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GEOTECHNICAL SITE ASSESSMENT

Site Classification to AS2870-2011

PROPOSED MIXED USE DEVELOPMENT

127 NEW ENGLAND HIGHWAY LOCHINVAR, NSW, 2321

LOT 1 DP 779536

For: Brown Commercial Building P/L

20/08/2025

Sanko
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GEOTECHNICAL INVESTIGATION
SITE CLASSIFICATION TO AS2870-2011
GEOTECHNICAL DESIGN PARAMETERS
ACID SUFATE SOIL ASSESSMENT AND
SITE SALINITY ASSESSMENT

PROPOSED MIXED USE DEVELOPMENT
172 NEW ENGLAND HIGHWAY
LOCHINVAR, NSW, 2321

LOT 4 DP 779536

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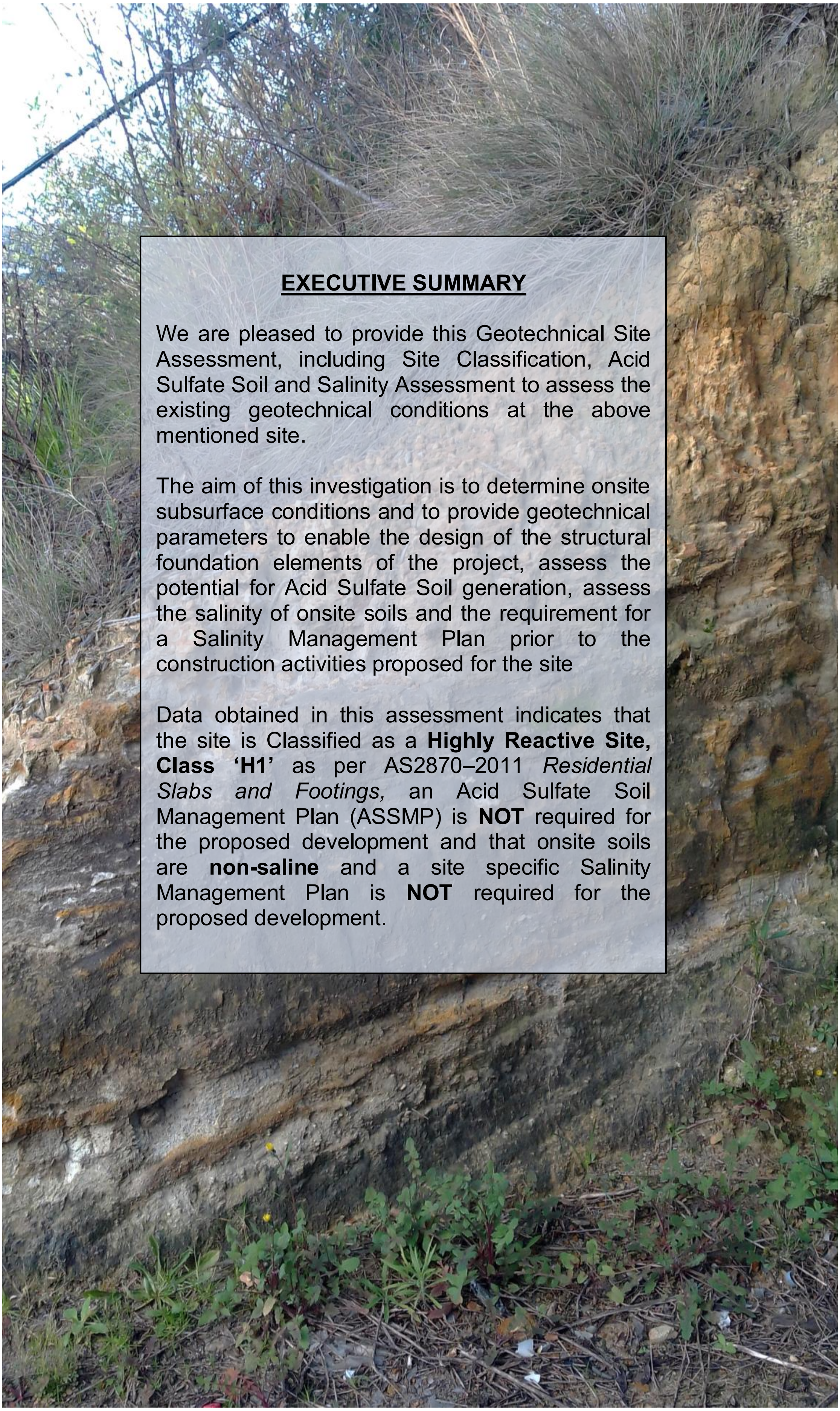
This report should be read in conjunction with the listed referenced reports



EXECUTIVE SUMMARY

We are pleased to provide this Geotechnical Site Assessment, including Site Classification, Acid Sulfate Soil and Salinity Assessment to assess the existing geotechnical conditions at the above mentioned site.

The aim of this investigation is to determine onsite subsurface conditions and to provide geotechnical parameters to enable the design of the structural foundation elements of the project, assess the potential for Acid Sulfate Soil generation, assess the salinity of onsite soils and the requirement for a Salinity Management Plan prior to the construction activities proposed for the site

Data obtained in this assessment indicates that the site is Classified as a **Highly Reactive Site, Class 'H1'** as per AS2870–2011 *Residential Slabs and Footings,* an Acid Sulfate Soil Management Plan (ASSMP) is **NOT** required for the proposed development and that onsite soils are **non-saline** and a site specific Salinity Management Plan is **NOT** required for the proposed development.

1.0 Introduction

This report presents the results of a geotechnical assessment carried out by Sanko Excavation Environmental & Civil Services P/L at the above-mentioned site.

Proposed development includes the demolition of all existing onsite structures and construction of a child care centre on the northern portion of the site comprising an outdoor play area, buildings and a concrete carparking pavement. Four residential units are proposed for the centre portion of the site. The proposed development is shown on the attached Figure 3.

The scope of work for the geotechnical assessment included providing recommendations on:

Site Classification

- Risk Assessment and Desktop Investigation including DBYD prior to fieldwork assessment;
- Surface and Sub-surface conditions including fill depths if encountered including a Geotechnical Cross Section;
- Laboratory testing results;
- Site preparation including Site Classification improvement options if applicable;
- Excavation conditions including depth to rock, excavatability and shoring options if required;
- Suitability of site soils for fill and filling procedures;
- Site Classification to AS 2870-2011 including alternative footing types and foundation design parameters;
- Retaining Wall Design parameters;
- Any other identified site-specific geotechnical issues
- Depth to groundwater (if encountered above borehole termination depth).

Acid Sulfate Soil Assessment

- Assessment of the potential for the creation of Acid Sulfate Soils during any proposed site excavations;
- Completion of laboratory tests undertaken as per the Acid Sulfate Soils Assessment Guidelines (1998);
- Development of an ASSMP and soil and groundwater disposal requirements if assessment indicates that this is required.

Salinity Assessment

- Laboratory testing results of samples collected;
- The assessed exposure design specifications as per AS AS2159-2009
- Requirements for Soil Salinity Assessment and Management Plan

2.0 Fieldwork

Field work was carried out by Sanko on 23 June 2025 and comprised:

- Machine excavation of 4 boreholes (BH1 to BH4) with a trailer mounted drilling rig equipped with solid flight augers to a termination depth of 3.0m and a hand auger (BH5) to a termination depth of 1.0m in the locations as shown on the attached Figure 3;
- Observation and mapping of relevant site features;
- Completion of DCP testing;
- Collection of representative soil samples for laboratory testing;

All field work was carried out in the full-time presence of a Senior Geotechnical Engineer from Sanko who located the boreholes, directed the sampling and testing and produced engineering logs of the boreholes. The borehole locations are shown on the attached site plan.

3.0 Site Description

The site is located on the southern side of The New England Highway between Windemere Road to the west and Station Street to the east in the central part of Lochinvar in the location as shown on the attached Figure 1.

Development currently on the site comprises a single storey weatherboard dwelling with a metal roof, a rear undercover deck covered with a metal roof and a 3 bay metal shed with annexe on concrete foundations to the south west of the dwelling. A small metal garden shed and outdoor above ground spa is located on the south eastern corner of the dwelling. Timber and metal fencing was located in the rear portion of the site to created 2 separate vacant paddocks. A small open bay metal shed and horse yard was located on the centre western boundary of the site.

3.1 Surface Conditions

The site is located on the upper portion of a south facing residual hillside with the site sloping from the front northern boundary of the site down to the rear southern portion of the site adjacent to Lochinvar Creek on the southern boundary of the site. Topography plans indicate that the northern boundary of the site has an RL of 39.5m AHD and the lowest rear southern portion of the site at an RL of 30.2m AHD. The top third of the site has a very gentle slope, with the middle third having a moderate slope and the rear third being nearly flat. Topography lines are shown on the attached Figure 3 – Proposed Development.

There was no evidence of significant areas of soil erosion or groundwater or surface water seepage noted over the main portion of the site with the exception of around the existing water tank at the rear of the shed. There was not significant cracking of the upper soil profile at the time of assessment with a moderate amount of rain being recorded in the area over the few months prior to the assessment.

3.2 Sub-surface Conditions

Site geotechnical parameters are detailed in the following Table 1;

TABLE 1 – SUMMARY OF SOIL TYPES ENCOUNTERED AT BORE HOLE LOCATIONS

SOIL UNIT	SOIL TYPE	DESCRIPTION
UNIT 1	TOPSOIL	Silty SAND; fine to medium grained, dark grey, low plasticity fines, moist, dense
UNIT 2	RESIDUAL	CLAY; high plasticity, grey / brown, trace of fine sand, moisture greater than the plastic limit, firm
UNIT 3A	RESIDUAL	Sandy CLAY; medium to high plasticity, pale brown, fine to medium grained sand, moisture equal to the plastic limit, stiff
UNIT 3B	RESIDUAL	Sandy CLAY; medium to high plasticity, pale brown / orange, fine to medium grained sand, moisture less than the plastic limit, very stiff

Table 2 provides a summary of the distributions of the above soil units at each borehole location.

TABLE 2 – SUMMARY OF DISTRIBUTION OF GEOTECHNICAL UNITS AT BOREHOLE LOCATIONS

BH'S	DEPTH ENCOUNTERED BELOW EXISTING GROUND LEVEL (m)			
	UNIT 1 TOPSOIL	UNIT 2 RESIDUAL	UNIT 3A RESIDUAL	UNIT 3B RESIDUAL
BH1	0.0 – 0.3	0.3 – 1.4	1.4 – 1.9	1.9 – 3.0 +
BH2	0.0 – 0.3	0.3 – 0.9	0.9 – 1.4	1.4 – 3.0 +
BH3	0.0 – 0.4	0.4 – 1.0	1.0 – 1.4	1.4 – 3.0 +
BH4	0.0 – 0.3	0.3 – 1.1	1.1 – 1.4	1.4 – 3.0 +
BH5	0.0 – 0.3	0.3 – 1.0+	NE	NE
NOTE: + denotes material continues for untested depth and NE denotes Not Encountered				

Groundwater and / or seepage was NOT encountered in any of the boreholes above termination depth at the time of assessment. It should be noted that fluctuations in the groundwater levels can occur as a result of seasonal variations, temperature, rainfall and other similar factors, the influence of which may not have been apparent at the time of investigation.

Reference to the 1:250K Singleton Regional Geology Map S1 56-4 indicates that the site located in Palaeozoic aged Permian material of the Dalwood Group, namely the Lochinvar Formation comprising Siltstone, Sandstone Basic Lava and Tuff as shown on the attached Figure 4.

Reference to the eSpade Soil landscape map indicates following that the site is located in Lochinvar (NKB lv) resudial soil landscape as detailed below:

NKB-lv	LOCHINVAR SOIL LANDSCAPE

GENERAL

This soil landscape covers undulating rises around the village of Lochinvar. The main soils are Non-calcic Brown Soils (Db1.12) on the gentle slopes with Brown Podzolic Soils (Db2.11, Db1.41) on the steeper areas. There are Yellow Solodic Soils (Dy2.12) on the mid to lower slopes of the steeper hills and in some drainage lines.

CLIMATIC ZONE: 3E

LANDFORM

Undulating rises with elevation ranging from 20 – 80 m. Local relief is around 20 m, with slope gradients of 4 – 6%. Average slope lengths are 800 – 1,000 m. Drainage lines occur at 400 – 800 m intervals.

NATIVE VEGETATION

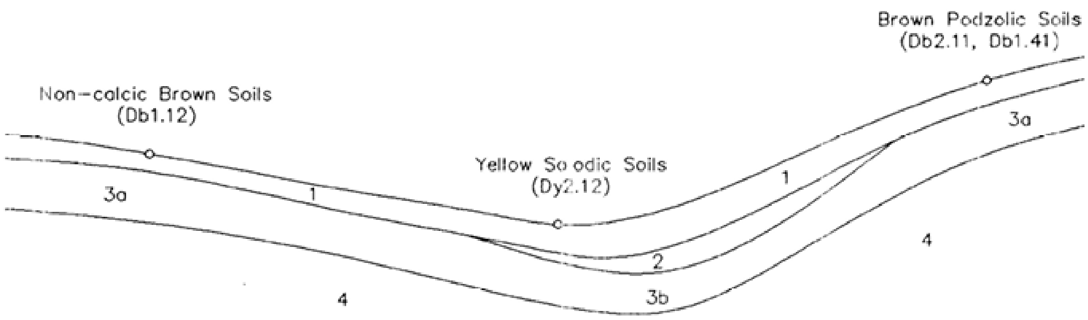
A woodland community of white box with silvertop stringybark, yellow box and red gum. Much has been cleared for grazing of improved pastures. There is rural residential subdivision in the area.

GEOLOGY

Geological Unit:	Lochinvar Formation
Parent Rock:	Siltstone, sandstone, basalt and tuff.
Parent Material:	*In situ* weathered parent rock and alluvium derived from it.

SOIL EROSION

Minor gully erosion problems throughout the landscape. This becomes severe in Yellow Solodic Soils.



1. Hardsetting; brownish black to brown light sandy clay loam to silty clay loam with weak to moderate structure.
2. Sometimes bleached; sandy loam to loam with weak to moderate structure.

3a. Brown medium to sandy clay with moderate to strong structure.

3b. Yellowish brown medium clay with strong structure.

4. Permian siltstone, sandstone, tuff and basalt.

4.0 Site Classification Laboratory Testing

Samples obtained from fieldwork activities were returned to GSG's NATA Accredited laboratory for testing.

To obtain information required the following testing was proposed:

- 1 Shrink / Swell test;

The result of the laboratory assessment is summarised in Table 3.

TABLE 3 – SUMMARY OF RESULTS OF SHRINK SWELL TESTING

LOCATION	SAMPLE DEPTH (m)	MATERIAL TYPE	SHRINK SWELL INDEX (%)
BH2	1.0 – 1.5	U2 –Residual CLAY	**4.1**

5.0 Recommendations

5.1 Site Classification

On the basis of the soil profiles encountered during the field investigation, **the site in current condition is classified as a Highly Reactive Site, Class "H1"** as defined in AS2870–2011 *Residential Slabs and Footings.* A characteristic free surface movement of up to **59mm** is estimated for the site in its current condition.

The effects of changes to the soil profile by additional cutting and filling and the effects of past and future trees should be considered in selection of the design value for differential movement.

5.2 Site Preparation

Site preparation and earthworks suitable for structure support should consist of:

- Proposed building and pavement areas should be stripped to remove all existing vegetative containing topsoil and deleterious material or demolition building waste affected materials encountered onsite. This material must be removed offsite as per Section 5.4 below;

- Approved fill beneath structures requiring bearing capacity of up to 150 kPa and pavements should be engineer controlled fill compacted in layers not exceeding 300mm loose thickness to a minimum density ratio of 98% Standard Compaction in accordance with AS1289 5.1.1 or equivalent within +/- 2% of Optimum Moisture Content (OMC) beneath structures and at 60% to 90% of OMC beneath pavements;

- Onsite subgrade material should be retained and the in-situ subgrade should be compacted to 100% Standard (or equivalent Density Index) at 60-90% of OMC.

- All fill should be supported by properly designed and constructed retaining walls as per *AS4678-2202 “Earth Retaining Structures”* or else battered at 1V:2H or flatter and protected against erosion;

- Earthworks should be carried out in accordance with the recommendations outlined in AS3798-2007 ‘*Guidelines for Earthworks for Commercial and Residential Developments*’.

5.3 Excavation Conditions and Methodologies

It is expected that excavations should be achievable using conventional excavator to at least the depth as indicated on the appended borehole logs (3.0m).

Temporary excavations should be battered at 2H:1V and protected against erosion and bulk excavations deeper than 1m should be benched to minimise the risk of upper-level collapse. Retaining measures should be implemented for **ALL permanent** excavations greater than 1.0m depth or battered at 4V:1H and protected against erosion. Permanent excavations less than 1.0m in depth should be retained or else battered at a rate of 2H:1V.

Based on the encountered relatively cohesive material in the boreholes, it is assessed that casing will not be required for bored piers. Screw piers and driven timber piers may also be an applicable solution for the site, however site materials comprise residual clays becoming hard at relatively shallow depths (ie around 1.5m depth).

5.4 Recommendations for Onsite Material to be Used as Fill

Based on the results of the field investigation, all encountered materials are considered suitable for reuse as onsite engineer-controlled fill with the exception of any topsoil that should be used for landscaping purposed or removed offsite and building demolition waste affected material that should be removed offsite. Any ROCK material to be used as Engineer Controlled Fill should be crushed to ensure that oversize material is not encountered in the fill.

Any material removed from site is subject to a Waste Classification and will require environmental testing / waste classification / pre classification for recycling to confirm the classification of the removed material. If this is required, testing may be done on stockpiled material once excavations are carried out or taken in-situ prior to excavations taking place.

5.5 Foundations

5.5.1 Shallow Footings

It is recommended that all shallow footing systems founded in Unit 2 Residual material comprising grey / brown CLAY or Engineer Controlled Fill may be proportioned for an allowable bearing pressure of **150kPa** as detailed in Table 4 below.

All structural footings (including edge beams, internal beams and load support thickenings) should be founded:

- Outside of, or below all zones of influence resulting from existing or future service trenches.
- Below any uncontrolled fill onsite.

Adequate surface and storm water drainage should be installed and maintained around the building site. All collected storm water and roof run-off should be piped to the storm water drainage system.

5.5.2 Deep Footings

If higher loads are required an alternative foundation option for the site is bored / driven / screw piles. Piles socketed in a minimum of 0.3m in the layer, may be designed for geotechnical strength parameters in accordance with the guidelines presented in AS2159–2009 Piling Design and Installation, as shown in Table 4.

TABLE 4 – FOUNDATION DESIGN PARAMETERS

FOUNDING MATERIAL	**SHALLOW FOOTINGS**		**DEEP FOOTINGS**		
	Allowable End Bearing Pressure (kPa)	**EXPECTED DEPTH TO FOUNDING MATERIAL BELOW EXISTING SURFACE LEVELS (m B.G.L)**	**Allowable End Bearing Pressure (kPa)**	**Allowable Shaft Adhesion (kPa)**	**APPROXIMATE EXPECTED DEPTH TO FOUNDING MATERIAL BELOW EXISTING SURFACE LEVELS (m B.G.L)**
Engineer Controlled Fill @98% std	150	NA	NA	NA	NA
UNIT 2 Grey / Brown CLAY	150	0.4	NA	NA	NA
UNIT 3A/3B Pale brown Sandy CLAY	NA	NA	250	25	1.0
			400	40	1.5 – 2.0

A geotechnical reduction factor of 0.7 should be applied to ultimate capacities to obtain limit state (serviceability) design parameters. Ultimate values are 3X allowable values. The settlement of footings proportioned as recommended above should not exceed 1% of maximum width or pile diameter. Shaft adhesion is not applicable to screw piers.

It is recommended that all footing excavations be inspected by during construction to confirm the above parameters are appropriate. This can be arranged on request.

5.6 Retaining Wall Design Parameters

Table 5 provides recommended parameters for general design of retaining measures and earthworks on site.

TABLE 5 – RETAINING WALL DESIGN PARAMETERS

GEOTECHNICAL UNIT	γ (kN/m^3)	c' (kPa)	ϕ' (°)	Su (kPa)	E (MPa)	ν
Engineer Controlled Fill	18	0	28	10	20	0.3
GRAVEL / SAND	16	0	40	100	20	0.3
CLAY Soils UNIT 2 / 3 Material	**19**	**2**	**28**	**75**	**30**	**0.3**
ROCK	22	10	30	200	60	0.3

NOTE:

γ = Unit Weight; c' = Effective Cohesion; ϕ' = Effective Friction Angle;

Su = Undrained Shear Strength; E = Young's Modulus; ν= Poisson's Ratio.

The pressure distributions given above do not allow for hydrostatic pressures resulting from a build up of water behind retaining walls. Groundwater inflows were not encountered in the geotechnical units for which permanent retention measures are expected to be required. It is therefore considered that, provided adequate surface and subsurface drainage and, where required, free draining backfill, are used in conjunction with all retaining measures, no design allowance is necessary to resist hydrostatic pressures in addition to earth pressures.

The parameters shown above do not allow for surcharge loading due to additional or sloping backfill above each geotechnical unit, or due to vehicle or building loads from adjacent properties, for which individual pressure distributions should be estimated and applied as required.

6.0 Acid Sulfate Soil (ASS) Assessment

6.1 ASS Definition

Acid Sulfate Soils are the common name given to naturally occurring sediments and soils containing iron sulfides (principally iron sulfide or iron disulfide or their precursors). The exposure of the sulfide in these soils to oxygen by drainage or excavation leads to the generation of sulfuric acid.

Acid Sulfate Soils (ASS) include Actual Acid Sulfate Soils (AASS) or Potential Acid Sulfate Soils (PASS). AASS and PASS are often found in the same soil profile, with actual acid sulfate soils generally overlying potential acid sulfate soil horizons usually below the water table.

AASS are soils containing highly acidic soil horizons or layers resulting from the aeration of soil materials that are rich in iron sulfides, primarily sulfide. This oxidation produces hydrogen ions in excess of the sediment's capacity to neutralise the acidity resulting in soils of pH of 4 or less when measured in dry season conditions. These soils can usually be identified by the presence of pale yellow mottles and coatings of jarosite.

PASS are soils which contain iron sulfides or sulfidic material which have not been exposed to air and oxidised. The field pH of these soils in their undisturbed state is pH 4 or more and may be neutral or slightly alkaline. However, they pose a considerable environmental risk when disturbed, as they will become severely acid when exposed to air and oxidised.

6.2 ASS Site Assessment

Reference to the eSpade ASS Risk Map indicates that the site is NOT located in an area known ASS occurrence, however areas that do contain known potential ASS occurrence as shown on the attached Figure 5 – ASS Risk Map.

Screening testing was conducted on initial samples obtained during the field investigation. To obtain information required the following testing was carried out:

- Ten (10) ASS Screening Tests as shown below in Table 6

Further testing of one sample was not required as indicated by the screening tests and was submitted to Envirolab's NATA Accredited laboratory to undertake SPOCAS Testing.

6.2.1 Screening Test Results

Test results for Screening Tests are summarised in Table 6 below.

TABLE 6 – SUMMARY OF ASS SCREENING TEST RESULTS

Sample	Material	Initial pH with Water	pH with Peroxide	pH Change	Further Testing Required
ASSMAC Criteria		**<4.0***	**<3.0^**	**>1.0**	
BH1 (0.2-0.3m)	Topsoil	5.9	5.3	0.6	**NO**
BH1 (1.0-1.3m)	CLAY	6.4	6.0	0.6	**NO**
BH2 (0.5-0.8m)	CLAY	6.0	5.6	0.4	**NO**
BH2 (1.2-1.5m)	Sandy CLAY	5.8	5.4	0.2	**NO**
BH3 (0.4-0.5m)	CLAY	6.3	5.5	0.8	**NO**
BH3 (1.0-1.5m) m	Sandy CLAY	5.6	4.4	1.2	**YES**
BH4 (0.5-1.0m)	CLAY	6.5	5.9	0.6	**NO**
BH4 (2.0-2.2m)	Sandy CLAY	5.5	5.2	0.3	**NO**
BH5 (0.1-0.2m)	Topsoil	6.1	5.5	0.6	**NO**
BH5 (0.6-0.8m)	CLAY	6.7	6.2	0.5	**NO**
Notes - * indicates Actual ASS and ^ indicates Potential ASS					

The laboratory test results are summarised below in Table 7.

TABLE 7 – SUMMARY OF ASS SPOCAS TEST RESULTS

LOCATION AND DEPTH	**sPOCAS** (%S w/w)	**NET ACIDITY** (H+/tonne)	**LIMING RATE** (Kg Lime/T)^
BH3 – 1.0-1.5m (UNIT 3A – Sandy CLAY)	0.10	62	5
ASSMAC Action Criteria	**>0.1*** >0.03**	**>62*** >18**	NA

Levels of concern as per methods 21Af and 21Bf of the 1998 ASSMAC Guidelines

A1 * Action criteria shown are those for fine textured soils (ie clays) and management of excavations involving disturbance of less than 1000 tonnes of coarse textured soil. (CLAY or <1000 T of SAND)

A2 ** Action criteria shown are those for management of excavations involving disturbance of more than 1000 tonnes of coarse textured soils (ie sands). (>1000T SAND)

^ Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime ($CaCO_3$) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from kg/t dry weight to kg/m3 in-situ soil, multiply reported results x wet bulk density of soil in t/m3.

NA – Not Applicable

ENCOUNTERED SITE SOILS COMPRISE FINE TEXTURED MATERIAL APPLICABLE TO ACTION CRITERIA A1

6.2.2 Interpretation of ASS Test Results

The laboratory test results for the residual CLAY material encountered onsite **do NOT** exceed the Acid Sulfate Soil Management Advisory Committee (ASSMAC) action criteria.

6.2.3 ASS Management Plan

Based on these results, an ASS management plan is **NOT required** for the proposed development.

Laboratory analysis results are attached to this report.

6.0 Salinity Assessment

A salinity assessment has been undertaken on the site to assess the aggressivity of onsite soils and the requirements for salinity management during construction activities.

6.1 Salinity Laboratory Testing

Samples obtained from the lot during the field investigation were returned to Eastwest NATA laboratory for testing. To obtain information required the following testing was proposed:

- 3X Salinity and Aggressivity to concrete and steel tests.

The results of the salinity laboratory assessment are summarised in Table 8 below.

TABLE 8 – SUMMARY OF SALINITY AND AGGRESSIVITY TESTING

SAMPLE	pH	Sulfates (mg/kg)	ECe (dS/m)	Chlorides (mg/kg)
BH2 (0.5m)	5.20	98	0.81	761
BH3 (1.2m)	7.84	12	0.20	24
BH4 (0.1m)	5.37	17	0.08	31

6.2 Soil Aggressivity Towards Concrete and Steel

The following table indicates the exposure specifications for concrete and steel for footings founded in Unit 2 CLAY (<1m depth) and Unit 3A or 3B Sandy CLAY (>1m depth).

TABLE 9 – EXPOSURE CLASSIFICATIONS

MATERIAL	CONCRETE	STEEL
Applies for UNIT 2 CLAY material encountered onsite (<1m depth)	**Non-Aggressive** Min Concrete Strength (MPa) Pre Cast – **50** Cast In Place – **25** Min Reo Cover (mm for 50 yr design) Pre Cast – **20** Cast In Place – **45** Min Reo Cover (mm for 100 yr design) Pre Cast – **25** Cast In Place – **65**	**Non-Aggressive** Corrosion Rates of **<0.01 mm/yr**

MATERIAL	CONCRETE	STEEL
Applies for UNIT 3A/B Sandy CLAY material encountered onsite >1m depth	**Mild** Min Concrete Strength (MPa) Pre Cast – **50** Cast In Place – **32** Min Reo Cover (mm for 50 yr design) Pre Cast – **20** Cast In Place – **60** Min Reo Cover (mm for 100 yr design) Pre Cast – **30** Cast In Place – **75**	**Non-Aggressive** Corrosion Rates of **<0.01 mm/yr**

6.3 Site Salinity

The salinity assessment is mainly conducted based on extract electrical conductivity (ECe). Salinity refers to the presence of excessive salt, which is toxic to most plants.

Because salt separates into positively and negatively charged ions when dissolved in water, the electrical conductivity of the water increases as the amount of salt increases.

To test the electrical conductivity of soil one part of the soil is mixed with 5 parts of water. The result is then multiplied by the soil texture conversion factor to give the final figure. This result is known as extract electrical conductivity (ECe).

SAMPLE	AQUEOUS CONDUCTIVITY (Ec)	ELECTRICAL CONDUCTIVITY (Ece)	SALINITY ASSESSMENT
BH1 (0.1m)	0.09	0.81	Non-Saline
BH1 (1.1m)	0.02	0.20	Non-Saline
BH3 (0.5m)	0.008	0.08	Non-Saline

[1]Based on EC to ECe multiplication factors in Department of Land and Water Conservation (2002) Guidelines (Table 6.1), a multiplication factor of 9 was applied to Clay loam, and 7 to crushed shale.
[2]Based on Table 6.2 of Department of Land and Water Conservation (2002) where ECe < 2dS/m = Non-saline; ECe= 2-4dS/m = slightly saline; ECe = 4-8dS/m = moderately saline; ECe = 8-16dS/m = very saline; ECe > 16dS/m = highly saline.

A salinity assessment has been undertaken involving 3 soil samples across the site. The laboratory results indicate that material above 1.0m depth (Unit 2 CLAYS) is considered non-aggressive to concrete and steel and material below 1.0m depth (Unit 3A/B Sandy CLAYS) is considered mildly-aggressive to concrete and non-aggressive to steel An exposure classification as per Table 4 above should be adopted for design of proposed concrete structures.

The report concludes that salinity is not a major issue on the site and the site soils are considered as NON-SALINE. Furthermore, it can be concluded that the groundwater table is likely to be well below the surface levels.

6.4 General Salinity Management

The following general management measures should be implemented for the proposed development.

Soil pH

Revegetation of disturbed areas is very sensitive to the soil pH. The pH is an important soil fertility parameter and where the pH is outside the desirable range, effective revegetation following disturbance is difficult and the potential for erosion is increased.

The surface site soils (0.1m to 0.3m) at the site fall within the pH range for optimal plant growth.

Soil Dispersivity

Dispersive soils are commonly associated with the following soil behaviour in urban development areas:

- sediment loss to streams;
- susceptibility to tunnelling or piping through earth dams and poorly backfilled trenches etc;
- limited ability to hold water within detention ponds unless appropriately engineered;
- soil softening when saturated.

The soils in the development area are considered generally not to be considered highly dispersive.

Soil Erosion Potential During construction

The principal factors that affect potential soil erosion under bare soil conditions are the erodibility of the soil, the slope angle and the length of the uninterrupted slope. The erodibility of the soils at the site is not anticipated to be high. Avoid water collecting in low lying areas, in depressions, or behind filling embankments. This can lead to water logging of the soils, evaporative concentration of salts, and eventual breakdown in soil structure resulting in accelerated erosion.

Soil Fertility

Plant growth in the low fertility site soils can be encouraged by the application of fertiliser where required. A fertiliser mix of nitrogen (N), phosphorous (P) and potassium (K) is recommended. The general application should be a minimum of 40 kg/ha of P and 100 kg/ha of K.

Soil Salinity

Salinity levels were measured on representative samples from the natural soil profile. The salinity results were assessed by reference to the Department of Land and Water Conservation (2002) document. The soil salinity in the soils at the site are considered as non-saline. The proposed development should be designed not to mobilise salinity. This can be achieved by the provision of surface and subsoil drains to intercept water that would otherwise infiltrate, leading to a possible build-up of the groundwater table level.

Some additional strategies

• Any pavements should be designed for well-draining of surface water. There should not be excessive concentrations of runoff or ponding that would lead to waterlogging of the pavement or additional recharge to the groundwater through any more permeable zones.
• Surface drains need to be provided along the top of any proposed batter slopes to reduce the potential for concentrated flows of water down slopes possibly causing scour.

Groundwater

A rising groundwater table condition is considered to be undesirable, as the groundwater is usually saline. Groundwater recharge will tend to be reduced by the proposed development due to the increased surface water runoff caused by the presence of paved and roofed area. Planning and design should include management of factors that can lead to a rise in the groundwater table level. Such measures include reduction of irrigation requirements, avoiding the use of infiltration pits to disperse surface water and preventing leakage from basins.

Bulk Earthworks

Design and construction recommendations for the proposed development, based on the reduction of salinity impacts are presented in this section. The recommendations are based on integration of salinity reduction techniques with the fundamental engineering principles used to design and control the engineering properties of the materials to be used in the earthworks for the development.

The following earthworks design details are recommended:

• the final surface of all proposed building areas be graded to prevent the ponding of surface water;

• subsoil drainage should be provided along both sides of any pavement subgrades

The following earthworks procedures are recommended:

• all topsoil should be separately stripped and stockpiled, for later use in landscaped areas;

• the non-saline soils are suitable to be used as general fill;

• in general, site preparation should be based on good engineering practices including topsoil stripping and grubbing, and the treatment of soft spots, areas of poor drainage and waterlogging etc;

• surface water runoff should be directed around all stockpiles and work areas, standard (Blue Book) methods can be used for these purposes and erosion control for the stockpiles and disturbed areas should be planned during all stages of construction using standard (Site Investigation for Urban Salinity) methods;

• temporary sediment control structures should be used during the site development works.

Landscape design should be based on the following:

• selection of plant species suitable for the given soil conditions;

• the establishment of deep-rooted trees should be planned and encouraged. Such trees will draw water from the groundwater system. This is of benefit as the trees will tend to assist retention of the groundwater at existing levels;

• retention of significant existing trees if possible or practical.

Proposed Buildings

The following construction management techniques are recommended:

• Around all stockpiles and work areas, surface water runoff shall be directed;

• During all stages of construction, erosion control for stockpiles and disturbed areas shall be implemented using methods such as grading and sealing of partially completed earthwork surfaces during construction; and

• The use of temporary sediment control structures during all site development works.

7.0 Construction Risk

The extent of surface observation and testing associated with this assessment is limited to discrete borehole locations and variations in ground conditions can occur between and away from such locations. If subsurface conditions encountered during construction differ from those given in this report further advice should be sought without delay.

If you have any further questions about this report, please contact the undersigned.

For and on behalf of
Sanko Excavation Environmental and Civil Services P/L

Damien Sankowsky *BE(Env) CPSS*

Principal Geotechnical / Environmental Engineer
Australian Geomechanics Society (AGS) Member – EA ID 5879317
Certified Professional Soil Scientist # 12219

Attachments:

Report Limitations

Site Photographs (4 pages)

Figure 1 – Site Location

Figure 2 – Existing Site Features and Borehole Locations

Figure 3 – Proposed Development

Figure 4 – Geology Map

Figure 5 – ASS Map of Site

Log Explanation Sheets

Borehole Logs (5X BH's)

GSG Shrink / Swell Laboratory Tests Results

Envirolab SPOCAS Laboratory Tests Results

GSG Salinity Laboratory Tests Results

Calculation Sheet

CSIRO Information Sheets

References:

AS2870-2011 "Residential Slabs and Footings – Construction"

AS2159–2009 "Piling Design and Installation"

AS3798-2007 "Guidelines for Earthworks for Commercial and Residential Developments"

AS4678-2202 "Earth Retaining Structures"

eSpade

REPORT LIMITATIONS

Sanko Excavation Environmental and Civil Service Pty Ltd have undertaken a site assessment in accordance with current industry and professional standards. The scope of works were limited to that as set out in the proposal as refered to in this investigation. This report is based upon limited site investigation and subsurface sampling and laboratory testing of samples as set out in the forementioned proposal. Report findings are based upon site conditions at the time of investigation and as such can not be relied upon for unqualified warranties or assume liablity for site conditions not observed and/or accessable during or at the time of investigation. The works are restricted to the site detailed in the report with no offsite investigations conducted. Despite all resaonable care and dilligance taken ground conditions encountered and contaminant concentrations may not represent conditions between sample locations. Site characteristics may also change subsequent to this investigation due to natural processes, chemical reactions, spilling or leaking of contaminants, change in water levels or dumping of fill. All observations and interpretation is made from a limited number of observation points assuming geological and chemical conditions are representative across the site. No other warranties are made or intended. Third parties should seek their own independent advice regarding report contents. This report has been prepared exclusively for the client as detailed on the report and remains the property of this company and the client and can not be reproduced without the written consent of the client as detailed on the report and can then only be reproduced in its entirety.

Site Photographs

GEOTECHNICAL SITE ASSESSMENT

127 NEW ENGLAND HIGHWAY, LOCHINVAR, NSW **AUG 2025**

GEOTECHNICAL SITE ASSESSMENT

127 NEW ENGLAND HIGHWAY, LOCHINVAR, NSW **AUG 2025**

GEOTECHNICAL SITE ASSESSMENT

127 NEW ENGLAND HIGHWAY, LOCHINVAR, NSW AUG 2025

Site

FIGURE 1 – SITE LOCATION AND BOUNDARY

GEOTECHNICAL SITE ASSESSMENT

127 NEW ENGLAND HIGHWAY, LOCHINVAR, NSW **AUG 2025**

FIGURE 2 – EXISTING SITE AND BOREHOLE LOCATIONS

127 NEW ENGLAND HIGHWAY, LOCHINVAR, NSW

GEOTECHNICAL SITE ASSESSMENT **AUG 2025**

FIGURE 3 – PROPOSED DEVEOPMENT

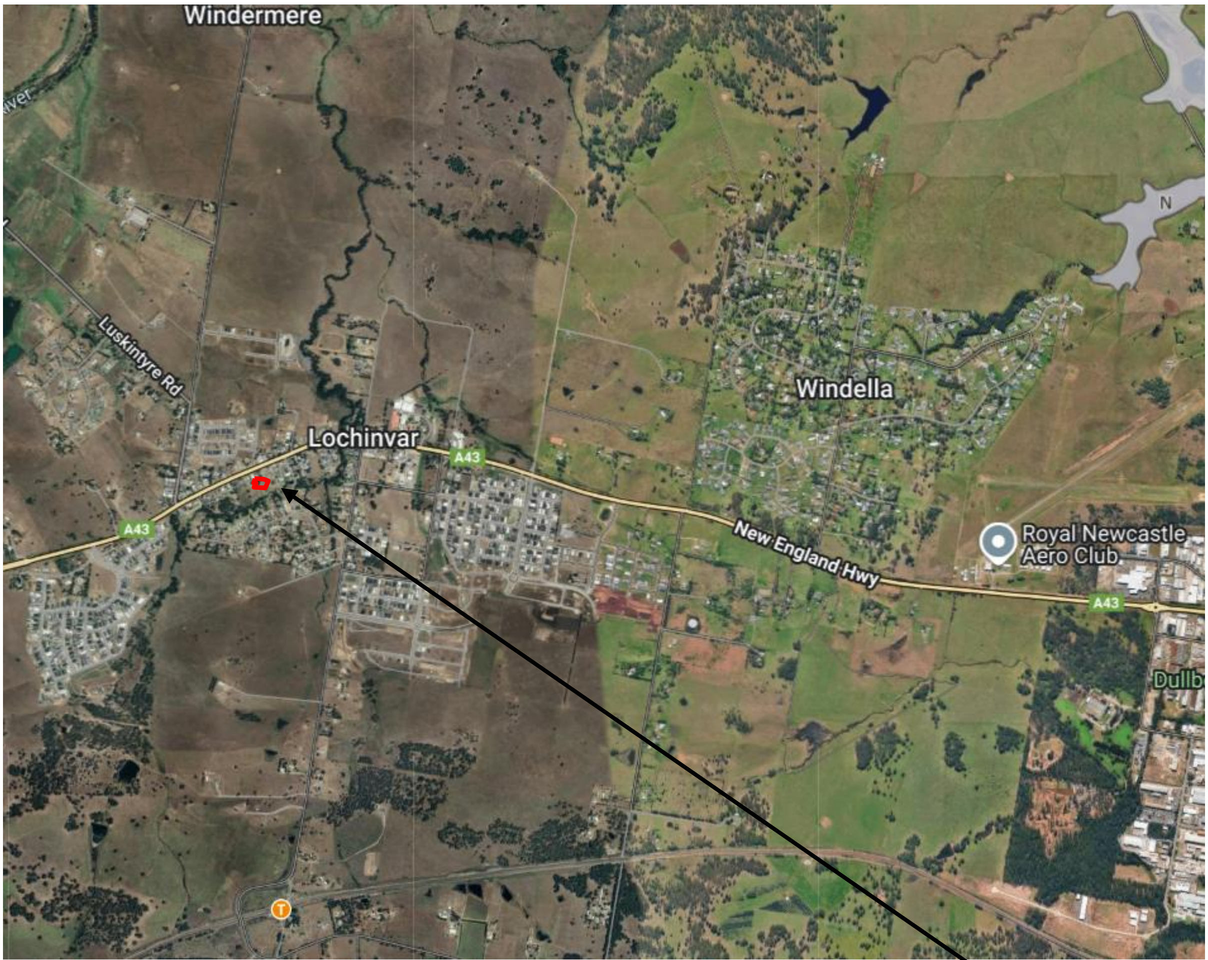
127 NEW ENGLAND HIGHWAY, LOCHINVAR, NSW

GEOTECHNICAL SITE ASSESSMENT **AUG 2025**

FIGURE 4 – GEOLOGY MAP OF SITE

127 NEW ENGLAND HIGHWAY, LOCHINVAR, NSW

GEOTECHNICAL SITE ASSESSMENT **AUG 2025**



SITE

FIGURE 5 – EXISTING SITE FEATURES

127 NEW ENGLAND HIGHWAY, LOCHINVAR, NSW

GEOTECHNICAL SITE ASSESSMENT AUG 2025

DEFINITION:

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

CLASSIFICATION SYMBOL & SOIL NAME

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

PARTICLE SIZE DESCRIPTIVE TERMS

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

MOISTURE CONDITION

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

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

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

CONSISTENCY OF COHESIVE SOILS

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

DENSITY OF GRANULAR SOILS

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

MINOR COMPONENTS

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

SOIL STRUCTURE

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

GEOLOGICAL ORIGIN

WEATHERED IN PLACE SOILS

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

TRANSPORTED SOILS

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

SOIL DESCRIPTION EXPLANATION SHEET 1/2

SOIL CLASSIFICATION INCLUDING IDENTIFICATION AND DESCRIPTION

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 60 mm and basing fractions on estimated mass)					USC	PRIMARY NAME
COARSE GRAINED SOILS More than 50% of materials less than 63 mm is larger than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than 2.0 mm	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	GW	GRAVEL
				Predominantly one size or a range of sizes with more intermediate sizes missing.	GP	GRAVEL
			GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)	GM	SILTY GRAVEL
				Plastic fines (for identification procedures see CL below)	GC	CLAYEY GRAVEL
		SANDS More than half of coarse fraction is smaller than 2.0 mm	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate sizes missing	SW	SAND
				Predominantly one size or a range of sizes with some intermediate sizes missing.	SP	SAND
			SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).	SM	SILTY SAND
				Plastic fines (for identification procedures see CL below).	SC	CLAYEY SAND

			IDENTIFICATION PROCEDURES ON FRACTIONS <0.2 mm.				
			DRY STRENGTH	DILATANCY	TOUGHNESS		
FINE GRAINED SOILS More than 50% of material less than 63 mm is smaller than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	SILTS & CLAYS Liquid limit less than 50	None to Low	Quick to slow	None	ML	SILT
			Medium to High	None	Medium	CL	CLAY
			Low to medium	Slow to very slow	Low	OL	ORGANIC SILT
		SILTS & CLAYS Liquid limit greater than 50	Low to medium	Slow to very slow	Low to medium	MH	SILT
			High	None	High	CH	CLAY
			Medium to High	None	Low to medium	OH	ORGANIC CLAY
HIGHLY ORGANIC SOILS			Readily identified by colour, odour, spongy feel and frequently by fibrous texture.			Pt	PEAT

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

COMMON DEFECTS IN SOIL

TERM	DEFINITION	DIAGRAM
PARTING	A surface or crack across which the soil has little or no tensile strength. Parallel or sub parallel to layering (eg bedding). May be open or closed.	
JOINT	A surface or crack across which the soil has little or no tensile strength but which is not parallel or sub parallel to layering. May be open or closed. The term 'fissure' may be used for irregular joints <0.2 m in length.	
SHEARED ZONE	Zone in clayey soil with roughly parallel near planar, curved or undulating boundaries containing closely spaced, smooth or slickensided, curved intersecting joints which divide the mass into lenticular or wedge shaped blocks.	
SHEARED SURFACE	A near planar curved or undulating, smooth, polished or slickensided surface in clayey soil. The polished or slickensided surface indicates that movement (in many cases very little) has occurred along the defect.	

TERM	DEFINITION	DIAGRAM
SOFTENED ZONE	A zone in clayey soil, usually adjacent to a defect in which the soil has a higher moisture content than elsewhere.	
TUBE	Tubular cavity. May occur singly or as one of a large number of separate or inter-connected tubes. Walls often coated with clay or strengthened by denser packing of grains. May contain organic matter	
TUBE CAST	Roughly cylindrical elongated body of soil different from the soil mass in which it occurs. In some cases the soil which makes up the tube cast is cemented.	
INFILLED SEAM	Sheet or wall like body of soil substance or mass with roughly planar to irregular near parallel boundaries which cuts through a soil mass. Formed by infilling of open joints.	

72810 / 07-06

SOIL DESCRIPTION EXPLANATION SHEET 2/2

LOCATION:	**127 NEW ENGLAND HWAY, LOCHINVAR**
JOB NUMBER:	**E25 036**
DATE:	**23/06/2025**
MACHINE / LOGGED BY:	**TRAILER RIG / DS**

BH – 1

DEPTH (m BGL)	DCP (blows)	MATERIAL PROPERTIES	STRUCTURE AND ADDITIONAL OBSERVATIONS
0.1		Silty SAND; fine to medium grained, dark grey, low plasticity fines, moist, dense	TOPSOIL
0.2			
0.3			
0.4		CLAY; high plasticity, grey / brown, trace of fine sand, moisture greater than the plastic limit, firm	RESIDUAL
0.5			
0.6			
0.7			
0.8			
0.9			
1.0			
1.1		Stiff	
1.2			
1.3			
1.4		Sandy CLAY; medium to high plasticity, pale brown, fine to medium grained sand, moisture equal to the plastic limit, stiff	
1.5			
1.6			
1.7			
1.8			
1.9			
2.0		Sandy CLAY; medium to high plasticity, pale brown / orange, fine to medium grained sand, moisture less than the plastic limit, very stiff	
2.1			
2.2			
2.3			
2.4			
2.5			
2.6			
2.7			
2.8			
2.9			
3.0			

BOREHOLE BH1 TERMINATED AT 3.0m (Limit of Investigation)

SEEPAGE NOT ENCOUNTERED

LOCATION:	**127 NEW ENGLAND HWAY, LOCHINVAR**
JOB NUMBER:	**E25 036**
DATE:	**23/06/2025**
MACHINE / LOGGED BY:	**TRAILER RIG / DS**

BH – 2

DEPTH (m BGL)	DCP (blows)	MATERIAL PROPERTIES	STRUCTURE AND ADDITIONAL OBSERVATIONS
0.1		Silty SAND; fine to medium grained, dark grey, low plasticity fines, moist, dense	TOPSOIL
0.2			
0.3			
0.4		CLAY; high plasticity, grey / brown, trace of fine sand, moisture greater than the plastic limit, firm	RESIDUAL
0.5			
0.6			
0.7			
0.8			
0.9		Sandy CLAY; medium to high plasticity, pale brown, fine to medium grained sand, moisture equal to the plastic limit, stiff	
1.0			
1.1			
1.2			
1.3			
1.4		Very stiff	
1.5		Sandy CLAY; medium to high plasticity, pale brown / orange, fine to medium grained sand, moisture less than the plastic limit, very stiff	
1.6			
1.7			
1.8			
1.9			
2.0			
2.1			
2.2			
2.3			
2.4			
2.5			
2.6			
2.7			
2.8			
2.9			
3.0			

BOREHOLE BH2 TERMINATED AT 3.0m (Limit of Investigation)

SEEPAGE NOT ENCOUNTERED

LOCATION:	127 NEW ENGLAND HWAY, LOCHINVAR
JOB NUMBER:	E25 036
DATE:	23/06/2025
MACHINE / LOGGED BY:	TRAILER RIG / DS

BH – 3

DEPTH (m BGL)	DCP (blows)	MATERIAL PROPERTIES	STRUCTURE AND ADDITIONAL OBSERVATIONS
0.1		Silty SAND; fine to medium grained, dark grey, low plasticity fines, moist, dense	TOPSOIL
0.2			
0.3			
0.4			
0.5		CLAY; high plasticity, grey / brown, trace of fine sand, moisture greater than the plastic limit, firm	RESIDUAL
0.6			
0.7			
0.8			
0.9			
1.0			
1.1		Sandy CLAY; medium to high plasticity, pale brown, fine to medium grained sand, moisture equal to the plastic limit, stiff	
1.2			
1.3			
1.4			
1.5		Sandy CLAY; medium to high plasticity, pale brown / orange, fine to medium grained sand, moisture less than the plastic limit, very stiff	
1.6			
1.7			
1.8			
1.9			
2.0			
2.1			
2.2			
2.3			
2.4			
2.5			
2.6			
2.7			
2.8			
2.9			
3.0			

BOREHOLE BH3 TERMINATED AT 3.0m (Limit of Investigation)

SEEPAGE NOT ENCOUNTERED

LOCATION:	**127 NEW ENGLAND HWAY, LOCHINVAR**
JOB NUMBER:	**E25 036**
DATE:	**23/06/2025**
MACHINE / LOGGED BY:	**TRAILER RIG / DS**

BH – 4

DEPTH (m BGL)	DCP (blows)	MATERIAL PROPERTIES	STRUCTURE AND ADDITIONAL OBSERVATIONS
0.1		Silty SAND; fine to medium grained, dark grey, low plasticity fines, moist, dense	TOPSOIL
0.2			
0.3			
0.4		CLAY; high plasticity, grey / brown, trace of fine sand, moisture greater than the plastic limit, firm	RESIDUAL
0.5			
0.6			
0.7			
0.8			
0.9			
1.0			
1.1			
1.2		Sandy CLAY; medium to high plasticity, pale brown, fine to medium grained sand, moisture equal to the plastic limit, stiff	
1.3			
1.4		Sandy CLAY; medium to high plasticity, pale brown / orange, fine to medium grained sand, moisture less than the plastic limit, very stiff	
1.5			
1.6			
1.7			
1.8			
1.9			
2.0			
2.1			
2.2			
2.3			
2.4			
2.5			
2.6			
2.7			
2.8			
2.9			
3.0			

BOREHOLE BH4 TERMINATED AT 3.0m (Limit of Investigation)

SEEPAGE NOT ENCOUNTERED

LOCATION:	127 NEW ENGLAND HWAY, LOCHINVAR
JOB NUMBER:	E25 036
DATE:	23/06/2025
MACHINE / LOGGED BY:	TRAILER RIG / DS

BH – 5

DEPTH (m BGL)	DCP (blows)	MATERIAL PROPERTIES	STRUCTURE AND ADDITIONAL OBSERVATIONS
0.1		Silty SAND; fine to medium grained, dark grey, low plasticity fines, moist, dense	TOPSOIL
0.2			
0.3			
0.4		CLAY; high plasticity, grey / brown, trace of fine sand, moisture greater than the plastic limit, firm	RESIDUAL
0.5			
0.6			
0.7			
0.8			
0.9			
1.0			

BOREHOLE BH5 AT 1.0m (Limit of Investigation)

SEEPAGE NOT ENCOUNTERED

Material Test Report

Report Number:	**GSNS-TAM-25-1038-1**
Issue Number:	1
Date Issued:	07/07/2025
Client:	SANKO EXCAVATION ENVIRONMENTAL & CIVIL SERVICES - CASH SALE 26 LEARMOUTH STREET, WILLOW TREE NSW 2339
Contact:	DAMIEN SANKOWSKY
Project Number:	GSNS-TAM-25-1038
Project Name:	Proposed Commercial Development
Project Location:	127 New England Highway, LOCHINVAR NSW 2321
Client Reference:	E25 036
Work Request:	3350
Dates Tested:	26/06/2025 - 07/07/2025
Location:	127 New England Highway, LOCHINVAR NSW 2321

GSG LABORATORIES
Tamworth Laboratory
82 Plain Street Tamworth NSW 2340
Phone: 1300 295 835
Email: matt.coleman@gsglabs.com.au

Matt Coleman (Geotechnical Lab Supervisor)

Shrink Swell Index AS 1289 7.1.1 & 2.1.1					
Sample Number	T3350A				
Date Sampled	23/06/2025				
Date Tested	07/07/2025				
Material Source	**				
Sample Location	BH2 (0.5-1.0m)				
Inert Material Estimate (%)	3				
Pocket Penetrometer before (kPa)	130				
Pocket Penetrometer after (kPa)	100				
Shrinkage Moisture Content (%)	31.0				
Shrinkage (%)	**6.4**				
Swell Moisture Content Before (%)	30.0				
Swell Moisture Content After (%)	35.7				
Swell (%)	**2.1**				
Shrink Swell Index Iss (%)	**4.1**				
Visual Description	CLAY				
Cracking	SC				
Crumbling	No				
Remarks	Sample Remoulded				

Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.

Cracking Terminology: UC Uncracked, SC Slightly Cracked, MC Moderately Cracked, HC Highly Cracked, FR Fragmented.

NATA Accreditation does not cover the performance of pocket penetrometer readings.

Envirolab Services Pty Ltd
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customerservice@envirolab.com.au
www.envirolab.com.au

CERTIFICATE OF ANALYSIS 384475

Client Details

Client	Sanko excavation Environmental & Civil Services
Attention	Damien Sankowsky
Address	76 Wollombi Rd, Millfield, NSW, 2325

Sample Details

Your Reference	**E25 036-127 New England Highway, Lochinvar**
Number of Samples	1 Soil
Date samples received	27/06/2025
Date completed instructions received	27/06/2025

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Report Details

Date results requested by	07/07/2025
Date of Issue	24/07/2025

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Results Approved By
Priya Samarawickrama, Senior Chemist

Authorised By
Nancy Zhang, Laboratory Manager

Acid Sulphate Soil Suite		
Our Reference		384475-1
Your Reference	UNITS	BH3
Depth		1.0-1.5
Date Sampled		23/06/2025
Type of sample		Soil
Date prepared	-	01/07/2025
Date analysed	-	02/07/2025
pH_{kcl}	pH units	3.9
s-TAA pH 6.5	%w/w S	0.08
TAA pH 6.5	moles H^+ /t	49
a-S_{POS}	moles H^+ /t	<5
S_{POS}	%w/w	0.006
S_P	%w/w	0.03
S_{KCl}	%w/w S	0.020
S_{HCl}	%w/w S	0.030
S_{NAS}	%w/w S	0.021
ANC_{BT}	% $CaCO_3$	[NT]
s-ANC_{BT}	%w/w S	[NT]
s-Net Acidity excluding ANC	%w/w S	0.10
a-Net Acidity excluding ANC	moles H^+ /t	62
Liming rate excluding ANC	kg $CaCO_3$ /t	4.7
s-Net Acidity including ANC	%w/w S	0.10
a-Net Acidity including ANC	moles H^+ /t	62
Liming rate including ANC	kg $CaCO_3$ /t	5

Method ID	Methodology Summary
Inorg-068	Determination of Acid Sulphate Soil analysis - a sample is analysed by traditional titration method and ICP-OES analysis. Based on Acid Sulfate Soils Laboratory Methods Guidelines, latest edition. Ideally samples should be received in the laboratory at <4oC. Please refer to SRA for sample temperature on receipt. Samples should also ideally be received within 24 hrs of sampling, otherwise there is the potential for oxidation to occur (as indicated by the lowering of the pH). Freezing the samples may help mitigate the potential for oxidation. There is no documented official holding time for frozen samples, we have assigned an arbitrary 180 days to frozen samples. Neutralising value (NV) of 100% is assumed for liming rate. Net Acidity with ANC calculation should only be used when corroborated by other data that demonstrates the soil material does not experience acidification during complete oxidation under field conditions. The recommendation that the SHCL concentration be multiplied by a factor of 2 to ensure retained acidity is not underestimated, has not been applied in the SHCL results reported.

QUALITY CONTROL: Acid Sulphate Soil Suite						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	[NT]
Date prepared	-			01/07/2025	1	01/07/2025	01/07/2025		01/07/2025	[NT]
Date analysed	-			02/07/2025	1	02/07/2025	02/07/2025		02/07/2025	[NT]
pH $_{kcl}$	pH units		Inorg-068	[NT]	1	3.9	3.9	0	95.0	[NT]
s-TAA pH 6.5	%w/w S	0.01	Inorg-068	<0.01	1	0.08	0.08	0	[NT]	[NT]
TAA pH 6.5	moles H^+/t	5	Inorg-068	<5	1	49	49	0	104	[NT]
a-S_{POS}	moles H^+/t	5	Inorg-068	<5	1	<5	<5	0	[NT]	[NT]
S_{POS}	%w/w	0.005	Inorg-068	<0.005	1	0.006	0.007	15	[NT]	[NT]
S_P	%w/w	0.005	Inorg-068	<0.005	1	0.03	0.03	0	87	[NT]
S_{KCl}	%w/w S	0.005	Inorg-068	<0.005	1	0.020	0.020	0	[NT]	[NT]
S_{HCl}	%w/w S	0.005	Inorg-068	<0.005	1	0.030	0.030	0	[NT]	[NT]
S_{NAS}	%w/w S	0.005	Inorg-068	<0.005	1	0.021	0.019	10	[NT]	[NT]
ANC_{BT}	% $CaCO_3$	0.05	Inorg-068	<0.05	1	[NT]	[NT]		84	[NT]
s-ANC_{BT}	%w/w S	0.05	Inorg-068	<0.05	1	[NT]	[NT]		[NT]	[NT]
s-Net Acidity excluding ANC	%w/w S	0.005	Inorg-068	<0.005	1	0.10	0.10	0	[NT]	[NT]
a-Net Acidity excluding ANC	moles H^+/t	5	Inorg-068	<5	1	62	62	0	[NT]	[NT]
Liming rate excluding ANC	kg $CaCO_3$/t	0.75	Inorg-068	<0.75	1	4.7	4.7	0	[NT]	[NT]
s-Net Acidity including ANC	%w/w S	0.005	Inorg-068	<0.005	1	0.10	0.10	0	[NT]	[NT]
a-Net Acidity including ANC	moles H^+/t	5	Inorg-068	<5	1	62	62	0	[NT]	[NT]
Liming rate including ANC	kg $CaCO_3$/t	0.75	Inorg-068	<0.75	1	5	5	0	[NT]	[NT]

Result Definitions

NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported

Quality Control Definitions

Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: >10xPQL - RPD acceptance criteria will vary depending on the analytes and the analytical techniques but is typically in the range 20%-50% – see ELN-P05 QA/QC tables for details; <10xPQL - RPD are higher as the results approach PQL and the estimated measurement uncertainty will statistically increase.

Air volumes are typically provided by customers (often as flow rate(s) and sampling time(s) and/or simply volumes) sampled or exposure times (determines 'volume' passive badges are exposed to)). Hence in such circumstances the volume measurement is inevitably not covered by Envirolab's NATA accreditation. An exception may occur where Envirolab Newcastle does the sampling where accreditation exists for certain types of sampling and hence volume determination(s). Note air volumes are often used to determine concentrations for dust and/or analyses on filters, sorbents and in impingers. For canister sampling, the air volume is covered by Envirolab's NATA accreditation.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals (not SPOCAS); 60-140% for organics/SPOCAS (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.

Analysis of aqueous samples typically involves the extraction/digestion and/or analysis of the liquid phase only (i.e. NOT any settled sediment phase but inclusive of suspended particles if present), unless stipulated on the Envirolab COC and/or by correspondence. Notable exceptions include certain Physical Tests (pH/EC/BOD/COD/Apparent Colour etc.), Solids testing, total recoverable metals and PFAS where solids are included by default.

For Dust Deposit Gauge (DDG) analysis the sampling, sampling period and funnel exposure area do not fall under Envirolab's NATA accreditation (unless the Newcastle laboratory where responsible for the sampling), hence the annotation on the DDG units of reporting.

Urine Analysis - The BEI values listed are taken from the 2022 edition of "TLVs and BEIs Threshold Limits" by ACGIH.

CHAIN OF CUSTODY - Client

ENVIROLAB GROUP - National phone number 1300 424 344

Client:	Client Project Name / Number / Site etc (ie report title): E25036 - 127 NEW ENGLAND HIGHWAY, LOCHINVAR
Contact Person: Damien Sankowsky	
Project Mgr:	PO No.:
Sampler:	Envirolab Quote No. : 17SY108C3
Address: 26 LEARMONTH ST, WILLOW TREE, NSW, 2339 0407 434 604	Date results required: Or choose: standard / same day / 1 day / 2 day / 3 day *Note: Inform lab in advance if urgent turnaround is required - surcharges apply*
Phone: Mob:	Additional report format: esdat / equis /
Email: seecservices@hotmail.com	Lab Comments:

Sydney Lab - Envirolab Services
12 Ashley St, Chatswood, NSW 2067
Ph: 02 9910 6200 / sydney@envirolab.com.au

Perth Lab - MPL Laboratories
16-18 Hayden Crt Myaree, WA 6154
Ph: 08 9317 2505 / lab@mpl.com.au

Melbourne Lab - Envirolab Services
1A Dalmore Drive Scoresby VIC 3179
Ph: 03 9763 2500 / melbourne@envirolab.com.au

Adelaide Office - Envirolab Services
7a The Parade, Norwood, SA 5067
Ph: 08 7087 6800 / adelaide@envirolab.com.au

Brisbane Office - Envirolab Services
20a, 10-20 Depot St, Banyo, QLD 4014
Ph: 07 3266 9532 / brisbane@envirolab.com.au

Darwin Office - Envirolab Services
Unit 7, 17 Willes Rd, Berrimah, NT 0820
Ph: 08 8967 1201 / darwin@envirolab.com.au

Sample information					Tests Required	Comments
Envirolab Sample ID	Client Sample ID or information	Depth	Date sampled	Type of sample	SPOCAS	Provide as much information about the sample as you can
1	B1+		23/6	SOIL BAG	✓	

Envirolab Services
12 Ashley St
Chatswood NSW 2067
Ph: (02) 9910 6200
Job No: 384475
Date Received: 27/06/25
Time Received: 1015
Received By: TT
Temp: Cool/Ambient
Cooling: Ice/Icepack
Security: Intact/Broken/None

Relinquished by (Company): SMKO	Received by (Company): ELS	*Lab use only:*
Print Name: D. SANKOWSKY	Print Name: Tony Trinh	Samples Received: Cool or Ambient (circle one)
Date & Time: 24.6.25	Date & Time: 27/06/25 1015	Temperature Received at: 10 °C (if applicable)
Signature:	Signature: TT	Transported by: Hand delivered / courier

Envirolab Services Pty Ltd
ABN 37 112 535 645
12 Ashley St Chatswood NSW 2067
ph 02 9910 6200 fax 02 9910 6201
customerservice@envirolab.com.au
www.envirolab.com.au

SAMPLE RECEIPT ADVICE

Client Details	
Client	Sanko excavation Environmental & Civil Services
Attention	Damien Sankowsky

Sample Login Details	
Your reference	E25 036-127 New England Highway, Lochinvar
Envirolab Reference	384475
Date Sample Received	27/06/2025
Date Instructions Received	27/06/2025
Date Results Expected to be Reported	07/07/2025

Sample Condition	
Samples received in appropriate condition for analysis	Holding time exceedance
No. of Samples Provided	1 Soil
Turnaround Time Requested	Standard
Temperature on Receipt (°C)	10
Cooling Method	Ice Pack
Sampling Date Provided	YES

Comments

Please contact the laboratory within 24 hours if you wish to cancel the aforementioned testing. Otherwise testing will proceed as per the COC and hence invoiced accordingly.

Please direct any queries to:

Aileen Hie	Jacinta Hurst
Phone: 02 9910 6200	**Phone: 02 9910 6200**
Fax: 02 9910 6201	**Fax: 02 9910 6201**
Email: ahie@envirolab.com.au	**Email: jhurst@envirolab.com.au**

Invoice will be emailed separately. Results will be reported only if payment has been made. Details of analysis on the following page:

Envirolab Services Pty Ltd
ABN 37 112 535 645
12 Ashley St Chatswood NSW 2067
ph 02 9910 6200 fax 02 9910 6201
customerservice@envirolab.com.au
www.envirolab.com.au

Sample ID	Acid Sulphate Soil Suite
BH3-1.0-1.5	✓

The '✓' indicates the testing you have requested. **THIS IS NOT A REPORT OF THE RESULTS.**

Additional Info
Sample storage - Waters are routinely disposed of approximately 1 month and soils approximately 2 months from receipt.
Requests for longer term sample storage must be received in writing.
Please contact the laboratory immediately if observed settled sediment present in water samples is to be included in the extraction and/or analysis (exceptions include certain Physical Tests (pH/EC/BOD/COD/Apparent Colour etc.), Solids testing, Total Recoverable metals and PFAS analysis where solids are included by default.
TAT for Micro is dependent on incubation. This varies from 3 to 6 days.

02 6762 1733
admin@gsglabs.com.au
82 Plain St, Tamworth NSW 2340
ABN 48 648 447 198

ANALYSIS REPORT SOIL

PROJECT NO:	**EW251454**	**Date of Issue:**	**25/07/2025**
Customer:	SANKO EXCAVATION ENVIRONME	Report No:	1
Address:	26 Learmouth Street WILLOW TREE NSW 2339	Date Received:	18/07/2025
		Matrix:	Soil
Attention:	Damien Sankowsky	Location:	127 New England Highw
Phone:	0407 434 604	Sampler ID:	Client
Fax:		Date of Sampling:	10/07/2025
Email:	seecservices@hotmail.com	Sample Condition:	Acceptable

Results apply to the samples as submitted. All pages of this report have been checked and approved for release.

Signed: Stephanie Cameron
Laboratory Operations Manager

NATA Accredited Laboratory 20956
Accredited for compliance with ISO/IEC 17025 - Testing

This analysis relates to the sample submitted and it is the client's responsibility to make certain the sample is representative of the matrix to be tested.

Samples will be discarded one month after the date of this report. Please advise if you wish to have your sample/s returned.

GSG LABORATORIES

ANALYSIS REPORT

PROJECT NO: EW251454 **Location: 127 New England Highway, Lochinvar**

				CLIENT SAMPLE ID	**BH2**	**BH3**	**BH4**	
				DEPTH	**0.5m**	**1.2m**	**0.1m**	
Test Parameter	**Method Description**	**Method Reference**	**Units**	**LOR**	**251454-1**	**251454-2**	**251454-3**	
pH (1:5 in CaCl2)	Electrode	R&L 4B2	pH units	na	5.20	7.84	5.37	
Chloride Soluble	DA	DAP-06	mg/kg	5	761	23.5	30.8	
Electrical Conductivity	Electrode	R&L 3A1	dS/m	0.01	0.81	0.20	0.08	
Sulphate-Sulphur	KCl40/ICP	R&L 10D1	mg/kg	3	98.2	12.0	17.4	

Soils are air dried at 40^{0}C and ground <2mm.

NB: LOR is the Lowest Obtainable Reading.

DOCUMENT END

251454

Sanko

1 8 JUL 2025
Raw KB

LABORATORY TEST REQUEST RECORD

INVOICE DETAILS:	
PROJECT: PROPOSED CHILD CARE	**PROJECT NO:** E25 036
LOCATION: 127 NEW ENGLAND HIGHWAY, LOCHINVAR	**SAMPLED BY:** DGS
LABORATORY: TMM	
TEST REQUESTED BY: DAMIEN 0407 434 604	
DATE OF SAMPLING: 10/7 **DATE REQUIRED:**	**DATE REQUESTED:** 15/7

SAMPLING CLAUSE: AS1289.1.2.1 ☐ 6.4 ☐ 6.5.1 ☐ 6.5.3 ☐ 6.5.4
SAMPLING CLAUSE: AS1141.3.1 ☐ 8.4.2 ☐ 8.4.3 ☐ 9.3 ☐ 9.4 ☐ 10.1

Test Method (RTA, AS1141, AS 1289, other)

251454

Test Required to be Done		SALINITY + AGGRESSIVITY											
Sample No:	**Sample Location**												
1	BH2 (0.5)m	/											
2	BH (1.2)m	/											
3	BH4 (0.?)m	/											

Sanko

Excavation Environmental & Civil Services P/L • Environmental and Geotechnical Engineering

Site Classification by characteristic surface movement (ys) as per AS2870-2011

Classification does not consider Class P conditions as set out in clause 2.1.3 of AS2870-2011

Client:	Brown Commercial Building	Job No.:	E25 036
Project:	Proposed Mixed Use Development	Date:	Aug-25
Location:	127 New England Highway, LOCHINVAR, NSW	By:	dgs
Lot No.:		Checked:	yd

Iss Used			
0.0 - 0.15m	Depth of watertable if <Hs (H)	10.0	m
0.70%	Depth of design suction change (Hs)	2.3	m
0.15 - 3.0m	Cracked depth multiplication factor (dx)	0.50	
4.10%	Depth of cracked zone (dc)	1.15	m
	Change in suction at ground surface (Δu)	1.2	pF
	Depth of bedrock if < Hs (dr)	10.0	m
	Depth / Height of controlled fill (<5 years old)	0	m
	Depth of proposed cut or exisitng cut (<2years old)	0	m

A single layer should not span the Crack depth, Watertable or Bedrock lines. Use separate layers above and below these lines.

Depth of fill should extend to the Base Depth of one layer.

Layers	Base Depth (m)	Thickness (m)	Mid Depth (m)	Iss (%)	ΔpF	Natural or fill conditions α	Ys (mm)
Layer 1:*	0.15	0.15	0.075	0.70	1.161	1.000	1.22
Layer 2 :	1.15	1	0.65	4.10	0.861	1.000	35.30
Layer 3:	2.3	1.15	1.725	4.10	0.300	1.655	23.41
Layer 4:		0	0		1.200	2.000	0.00
Layer 5:		0	0		1.200	2.000	0.00
Layer 6:		0	0		1.200	2.000	0.00
						Total y_s	59.92

Site Classification for Natural/Fill Conditions — **H1**

Check base depth of a layer is equal to the depth of original cracked zone — OK

Check base depth of a layer is equal to the depth of controlled Fill — OK

Does the cut affect Site Classification — NO — **Disregard the Cut Conditions Table Below**

Depth of revised cracked zone in cut area — 1.15 m

Layers	Base Depth below cut surface (m)	Thickness (m)	Mid Depth (m)	Iss (%)	ΔpF	Cut conditions α	Ys (mm)
Layer 1:		0	0		1.200	1.000	N/A
Layer 2 :		0	0		1.200	1.000	N/A
Layer 3:		0	0		1.200	1.000	N/A
Layer 4:		0	0		1.200	1.000	N/A
Layer 5:		0	0		1.200	1.000	N/A
						Total y_s	N/A

Site Classification for Cut Conditions — **N/A**

N/A

Site Classification of Lot (based on ys) — H1

Foundation Maintenance and Footing Performance: A Homeowner's Guide

CSIRO

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).

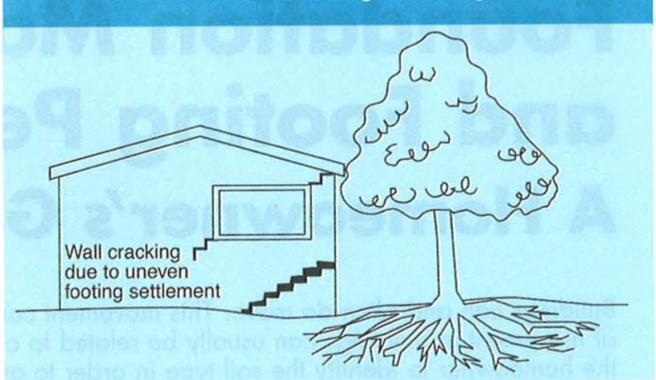
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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

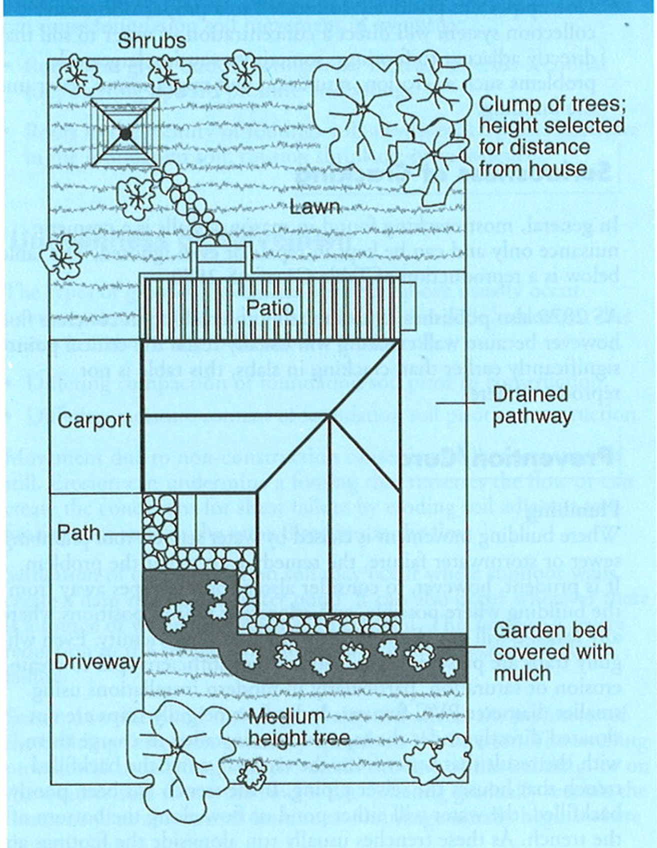
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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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BUILDING TECHNOLOGY *file*

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A builder's guide to preventing damage to dwellings

Part 1 – Site investigation and preparation

THE PROBLEMS

History

Many homes in Australia suffer from one or more of the several maladies that result from conditions that could have been prevented had the engineer and/or builder undertaken thorough site investigation and subsequent site preparation. This work is just as important as employing sound practice in construction – in fact, at law it is increasingly seen as part of sound building practice. The result is that a reasonably competent builder is now expected to know more about building movement caused by foundation soils than was the case before the landmark legal battles of the middle 1990s.

The growth of consumerism has led to the notion that a consumer can rely on the builder to be competent in all matters related to construction. We know that the builder relies on the competence of specialists and professionals, but in the end it is the builder's duty to the customer to ensure that the building is not adversely affected by defective foundations. There are many builders who are sufficiently competent in soils to carry out the level of elementary investigation required for most small sites. For them, this document may serve as a checklist for their initial inspection and a reminder that if they discover any soil problems, they should engage a suitably qualified engineer. For those builders who are not familiar with site investigation, this document is designed to give the rudiments of soils as they affect housing in most parts of Australia, and to help the practitioner on the road toward an understanding of the issues. Such builders, while in the process of learning, would be wise to engage an expert engineer for site investigation prior to finalisation of the engineering design drawings.

The predominant practice in residential construction is for the builder to ignore the soil except for the provision of bearing surfaces for footings. In fact, Clause 3.2 of AS 1684 requires the site to be clear of tree roots etc. and to be well drained. AS 2870 requires soil classification and gives a brief description of the allowable methods. AS 3798 details a number of issues that should be covered in a site investigation. All of these standards have been incorporated into the Building Code of Australia (BCA). Because the BCA has been adopted by every relevant jurisdiction in the nation, the law requires the builder to abide by the provisions in the standards or have an engineered solution accepted that will meet the performance requirements of the BCA.

Results of soil problems

The upshot of all the above is that no longer are defects such as falls in floor levels, cracking in floor tiles, cracking in concrete slabs, cracking in walls and ceilings (especially cornices), squeaky flooring, binding doors and windows, deflecting roof slopes, and cracked mortar bedding to ridge and hip caps believed to be caused by a natural phenomenon beyond the responsibility of the builder. The builder should therefore carry out proper site investigation and prepare the site accordingly.

Water problems

The principal enemy is water – either flowing, ponding, seeping by gravitational force, migrating by capillary action or in the air as vapour. Any masonry product that can absorb water can be damaged by it or by the chemicals carried with water; any permeable mortar is also susceptible; timber will decay in contact with water or vapour; gypsum plasterboard decomposes; steel is obviously also vulnerable.

Aside from direct damage to building elements, water very commonly causes damage to buildings indirectly by working on the foundation soil – erosion, subsidence, swelling and shrinkage of soil by absorption and shedding of moisture.

Buildings with subfloor voids, such as found when timber or steel frame floors are constructed, also suffer from high humidity in the subfloor when water flows or ponding exist. This can encourage decay of the timber, cup the floorboards and raise the humidity level in the living space.

This introduces another dimension of the problems created by water – that of living organisms. The presence of water attracts insects including termites. In turn, predators such as spiders are also attracted. Perhaps the most insidious and serious hazard is introduced by dust mites and some types of fungus, that have been shown to greatly increase the incidence of respiratory ailment symptoms in susceptible occupants.

Slab-on-ground construction is also subject to water incursion problems. The added problem this method has is the ease with which water can gain access to the cavity via weepholes. Once in the cavity, it creates a damp environment which is very slow to dry, transferring moisture to the inner leaf walls and timber finishes and creating high humidity in the living space.

Vegetation problems

The other source of instability to structures that this BTF deals with is vegetation and organic matter. Tree roots can cause upheaval when growing and subsidence when decomposed, as well as creating uneven moisture content by taking in water. Organic material generally in the subsoil is not stable and does not properly compact, therefore making a poor foundation for a structure.

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 cohesive. Quite often foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Cohesive soils are either clay or silt. Clay soils are by far the more common and are subject to saturation and swell/shrink problems.
As most buildings suffering continuing 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 following table is reproduced from AS 2870.

TABLE 2.1
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* 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 (see Clause 2.4.6)
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

* For examples of clay sites classified as Class S, refer to Appendix D.

SOIL PROBLEMS

Rock
Excluding movement caused by seismic events, monolithic rock is not subject to movement problems. However, there are things to watch for:
- Footings may be founded on boulders or 'floaters' which can move due to erosion of soil around them.
- Rock is susceptible to water migration via faults and between strata. Many dwellings founded on sandstone suffer from water in the subfloor.

Granular soils
There are a number of problems to be avoided:
- These soils are not cohesive and can be susceptible to local shear failure when not confined. For this reason, building on sand dunes is inadvisable.
- Sandy soils are prone to erosion so service trenches, pipes, surface water and ground water flows can be hazards.
- Organic material left in the soil may be eaten by termites, leaving a void which will be filled by surrounding granular soil, thus reducing the bearing capacity of the foundation in that area.
- Sand expands when damp – surface tension will adhere water to grains, thus expanding the volume. Conversely, when saturated, sand is at its lowest volume. The fact that these changes occur means that care must be exercised to ensure that sand is well-compacted when constructing footings.

Silt
The chief risk presented by silt is its susceptibility to erosion, so the hazards that apply to granular soils may also apply to silt.

Clay
Most clays provide good residential foundations when dry, but most clays react significantly to the introduction of water:
- Local shear failure is not uncommon when soft clays are wet.
- When saturated, virtually any clay substantially loses its bearing capacity.
- The cohesive quality of clay makes it slower to compress under load than other soil types.
- A small volume of water can have a significant effect on clay.
- Clay absorbs and sheds water slowly.

CAUSES OF MOVEMENT

Settlement due to construction
There are two types of settlement that occur as a result of construction:
- Immediate settlement takes place 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 largely take place during the first few months after construction, but has been known to take many years in exceptional cases.

Erosion
All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay, particularly 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.

Seasonal swelling & shrinkage of soil
As can be seen in the table above, all clays react to the presence of water by slowly absorbing it, making the soil increase in volume. The degree of increase varies considerably in various 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 significant 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. This can occur through saturation of clay, failure of a damp reactive clay when attempting to raise a footing that is being acted on by a superior downward force, or any soil that loses its compaction.

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.

In addition, roots that are left in the ground after the tree is felled can be eaten by termites and/or destroyed by decay. This leaves a void which can turn into a watercourse and/or cause subsidence under or adjacent to the footings.

SITE INVESTIGATION

Factors
The factors that need to be investigated are:
- Soil classification.
- Soil condition.
- Watertable.
- Ground slope.
- Trees, shrubs and organic material.
- Service trenches.
- Water run-off.

Soil classification test
AS 2870 requires that the soil to be used as foundation for construction be classified. The requirement is that the soil be classified not by its geotechnic type, but by its reactivity. Reactivity can be defined as the change in volume brought about in the soil by the introduction or removal of water – in other words, the swell and shrinkage. Soil classes A, S, M, H and E cover the range of reactivity, and P is used where soil has abnormalities that do not allow normal classification. In some long-established areas, information on soil class may be obtained from buildings adjacent to the site, where the buildings are footed on lightly stiffened strip footings or slabs-on-ground. AS 2870 Tables 2.2, C1 and C2 are a guide to determining soil class by measuring differential movement or masonry cracking.

This easy classification method should, however, be regarded as the exception rather than the rule, because the majority of new buildings are constructed in areas where adjacent buildings, if they exist, are not sufficiently well established to enable sound data to be taken. In years gone by, local councils assumed some responsibility for providing soil classification to applicants for developments, but local authorities are increasingly divesting themselves of this type of service and, in any case, council area classifications do not necessarily apply to specific sites. Therefore, the job falls back on the engineer and the builder to ascertain the soil class which will determine the footing and masonry design.

It is desirable to inspect the site before clearing and/or excavation, because although the ground may be covered with topsoil, organic material or vegetation, there may be valuable evidence that will not be apparent after excavation. Usually, test pits or boreholes can, without difficulty, be dug to reach the depth required by Clause 2.3.3 and Table 2.4 of AS 2870, reproduced below.

> ***2.3.3 Depth of investigation*** *The soil profile shall be examined to a minimum depth equal to 0.75 times the depth of the suction change, H_s, as given in Table 2.4, but not less than 1.5 m, unless rock is encountered or in the opinion of the classifier, further drilling is unnecessary for the purpose of identifying the soil profile in accordance with Clause 2.2.1(a).*

TABLE 2.4
RECOMMENDED SOIL SUCTION CHANGE PROFILES FOR CERTAIN LOCATIONS

Location	Change in suction at the soil surface (Δu) pF	Depth of design suction change (H_s) m
Adelaide	1.2	4.0
Albury/Wodonga	1.2	3.0
Brisbane/Ipswich	1.2	1.5–2.3 (see Note)
Hobart	1.5	2.0
Hunter Valley	1.5	2.0
Launceston	1.2	2.0
Melbourne	1.2	1.5–2.3 (see Note)
Newcastle/Gosford	1.5	1.5
Perth	1.2	3.0
Sydney	1.5	1.5
Toowoomba	1.2	1.8–2.3 (see Note)

NOTE: The variation in H_s depends largely on climatic variation.

This investigation is necessary if correct soil classification has not been ascertained by other means. For a Class 1 building, a single test hole is usually sufficient for soil classification. However, if at a predominantly clay site, the clay extends to the bottom of the borehole, or if abnormalities are apparent, further investigation will be required. This may need to be carried out or followed up by a suitably qualified engineer and, in the case of clay soil, some laboratory analysis may be needed. In any case, while soil class may be ascertained by one borehole, a better picture of class and condition will emerge if investigation extends to the footprint extremities, particularly on sloping sites. For most purposes, a manually dug test pit is more useful than a borehole, but if boreholes are to be used, 400 mm diameter gives good vision.

The site investigation will also incorporate examination of the surface for cracking, gilgais, grades, identification of tree species and their locations relative to the proposed building, signs of ponding, saturation or erosion, condition of the road, kerbs, gulleys, surrounding land as to water run-off, and filled trenches carrying services such as stormwater, sewer, telephone, gas, electricity.

There is a trend, particularly in the case of standard designs like project homes, for engineers to assume a soil class when designing a structure, then visit the site when the footings excavation is under way in order to verify their assumption or, if the soil turns out to be less stable, order more and/or deeper piers. This practice has shortcomings:

- The engineer tends to rely on the excavation contractor to report on issues instead of carrying out his/her own tests.
- It is usually not possible to ascertain the difference between S, M and H class soils by a site inspection undertaken soon after excavation has been carried out, particularly where imported fill is used.
- In the event of a change being deemed necessary, the ensuing instructions become ad hoc corrective measures rather than holistic design considerations which would be worked through if the design were undertaken with the site's characteristics in mind.
- The instructions inevitably mean that the consumer pays for a variation due to 'latent conditions' that were within the builder's power to discover.
- Site drainage characteristics and requirements are never addressed.

This is not to say that the engineer should not visit the site to view the footings excavations, but rather to point out that this is not the time to be designing the structure.

Soil condition

When assessing the condition of soil for use as foundation material, the primary concerns are moisture content, depth of watertable, evidence of surface and ground water flows or moisture migration, and voids which may cause subsidence and/or act as ducts for water flows.

Ignoring any topsoil, which will be skimmed off before construction, the walls of the test pit will give an indication of the moisture content of the soil:

- Dry sand will tend not to hold its shape when squeezed.
- Moist or wet sand will tend to hold its shape when squeezed.
- Dry clay, even soft clay, tends to be firm.
- Moist clay tends to be plastic.
- Saturated clay tends to be boggy.

The next sign to look for is seepage, which will usually but not always emanate from the uphill side of the hole. The depth, compaction, amount of flow and type of soil should be noted. It should be realised that seepage or any other form of moisture migration may not show itself immediately and, where testing for moisture migration, it may be necessary to seal the top of the pit and leave it for several days or longer.

Watertable

A hole that is 1.5 m or more deep is likely to show the watertable, especially in deforested or built-up areas. The watertable becomes important where it is high and can affect the ability of the soil surface to dry out and, in the case of clay, to achieve a reasonably even moisture content throughout the footprint.

Ground slope

The fall of the land is important for two reasons:

- In order to achieve even settlement and maintain equilibrium across the structure, it is essential to found it on similar soil throughout. With a sloping site this can become difficult because strata may not be consistently deep around the footprint; they may not, in fact, even be continuous as the slope continues down. It is not unusual for a slope to cut through strata and in this event it is essential for the designer to know beforehand because it may affect the whole approach to footings.
- Either because of discontinuous strata or because of the necessity to cut at the uphill elevation, water flows often reach the surface adjacent to the footings or in the subfloor.

For both the above reasons it is advisable to dig holes at the upper and lower extremities, first to check for a satisfactory common soil, then to look for seepage. To check for water surfacing within the footprint, it is only necessary to inspect and walk on the soil. Another sign may be profusion of vegetation or a different type of vegetation.

Trees, shrubs & organic material

It is important to mark on a site plan the location of any tree, large shrub or stump within or adjacent to the footprint. It is not unusual for arborists to grub out stumps after felling but leave major roots. The same result can occur when trees are removed by a machine. It is essential to ensure that the stump and significant roots are removed and the soil is compacted in the void. The excavator should be instructed to remove any organic material while cutting or skimming. In addition, particularly where a sandy foundation exists, it is good practice to probe the subsoil in the immediate area around where a stump has been removed. A good tool to use is a 1 m length of 6–10 mm round reinforcement bar. Driven with a hammer, this will discover not only tree roots, but floaters and voids or poorly compacted areas. In some cases, poorly compacted areas are composed of leaves and other decayed vegetable matter. This material must not be left under or adjacent to the location of any footings as it will reduce in volume and cause a void.

Service trenches

It is not unusual to find that trenches that are dug to house services are not well backfilled or compacted. Often the trench is used as a repository for trade spoil. Where a subsoil water flow picks up such a trench, a watercourse is provided where water may be delivered alongside or even under footings. Typically, sewer and stormwater pipes run adjacent to and/or under footings. Where building additions are being constructed it is important to check around existing service trenches that may carry water to the proposed construction. Of course, it is also imperative to ensure that trenches dug for the new project are properly located, backfilled and compacted, but this topic is dealt with in BTF 20. During the site investigation, other than any pre-existing domestic service trenches, the following are some of the possible problems:

- Trenches under the footpath or roadway for telephone cables, gas, electricity, stormwater or sewer all have risers to the surface. Often, water can gain access to the trench from around the riser or manhole, then flow along or pond in the trench until finding a way to flow out, through the proposed domestic feed, or just by permeating the soil in the area.
- Street stormwater gullies can also be vulnerable, particularly older ones with brickwork in their structure.
- The possibility of leaking water, stormwater or sewer piping should not be ignored.

Where the new structure is downhill from these water sources, moisture can surface under the building or at the external footing where the soil has been cut. Builders sometimes believe that running agricultural pipe around the external side of the footing excavation solves the problem. This is not always the case, because some systems in common use may collect only a moderate percentage of the water, particularly when not expertly installed. In fact, this practice often delivers water directly to the footing area.

Water run-off

Surface water must not be allowed to flow to the building. A thorough inspection of the topography is necessary in order to properly allow for finished ground falls and water run-off collection. Particularly on a sloping site, the finished falls can be critical to the maintenance of good drainage.

REMEDIAL MEASURES

Other than the exception of water flow through rock faults, which is very difficult to stop, almost all of the problems above can be addressed by correct drainage of the soil or, in the case of poor existing trenches, removal of poor ballast material then refilling and compacting.

Correct drainage is an engineering matter and, unless very straightforward, should be the province of a suitably qualified person, however in essence the job is to prevent water from coming into contact with the building or entering the soil within the footprint and its environs.

The object of good ground drainage should be to exclude all possible water from the building, the foundation and its area of influence. There is a notion that reactive clays should be kept at a constant moisture content in order to provide equilibrium. Irrigation systems have been developed to try to provide constant moisture content to subfloor areas, but these can fail because there are other factors involved, i.e.:

- A building creates its own environment and predominant weather conditions will either create moisture flow toward the centre of the subfloor or away from it. This influence is never evenly distributed but varies with several factors.
- Solar influence dries some areas more rapidly than others.
- Ground slope or other factors can result in uneven water content at various parts of the perimeter.

These and other naturally occurring factors mean that the irrigation system would have to be very sophisticated indeed in order to keep all the foundation soil and immediately adjacent soil at the same stage of volumetric expansion.

In practice, the best solution in all but extreme cases is to drain the ground and surface water away from the building and keep the foundations dry. In reactive clay this is likely to result in cracking due to some shrinkage, and this needs to be redressed, but once this has been remedied and providing the drainage system is kept in working order, the building will remain stable.

This document has covered the bulk of the issues that a builder should deal with in regard to discovery of pre-existing conditions that can affect the stability of the foundation soil. There are also several construction do's and don'ts that the builder must know about and put into practice in order to make sure that the building itself does not contribute to instability of the soil and resultant movement in the structure. These matters are dealt with in BTF 22.

FURTHER READING

AS 1684, *Residential Timber-Framed Construction*, Standards Australia, Sydney, 1999.

AS 2870, *Residential Slabs and Footings – Construction*, Standards Australia, Sydney, Amdt 2, 2003.

AS 3798, *Guidelines on Earthworks for Commercial and Residential Developments*, Standards Australia, Sydney, 1996.

BTF 22, *A Builder's Guide to Preventing Damage to Dwellings: Part 2 – Sound Construction Methods*, CSIRO, Highett, Victoria, 2003.

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BUILDING TECHNOLOGY file

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A builder's guide to preventing damage to dwellings

Part 2 – Sound construction methods

THE PROBLEMS

Site water problem identification
It is essential to investigate the site and prepare it in such a way that ground and surface water are prevented from entering the building footprint, whether the building has suspended floors or is footed on a ground slab. Site investigation methods are dealt with in BTF 19, which should be read prior to reading this BTF. It is also recommended that BTF 18 be read as additional information on this subject.

Legal considerations
Good site drainage always addresses both surface and ground water flows. Lack of attention to potential building movement caused by moisture migration can be a costly oversight for the builder, who may be found liable for damage long after any statutory warranty has expired. The Building Code of Australia (BCA) has not made site drainage mandatory, although it does set out acceptable construction practice in Volume 2, Clause 3.1.2, to be used where a local drainage authority deems it necessary. This makes for uncertainty in the minds of builders as to their responsibilities, but the courts tend to view the builder as the expert and, where some foreseeable damage occurs, it is usually found that the builder should have used methods that would have prevented the damage.

Where site investigation has revealed that there is existing or potential erosion problem, or where reactive clay subsoil is present, the builder is wise to give written advice to the owner and strongly recommend that ground drainage be installed. Where the owner declines in writing, some jurisdictions are known to have accepted that it is within the contractor's rights to continue the project. However, ground drainage is an area where contractors ignore or try to side-step at their own peril.

As to water entering a building, the BCA is quite clear. It is the task of the builder to prevent rainwater from entering a building, even when the rainwater is propelled by a storm of a magnitude that would only be expected to occur, on average, once in a hundred years. What is not so obvious to many is that water should not be allowed to enter the cavity, which is there not as a drain or repository for water that enters through openings, but as a break between the outer and inner leaves of exterior walls to prevent water from permeating through as it used to do when buildings were constructed of 230 mm solid brickwork. When water enters the cavity in volume, a wet, dark and enclosed environment is set up that can result in serious consequences for the health and amenity of the occupants.

Water problems in buildings are usually cumulative, resulting from several oversights rather than from a single source. This BTF is designed as a general checklist of commonly occurring flaws in construction methods, to help the builder deliver a product that will be durable, weatherproof and provide a healthy environment.

SURFACE AND GROUND WATER PREVENTION

It is no longer acceptable for a builder to claim that building movement is outside his or her power to prevent. The subsoil of land that is available for building development normally has an allowable bearing capacity well in excess of the loads imposed by class 1a buildings. The movement problems that are experienced by buildings are very often brought about by the failure of the builder and designers to deal with site water.

Surface and ground water that is allowed within the footprint of the building causes erosion and foundation soil movement, which in turn causes an exacerbation of cracking in slabs; cracking and failure in masonry and finishes; doming and dishing of floors; cupping and lifting of timber flooring; decay to timber members; degradation of metals and mortar; doming and dishing of roofs, leading to breakage of tiles and degradation of mortar beds.

Surface drainage methods
The basis of good surface water drainage is to:
- Have the finished exterior ground level at the building perimeter a minimum of 150 mm below finished floor level, ground floor cavity flashing weepholes or subfloor vents, whichever are the lowest. However, where a slab is used as part of a termite management system, 75 mm at the top of the slab edge must be visible or able to be made visible.
- In the finished ground, provide a 1:20 fall away from the building for at least the first metre. Nothing that needs to be watered, including lawn, should be within this graded area and it should preferably be a hard surface.

The above requirements mean that thought may need to be given to finished floor level etc. before the plans go to council.

Where there is natural topography that leads to surface water being encouraged toward the building, a dish or other surface drain should be installed and connected to the stormwater system through a pit.

Ground water drainage methods
If it is desired to keep the soil dry in areas other than the building footprint, it should be realised that this other drainage may not be sufficient to prevent water entering the footprint, and additional drainage for the building may be necessary. It should be understood that ground drainage is a complex subject, often requiring the expertise of an engineer who is suitably competent in hydrology and geotechnics. For anything other than straightforward problems, even drainers or builders experienced in installing ground drainage should engage a consultant to assist in the design. This section is therefore intended to give reminders to already competent people, and to assist others toward a rudimentary understanding to help them discuss the issues with a consultant. In addition, it is essential for a builder or drainer to comply with the minimum requirements of BCA Volume 2, Clause 3.1.2, and AS 3500.3.2, Sections 6–8, unless installing a system certified by an engineer.

The first step is to investigate the depth and volume of the subsoil flow of water. Test pits, particularly on the uphill perimeter of the footprint should be dug as outlined in BTF 19. It is, however, important to remember that ground drainage problems are not restricted to sloping sites. Some of the most susceptible sites are on flat land, particularly where the area is ringed by higher ground. In addition, as explained in BTF 18, where warm, wet summers and colder, dry winters are experienced, the building itself will tend to cause inward water migration.

In any case, the minimum depth of drainage should comply with BCA Volume 2, Clause 3.1.2.4, that the top of the drain be a minimum of 400 mm below ground and 100 mm below the adjacent footing. This means that the trench should be dug at a safe distance from the footing to ensure that the foundation is not affected. If this is not practicable, temporary measures to support the trench walls may be needed and/or the strength of the pipe material may need to be increased. It is important to remember that in clay the allowable angle between the external bottom corner of the footing and the nearest part of the bottom of the trench is usually 45°, whereas the normally applicable angle for compact granular soil is 30°. These may be exceeded where the trench fill is well compacted and the piping is non-compressible, but supervision by a competent engineer is normally necessary for soil classification and strength issues. A good working arrangement is to locate the trench toward the edge of the area that is graded away from the building to allow run-off of surface water.

Having discovered the required depth, the next step is to establish whether it is above the depth of the local authority's stormwater system, to determine the method of dispersal of the captured water. It must be borne in mind that the BCA's minimum fall for ground drainage is 1:300, and a silt arrestor requires a minimum drop of 50 mm from the invert of the inlet to the inner roof of the outlet. If the depth of the ground drainage is too low for the council system, councils may allow a soakage pit for any naturally occurring ground water, so that the drainage can divert the water from the uphill side of the building to the downhill side. The builder should confirm this with the council.

Next, the type of drainage should be determined. For general purposes, a geocomposite system using 90 mm slotted stormwater pipe with fabric sock and geofabric perimeter material is adequate, however suppliers can advise on other systems. It is desirable in any ground drainage system and essential where the fall is shallower than 1:100 to install inspection openings to enable the system to be flushed out. These should be at changes of direction greater than 45° and at the connection to the stormwater system. Where practicable, pits make the ideal inspection opening, particularly when configured as silt arrestors.

Drainage to rock substrates
BTF 19 discusses the special drainage problems with rock foundations. While a solid rock foundation remains stable regardless of water flows, water damage to building elements and high subfloor relative humidity can have potentially serious consequences. When the ground floor is to be suspended, and particularly when using timber framing and/or flooring, drains should be cut around the perimeter where water can otherwise enter the subfloor. Totally preventing water entering the subfloor area can be impracticable because of faults and interstrata gaps. Where water flows on rock foundations cannot be prevented, the design should allow for an open subfloor and an increased minimum clearance between the floor and the ground, commensurate with the volume of water experienced. If a completely open subfloor is impracticable, openings should be as large as possible, particularly where subfloor walls would otherwise dam water. Watercourses should be cut out to divert water if this is beneficial to the aim of removing water as soon as possible. A mechanical ventilation system may need to be installed as an augmentation to the measures discussed above, but when relied upon without sufficient other precautions, such a system may be inadequate.

Subfloor ponding
When constructing dwellings with suspended floors, it is essential to grade the subfloor area so that no depressions remain that can allow water to pond. With rock foundations it may be necessary to use concrete to fill depressions.

Dampproof courses
Ground moisture usually carries salts and other chemicals. When moisture migrates through masonry by capillary action, some chemicals may be transported. It is often these chemicals that attack the building elements. Different dampproof course (DPC) materials are susceptible to different chemicals.

It is not always possible to predict the nature of pollutants to which the underside of a DPC will be exposed. This is one of the reasons that moisture should be kept away from the building. DPCs that have poor plasticity or develop poor plasticity through exposure to water and chemicals, are unsuited for use where building movement cannot be totally prevented, because they tend to break. When a DPC is discontinuous it allows water to penetrate the gap. This is one common way that rising damp occurs in buildings constructed in the modern era.

The safest suggestion for overcoming the problem of lack of durability in DPCs for applications where high moisture content is expected, is to double up, perhaps using two different types, one on top of the other.

Antcapping
Antcapping should never be used as a DPC unless is has been tested and designed for this purpose. Galvanising will break down over time when in constant contact with moisture, particularly when salts are present. It is essential to isolate the antcapping from any water in the masonry by using a DPC between. The galvanising should also be checked for quality and any cuts or damage should be coated with cold galvanising, because even when the antcapping is isolated from direct contact with water, constant high humidity in the air will tend to attack the steel. Once corrosion has eaten through the metal, termites are given a path of entry to the building. This is not a rare condition.

RAINWATER PREVENTION

In addition to surface and ground water considerations, there are several issues of construction that builders must address in order to prevent rainwater from entering the building.

Rainwater is not only a problem when it enters the living area as water, but also when it is allowed into the cavities and voids and onto building members that can degrade or decay. In addition, rainwater has a more insidious danger in that it gives life to fungus and promotes pests like dust mites - these conditions are conducive to illness in people who are abnormally susceptible to breathing disorders.

Builders and tradespeople often attempt to make a building weatherproof by the use of sealants. It should be realised that sealants cannot be regarded as a durable solution to most weatherproofing problems. Durability can only be attained by sound construction method.

Ridge capping
Mortar bedding to ridge capping is permeable, even with flexible pointing applied over it. Water can migrate through the bedding and pond on the tile above the bedding. Any condensation tends to perpetuate the moisture and, in addition, where summers are warm and wet and winters are cold and dry the tendency is for moisture to be drawn in. The above factors tend to create an overflow of water that may drip into the roof space or run down the soffit of the tiling, decaying battening or framing and/or eventually damaging fastenings. This flow adds to flows caused by the natural absorption of water through tiles and any wind-driven rain that penetrates the gaps between tiles. These are the flows that lead to inundation of the roof. Weepholes should be created in the beds at the depressions in tiles to allow water to flow to the top surface of the tiles.

Where footing movement occurs, usually due to the action of water on the foundation soil, the roof moves. Cut and pitched roofs will dome and dish in the same way that floors do, because of the uneven rise and fall of reactive clay soils. This movement causes a stress on rigid members of the roof structure such as mortar beds to hips, ridges and verges, which hog and sag, tending to crack the mortar and/or the tiles. When 1:2 cement: sand mortar pointing is used, this will retard the cracking, but it will eventually crack and when it does, the water entry will increase accordingly. On truss roofs the effect is less but still sufficient to cause cracking. If there is no footing movement, the pointing tends to last many years. Where some movement is expected, it is recommended that flexible pointing be used.

Sarking
In general, roof tiles are of marginal suitability for installing on a roof slope of less than 18° and should never be used where the pitch is lower than 15° For other roof slopes below 25°, the manufacturer's recommendations should be checked before

installing a particular profile. Where flat profile tiles are to be used on a roof that has a pitch below 25° or where any tiles are to be used on a roof below 20°, sarking should be installed to prevent water entering the roof void. Where the common rafter length is greater than 4500 mm and sarking is not fitted to the whole slope, the table shown below (source: AS 2050, Table 5) should be consulted and sarking may have to be fitted to the lower end of the slope.

SARKING REQUIREMENTS IN RELATION TO PITCH/RAFTER LENGTH

Roof (degrees of pitch)	Maximum rafter length without sarking (mm)
≥18<20	4500
≥20<22	5500
≥22	6000

In addition, on any slope with a pitch of 20° or less, an anti-ponding board should be installed between the bottom batten and the oversail to ensure that the sarking does not sag sufficiently to create ponding, or allow rainwater into the eaves or structural elements.

Guttering too high

The front bead of eaves guttering is usually higher than the highest point of the rear vertical face that sits against the fascia board. A common mistake where there is a long run to the downpipe, is to install the guttering with the front bead level with or above the top of the fascia so as to allow for fall to the downpipe. The reasons why this is an error are:

- Where there is a roof overhang, this allows water to overflow onto the eaves lining. In the case of framed external leaf walls, the rainwater is fed into the frame.
- Where there is no overhang and extruded bricks are used for the external leaf, the overflowing water spills into the core holes and saturates the brickwork from within.
- Where water cannot feed entirely into the extruded brickwork or where pressed clay bricks are used, rainwater falls directly into the cavity if one is present.

This is one of the reasons that the BCA calls for downpipes at a maximum of 12 m intervals. Such intervals mean that 6 m should be the maximum distance away from a downpipe for any part of the guttering. The minimum fall for eaves gutters is 1:500, so gutters can be installed with a 12 mm fall from the highest point to the downpipe.

Section 3 of AS 3500.3.2 requires that the front bead of the guttering is lower than the top of the fascia, so as to allow overflow and prevent rainwater entering the building. A process contained in AS 3500.3.2, Appendices G and H, is used to determine how much lower the front bead of the guttering must be than the top of the fascia board. Appendix G also contains some examples of acceptable alternatives.

Roof flashings

All metal materials on a roof should be compatible. Lead flashings should not be used with Colorbond/Zincalume roofing. Galvanic action will degrade the zinc and cause corrosion that will lead to roof leakage. In the event that re-roofing introduces Colorbond/Zincalume to a roof that has existing lead flashings, the lead should be coated on both sides using a suitable paint. Other incompatibilities are listed in AS 3500.3.2, Tables 4.2 and 4.3.

Rainwater spreaders

Where water is collected by guttering to an upper roof and deposited onto a lower roof via a spreader, the lower slope is called upon to carry an additional volume of water – sometimes too great a volume. It must be realised that tile systems are designed to prevent water entry in accordance with the performance requirements of the BCA Volume 2, Clause 2.2.1 (b), which states: '*(b) Surface water, resulting from a storm having an average recurrence interval of 100 years must not enter the building.*'

When rainwater is gathered from a large catchment and concentrated by a spreader on another catchment, the volume of water on that catchment may well be above the capacity of the tiling to cope, particularly in a case where wind is tending to drive the rain up the slope. This type of overloading cannot be taken into account by tile designers or building designers. If it is intended to use a rainwater spreader on a tiled roof, the tile manufacturer should be consulted. Spreaders may also create a local guttering overflow.

Another even more serious problem is caused by the practice of locating a spreader on a flashing. This allows the combination of wind and the proximity of the flashing and the tile to push water up and over the top of the tile, then into the roof space. This practice should never occur. If a spreader is allowable on a roof slope, it should always be well below any flashing, but the best practice is to run the water from the upper roof to the ground by a downpipe.

Roof/wall interfaces

Where a roof meets a cavity wall and the wall then becomes internal, such as a garage abutting a two-storey dwelling, a tray flashing is necessary to carry water to an external wall cavity flashing. Where the roof slopes away from the wall this can be a horizontal combination of overflashing and cavity flashing. The most important consideration is the provision of a positive method of transferral from the tray flashing to the standard floor-level cavity flashing so that no water can escape.

Where the roof slopes along the wall the combination overflashing/cavity flashing is stepped. A requirement of this is that the 'uphill' end of the cavity flashing be turned up to ensure that water follows the steps down to the standard floor-level cavity flashing. Other information is available in BCA Volume 2, Clause 2.2.4.10.

Cavity flashings

Brickwork is permeable. A single leaf of brickwork will allow water to migrate from the exterior to the cavity. This is the main reason that a cavity is necessary. In fact, when significant wind-driven rain falls against single-leaf brickwork, water can be plainly seen running down the internal face.

More and more is being learned about the problems associated with water that is trapped in the cavity. This water can quickly accumulate, but because it is not exposed to sunlight, it can take a significant time to dissipate. Water in a cavity is not just harmful to building elements, but it also promotes fungal growth and creates an ideal environment for termites, other insects, spiders and mites, including dust mites, which are known to be harmful to people who are susceptible to respiratory ailments. In addition, the humidity that is created can transfer moisture into the inner leaf of walling that is measurable on the internal face. This is particularly true in southern exposure rooms and is undesirable, particularly in living or bedroom areas.

Because cavity flashings are bedded into the masonry during the building of the wall, mortar is dropped into the flashing as the wall rises. These droppings accumulate and harden. Because of their height inconsistency, water will inevitably be dammed in the cavity. Also, weepholes become partially or fully blocked by these mortar droppings, further reducing the possibility that water will escape.

Mortar droppings should be cleaned out of the flashing before they become difficult to remove, at least once a day during the bricklaying process. As the wall rises and cleaning by hand becomes impracticable, a hose can be used, provided that the mortar beds at the flashing level are sufficiently cured to resist deterioration by the water. Anything that bridges the cavity between the inner and outer leaves of walling and allows the transfer of water to the inner leaf must be removed.

Another common defect is that the flashing does not extend to the outer edge of the external leaf. The function of a cavity flashing is to gather water and direct it to the external face of the brickwork. It usually also acts as a DPC whose function is to prevent vertical moisture migration (either up or down). A DPC or flashing that does not extend to the outer edge of the brickwork will allow migration down by gravity or up by capillary action.

If the brickwork is to be cement rendered, the flashing should be continuous to the face of the render. A neat way to overcome this is to create a v-joint at the flashing, then cut the flashing off at the inner extremity of the v-joint. This method creates a control joint that will prevent unsightly cracking of the render.

Weepholes
AS 3700, Clause 12.7.2.3, requires that weepholes are formed immediately above the cavity flashing and that mortar is removed from the joint so that the opening is clean and the flashing is exposed. This is to ensure the free flow of water from the cavity. It is not uncommon to find blocked weepholes, recessed DPCs and fouled cavity flashings all on the same job.

Window and door openings
The popularity of unevenly faced bricks has led to a problem at openings. The problem arises where brickwork reveals do not present a straight line against windows, and is exacerbated by the fact that these bricks are generally not suited to flush mortar bedding. Consequently, it is common to see gaps at window/reveal interfaces caused by brick unevenness and raked joints. Such gaps mean that the building envelope is not weatherproof within the requirements of the BCA.

It should be realised that the cavity is not envisaged as a part of a water removal system, but is there to prevent moisture permeation from the outer skin to the inner skin. It may also act as a last line of defence in the event of an extraordinary event, however the idea that a builder should leave gaps in the building envelope through which water can penetrate into the cavity is in direct conflict with the objectives and requirements of the BCA. An external wall that routinely allows water to enter the cavity, turns that cavity into a hazard to the building elements, and to the health and amenity of the occupants. It is the job of the builder to make the envelope weatherproof. The construction system must prevent significant volumes of water entering the cavity.

In the case of window and door reveals, the bricklayer, while being mindful of the danger of ceramic growth, should not rake or iron the joint past the leading edge of the frame. In some cases where gaps must be left because long walls make ceramic growth a hazard, or where the brick profile is badly uneven, storm moulds should be installed, and bedding should be left flush with the leading edge of the storm mould.

It is also common to see cases where an overwide cavity creates insufficient overlap between the window and the brickwork reveal. Where this occurs, storm moulds are also called for.

Window gaskets
When fitted to brick veneer construction, windows need to be clear of the brickwork sill so as to allow for timber shrinkage in the frame. The usual allowance is 5–10 mm clearance to ground floor windows and a minimum of 15 mm on the second storey. For this purpose, aluminium window assemblies are fitted with neoprene gaskets to bridge the gap between the window frame and the brickwork sill. As with reveals, the brickwork sill should have joints left flush from the leading edge of the gasket to the rear edge of the sill. Commonly, little attention is paid to seating the gasket to provide a waterproof surface. Mortar is left on top of sill bricks which, when timber shrinkage reduces or closes the gap, pushes the gasket up and away from the brick and allows water to enter the cavity. Mortar should be cleaned off the top of bricks while laying. In addition, bricklayers commonly turn the ends of gaskets down into the perpends at the sill/ reveal joints. This is poor practice, as it leaves a gap above the gasket where water can gain entry to the cavity and which also encourages water into the mortar where the gasket turns down. These gaskets should be cleanly cut off flush with the reveal and the mortar should be flush with the sill brickwork. If the reveal bed aligns with the gasket there is no reason that the gasket cannot be bedded into it.

Sills and thresholds
Where brickwork sills are significantly sloped, it is common to find that the bricks are cut to have a minimal overlap with the gasket. These gaskets need a minimum 15 mm overlap with the sill bricks where the sill is at 30° to the horizontal. For lesser angles the necessary overlap increases.

Brickwork patio and other door thresholds are often laid without any fall away from the building. This will always result in water entering the cavity. Some bricklayers fill the cavity in at the doorway to prevent water incursion, but this does not work and only inhibits the operation of the flashing. The builder must provide the bricklayer with sufficient height to allow for weepholes to be continued across the doorway as necessary, and for either a soldier course sill with sufficient fall or room to lay a sloped tiling threshold.

Subfloor vents
In dwellings having suspended ground floors, particularly where timber floor framing is used, adequate cross-flow ventilation must be installed to counteract condensation. BCA Volume 2, Section 3.4.1, gives minimum ventilation standards that are deemed to satisfy the performance requirements. The required ventilation area is based on the perimeter length of the building and differs depending on:

- The zone in which the dwelling is located.
- The moisture content of the foundation soil.

It is also important to realise that where the floor is lower to the ground, there is less volume of air to dissipate the moisture that is transferred to it from the ground.

Landscaping
Two important aspects of landscaping that relate to water entry were introduced in the surface drainage section above, viz.:

- The finished exterior ground level at the building perimeter should be a minimum of 150 mm below finished floor level, ground floor cavity flashing weepholes or subfloor vents, whichever are the lowest. However, if paving is to be used around the building perimeter, the clearance may be 50 mm. Where a slab is used as part of a termite management system, 75 mm at the top of the slab edge must be visible or able to be made visible.
- The finished ground should have a 1:20 fall away from the building for at least the first metre. Nothing that needs to be watered, including lawn, should be within this graded area and it should preferably be a hard surface.

In addition, the landscaper should only install automatic watering systems where the beds that they service are lower than the base of the footings or where they are separated from the building by a properly engineered surface and ground water drainage system.

FURTHER READING/REFERENCED DOCUMENTS

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END OF REPORT