020
**logged:** MAB
**checked:** WND
**RL surface:**
**datum:**

| excavation information | | | | | | material information | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| method | support | water | notes samples, tests, etc | RL | depth metres | graphic log | USCS symbol | **material**<br>soil type: plasticity or particle characteristics, colour, secondary and minor components. | moisture condition | consistency/ density index | hand penetro-meter kPa<br>100 200 300 400 | **structure and additional observations** |
| EX | N | None observed | | | | | ML | Sandy SILT, medium plasticity, dark brown, grass roots | >Wp | F | | TOPSOIL |
| | | | | | 0.1 | | SC | Clayey SAND, fine to coarse grained, grey/brown, some cobbles | M | MD | | FILL |
| | | | | | 0.4<br>0.5<br>1.0 | | SC | Clayey SAND, medium to coarse grained, light brown | | D | | COMPLETELY DECOMPOSED GRANITE |
| | | | | | 1<br>1.5<br>2.0 | | | Excavation No: TP1 terminated at 1m | | | | |

Refer to Information Sheets for Terms and Symbols

# Excavation Log

| | |
|---|---|
| **EX no:** | **TP2** |
| **sheet:** | 1 of 1 |
| **job no.:** | 6262 |

| | | | |
|---|---|---|---|
| **client:** | EVT / Kosciuszko Thredbo Pty Ltd | **started:** | 4.10.2020 |
| **principal:** | | **finished:** | 4.10.2020 |
| **project:** | Proposed Snowmaking Pipeline Replacement | **logged:** | MAB |
| **location:** | Thredbo | **checked:** | WND |
| **equipment:** | Kubota U17-3 Excavator | **RL surface:** | |
| **dimensions:** | 0.9 x 0.9m **E:** **N:** | **datum:** | |

| **excavation information** | | | | | | **material information** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| method | support | water | notes samples, tests, etc | RL | depth metres | graphic log | USCS symbol | **material**<br>soil type: plasticity or particle characteristics, colour, secondary and minor components. | moisture condition | consistency/ density index | hand penetro-meter kPa<br>100 200 300 400 | **structure and additional observations** |
| EX | N | None observed | | | | ▨ | | Mixture of cobbles and small boulders to 300mm size and Clayey SAND, fine to medium grained, light brown | M | MD to L | | FILL, appears moderately well compacted to poorly compacted |
| | | | | | 0.5<br>0.5<br>1.0 | ▨ | | Mixture of cobbles and small boulders to 300mm size (some to 500mm size) and Clayey SAND, fine to medium grained, light brown | | | | |
| | | | | | 1.2<br>1.5<br>2.0 | | | Excavation No: TP2 terminated at 1.2m | | | | Large cobble at 1.2m depth |

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# Excavation Log

|  |  |
|---|---|
| **EX no:** | **TP3** |
| **sheet:** | 1 of 1 |
| **job no.:** | 6262 |

|  |  |  |  |
|---|---|---|---|
| **client:** | EVT / Kosciuszko Thredbo Pty Ltd | **started:** | 4.10.2020 |
| **principal:** |  | **finished:** | 4.10.2020 |
| **project:** | Proposed Snowmaking Pipeline Replacement | **logged:** | MAB |
| **location:** | Thredbo | **checked:** | WND |
| **equipment:** | Kubota U17-3 Excavator | **RL surface:** |  |
| **dimensions:** | 0.9 x 0.9m  **E:**  **N:** | **datum:** |  |

| **excavation information** |  |  |  |  |  | **material information** |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| method | support | water | notes samples, tests, etc | RL | depth metres | graphic log | USCS symbol | **material**<br>soil type: plasticity or particle characteristics, colour, secondary and minor components. | moisture condition | consistency/ density index | hand penetro-meter kPa<br>100 200 300 400 | **structure and additional observations** |
| EX | N | None observed |  |  | 0.5<br>1.0 | ▨ |  | Mixture of cobbles and small boulders to 300mm size and Clayey SAND, medium to coarse grained, grey/brown | M | D |  | FILL (roadway), gravel over geofabric at top side of test pit<br>FILL appears well compacted |
|  |  |  |  |  | 1.4<br>1.5<br>2.0 |  |  | Excavation No: TP3 terminated at 1.4m |  |  |  |  |

Refer to Information Sheets for Terms and Symbols

Excavation Log - Revision 9

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# Excavation Log

**EX no:** TP4
**sheet:** 1 of 1
**job no.:** 6262

**client:** EVT / Kosciuszko Thredbo Pty Ltd
**principal:**
**project:** Proposed Snowmaking Pipeline Replacement
**location:** Thredbo
**started:** 4.10.2020
**finished:** 4.10.2020
**logged:** MAB
**checked:** WND
**equipment:** Kubota U17-3 Excavator
**RL surface:**
**dimensions:** 0.9 x 0.9m
**E:**
**N:**
**datum:**

| excavation information | | | | | | material information | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| method | support | water | notes samples, tests, etc | RL | depth metres | graphic log | USCS symbol | **material**<br>soil type: plasticity or particle characteristics, colour, secondary and minor components. | moisture condition | consistency/ density index | hand penetro-meter kPa<br>100 200 300 400 | **structure and additional observations** |
| EX | N | None observed | | | | | GP | GRAVEL, fine to medium grained, over geofabric | M | D | | FILL |
| | | | | | 0.1 | | CL | CLAY, medium plasticity, dark brown to orange-brown, some cobbles to 200mm | <Wp | H | | COLLUVIUM? |
| | | | | | 0.5 | | | | | | | |
| | | | | | 1.0 | | | | | | | |
| | | | | | 1.2 | | CL | CLAY, medium plasticity, orange-brown | =Wp | VSt | | |
| | | | | | 1.4 | | | Excavation No: TP4 terminated at 1.4m | | | | |
| | | | | | 1.5 | | | | | | | |
| | | | | | 2.0 | | | | | | | |

Refer to Information Sheets for Terms and Symbols

assetgeoenviro

# Excavation Log

| | |
|---|---|
| **EX no:** | **TP5** |
| **sheet:** | 1 of 1 |
| **job no.:** | 6262 |

**client:** EVT / Kosciuszko Thredbo Pty Ltd
**principal:**
**project:** Proposed Snowmaking Pipeline Replacement
**location:** Thredbo
**equipment:** Kubota U17-3 Excavator
**dimensions:** 0.9 x 0.9m **E:** **N:**

**started:** 4.10.2020
**finished:** 4.10.2020
**logged:** MAB
**checked:** WND
**RL surface:**
**datum:**

| excavation information | | | | | | material information | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| method | support | water | notes samples, tests, etc | RL | depth metres | graphic log | USCS symbol | **material**<br>soil type: plasticity or particle characteristics, colour, secondary and minor components. | moisture condition | consistency/ density index | hand penetro-meter kPa<br>100 200 300 400 | **structure and additional observations** |
| EX | N | None observed | | | | | ML | SILT, medium plasticity, dark grey, grass roots | M | F | | TOPSOIL |
| | | | | | 0.2 | | CL | CLAY, medium plasticity, brown, some cobbles and small boulders to 500mm size | >=Wp | St | × 100<br>× 100 | COLLUVIUM? |
| | | | | | 1.2 | | SC | Clayey SAND, medium to coarse grained, light grey/brown | M | D | | RESIDUAL (COMPLETELY WEATHERED GRANITE) |
| | | | | | 1.4 | | | Excavation No: TP5 terminated at 1.4m | | | | |

Depth scale: 0.5, 1.0, 1.5, 2.0

Refer to Information Sheets for Terms and Symbols

Excavation Log - Revision 9

assetgeoenviro

# Excavation Log

**EX no:** TP6
**sheet:** 1 of 1
**job no.:** 6262

|  |  |  |  |
|---|---|---|---|
| **client:** | EVT / Kosciuszko Thredbo Pty Ltd | **started:** | 4.10.2020 |
| **principal:** |  | **finished:** | 4.10.2020 |
| **project:** | Proposed Snowmaking Pipeline Replacement | **logged:** | MAB |
| **location:** | Thredbo | **checked:** | WND |
| **equipment:** | Kubota U17-3 Excavator | **RL surface:** |  |
| **dimensions:** | 0.9 x 0.9m E: N: | **datum:** |  |

| **excavation information** |  |  |  |  |  | **material information** |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| method | support | water | notes samples, tests, etc | RL | depth metres | graphic log | USCS symbol | **material**<br>soil type: plasticity or particle characteristics, colour, secondary and minor components. | moisture condition | consistency/ density index | hand penetro- meter kPa<br>100 200 300 400 | **structure and additional observations** |
| EX | N | None observed |  |  |  |  | GP | GRAVEL, fine to coarse grained, over geofabric | M | D |  | ACCESS TRACK |
|  |  |  |  |  | 0.1<br>0.5<br>1.0 |  |  | Mixture of Clayey SAND and Cobbles and small boulders to 300mm size, tree roots | M | L |  | FILL<br>buried tree roots<br>Fill appears poorly compacted |
|  |  |  |  |  | 1.3<br>1.5 |  | CL | Sandy CLAY, medium plasticity, grey brown, some granite boulders | >Wp | F |  | COLLUVIUM? |
|  |  |  |  |  | 1.5<br>2.0 |  |  | Excavation No: TP6 terminated at 1.5m |  |  |  |  |

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# Excavation Log

| | |
|---|---|
| **EX no:** | **TP7** |
| **sheet:** | 1 of 1 |
| **job no.:** | 6262 |

| | | | |
|---|---|---|---|
| **client:** | EVT / Kosciuszko Thredbo Pty Ltd | **started:** | 4.10.2020 |
| **principal:** | | **finished:** | 4.10.2020 |
| **project:** | Proposed Snowmaking Pipeline Replacement | **logged:** | MAB |
| **location:** | Thredbo | **checked:** | WND |
| **equipment:** | Kubota U17-3 Excavator | **RL surface:** | |
| **dimensions:** | 0.9 x 0.9m **E:** **N:** | **datum:** | |

| **excavation information** | | | | | | **material information** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| method | support | water | notes samples, tests, etc | RL | depth metres | graphic log | USCS symbol | **material**<br>soil type: plasticity or particle characteristics, colour, secondary and minor components. | moisture condition | consistency/ density index | hand penetro-meter kPa<br>100 200 300 400 | **structure and additional observations** |
| EX | N | None observed | | | 0.5<br>1.0 | ▩ | SC | Clayey SAND, medium to coarse grained, grey (decomposed grainte), some granite cobbles | M | VD | | FILL (old access road) |
| | | | | | 1.1 | ▨ | CL | Silty CLAY, medium plasticity, dark grey | >Wp | St | | TOPSOIL |
| | | | | | 1.4<br>1.5<br>2.0 | | | Excavation No: TP7 terminated at 1.4m | | | | |

Refer to Information Sheets for Terms and Symbols

Excavation Log - Revision 9

assetgeoenviro

# Excavation Log

| | |
|---|---|
| **EX no:** | **TP8** |
| **sheet:** | 1 of 1 |
| **job no.:** | 6262 |

| | | | |
|---|---|---|---|
| **client:** | EVT / Kosciuszko Thredbo Pty Ltd | **started:** | 4.10.2020 |
| **principal:** | | **finished:** | 4.10.2020 |
| **project:** | Proposed Snowmaking Pipeline Replacement | **logged:** | MAB |
| **location:** | Thredbo | **checked:** | WND |
| **equipment:** | Kubota U17-3 Excavator | **RL surface:** | |
| **dimensions:** | 0.9 x 0.9m **E:** **N:** | **datum:** | |

| **excavation information** | | | | | | **material information** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| method | support | water | notes, samples, tests, etc | RL | depth metres | graphic log | USCS symbol | **material**<br>soil type: plasticity or particle characteristics, colour, secondary and minor components. | moisture condition | consistency/ density index | hand penetro-meter kPa<br>100 200 300 400 | **structure and additional observations** |
| EX | N | None observed | | | | ▩ | ML | Clayey SILT, medium plasticity, dark brown | >Wp | F | | TOPSOIL |
| | | | | | 0.1 | ▨ | SC | Clayey SAND, medium to coarse grained, light brown, completely weathered granite | M | VD | | FILL, appears well compacted |
| | | | | | 0.55 | ▨ | | Mixture of Clayey SAND, granite cobbles, pices of wood, dark grey gravel | | MD-D | | FILL, appears poorly to moderately compacted |
| | | | | | 1.2 | | | Excavation No: TP8 terminated at 1.2m | | | | |

Refer to Information Sheets for Terms and Symbols

Excavation Log - Revision 9

# Form 4 – Minimal Impact Certification

DA Number: ________________________

This form may be used where minor construction works which present minimal or no geotechnical impact on the site or related land are proposed to be erected within the "G" line area of the geotechnical maps.

A geotechnical engineer or engineering geologist must inspect the site and/or review the proposed development documentation to determine if the proposed development requires a geotechnical report to be prepared to accompany the development application. Where the geotechnical engineer determines that such a report is not required then they must complete this form and attach design recommendations where required. A copy of Form 4 with design recommendation, if required, must be submitted with the development application.

**Please contact the Alpine Resorts Team in Jindabyne for further information - phone 02 6456 1733.**

To complete this form, please place a cross in the appropriate boxes ☐ and complete all sections.

## 1. Declaration made by geotechnical engineer or engineering geologist in relation to a nil or minimal geotechnical impact assessment and site classification

I,

Mr ☒ Ms ☐ Mrs ☐ Dr ☐ Other ☐

| First Name | Family Name |
|---|---|
| Mark | Bartel |

OF

Company/organisation

Aretas Group Pty Ltd (formerly AssetGeoEnviro)

certify that I am a geotechnical engineer /engineering geologist as defined by the "Policy" and I have inspected the site and reviewed the proposed development known as

Snowmaking Unit No 2, Friday Flat, Thredbo NSW

As a result of my site inspection and review of the following documentation

(List of documentation reviewed)

Site Plan by Kosciuszko Thredbo Pty Ltd, Snowmaking All Weather Unit 2, ref 25002-001-r1, ed1, 5 Aug 2026

Cut and Fill Plan.1 by Kosciuszko Thredbo Pty Ltd, Friday Flat Snowmaking Unit 2, ref 25002_001_r1 dated 18.08.26

Cut and Fill Section.1 by Kosciuszko Thredbo Pty Ltd, Friday Flat Snowmaking Unit 2, ref 25002_002.2_r1 dated 18.08.26

KTI-Plersch Kältetechnik GmbH, model CPSP 360 kpl Doku (SnowPro 400), ref 10067243, dwg 00, dated 26.09.25

I have determined that;

- ☒ the current load-bearing capacity of the existing building will not be exceeded or adversely impacted by the proposed development, and
- ☒ the proposed works are of such a minor nature that the requirement for geotechnical advice in the form of a geotechnical report, prepared in accordance with the "Policy", is considered unnecessary for the adequate and safe design of the structural elements to be incorporated into the new works, and
- ☒ in accordance with AS 2870.1 Residential Slabs and Footings, the site is to be classified as a type

(insert classification type)

Class P

- ☒ I have attached design recommendations to be incorporated in the structural design in accordance with this site classification.

I am aware that this declaration shall be used by the Department as an essential component in granting development consent for a structure to be erected within the "G" line area (as identified on the geotechnical maps) of Kosciuszko Alpine Resorts without requiring the submission of a geotechnical report in support of the development application.

## 2. Signatures

| | |
|---|---|
| Signature | Chartered professional status |
| Mark Bartel | CPEng 35641 NER (Civil) |
| Name | Date |
| Mark Bartel | 25 August 2026 |

## 3. Contact details

**Alpine Resorts Team**
Shop 5A, 19 Snowy River Avenue
P O Box 36, JINDABYNE NSW 2627
Telephone: 02 6456 1733
Facsimile: 02 6456 1736
Email: alpineresorts@planning.nsw.gov.au