Date: 13/02/2025

Attention: **Mr. Iman Ahmadian**

Re: Geotechnical Assessment

Project No: KFMGR-240309-Rv01

Address: 78 Mccarrs Creek Road, Church Point NSW 2105

1. INTRODUCTION

KFM Geotech (KFM) was engaged by Mr. Iman Ahmadian to carry out a geotechnical assessment of the site for the proposed retaining wall design at 78 Mccarrs Creek Road, Church Point NSW 2105. The site is bordered by residential properties to the south, north, and west, and Mccarrs Creek Road is located to the northeast. The site descends sharply from the roadside, presenting a striking slope that cascades towards the sea. The proposed development includes constructing a new retaining wall adjacent to the roadside to ensure structural stability and aesthetic integration. The height of the existing retaining wall is approximately 1.3-1.5m. As previously mentioned, the site has undergone significant earthworks, evident in the visible cuts and fills that have shaped the terrain. A timber retaining wall had initially been installed to manage the pressure of the roadside fill materials, though its condition now necessitates enhancement for long-term functionality.

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Figure 1. Site Plan

2. SITE INSPECTION & FINDINGS

The site was inspected on 11 December 2024 by KFM Geotechnical Engineer. Two boreholes (BHs) were drilled at the upper level of the existing retaining wall using a hand auger to investigate subsurface conditions. Additionally, four (4) Dynamic Cone Penetration (DCP) tests were conducted to evaluate the strength of the soil layers and determine the potential depth of underlying rock. Two of the DCP tests were strategically positioned adjacent to the boreholes to correlate data, while the remaining two were conducted at the lower level of the retaining wall to assess soil conditions in critical areas influencing the stability and footing of the retaining wall. The location of BHs and DCPs is shown in Figure 1. The hand auger reached refusal at a maximum depth of 0.9m. The borehole logs and DCP test results are attached to this report. The borehole drilling observations and DCP test results indicate the site subsurface materials are assessed to comprise poorly to moderately compacted fill materials to a depth of around 2m. Below 2m is inferred to be natural soil considering the DCP test results. Note, that natural materials were not encountered during our site investigation using hand auger due to shallow refusal on hard layers. KFM Geotech cannot confirm the presence and depth of natural soil at the site, though it may become visible during excavation. Note, that the site subsurface materials across the site may differ from our assessment based on the investigation carried out in this report. The recommendations provided in this report can be updated during the foundation works subject to site inspections by a geotechnical engineer if the site subsurface materials differ from our assumption in this report.

Figure 2. Borehole and DCP locations

A summary of the subsurface profile encountered in the borehole/DCPs is presented in Table 1 with the detailed log attached to this report.

Table 1. Summary of Site Subsurface Profile

Unit #	Material	Top of Unit (m, below ground level (bgl))	
		BH 1	**BH2**
1	**Fill,** gravel, sand, brown	0.0	0.0
2	**Possible Natural soil**	1.9	2

Groundwater was not encountered in the boreholes/DCPs during the investigation. It should be noted that the fluctuations in the level of groundwater might occur due to variations in rainfall, temperature, and/or other factors. KFM believes that during the construction of the proposed retaining wall groundwater flow is unlikely to be encountered.

The regional geology map demonstrates that the site is underlain by Middle Triassic rocks of the Gosford Subgroup (Tngn) from the Constitue unit. Unit Tngn comprises Interbedded laminite, shale, and sandstone; white quartz to quartz-lithic, very fine- to medium-grained sandstone; minor shale breccia and pebble polymictic conglomerate (at base of sandstone units), minor red clays.

Considering the site subsurface profile, depth of fill materials, and foundation construction works, a site classification “P” is to be adopted for the site according to AS 2870-2011, Residential Slabs and Footings Standard.

3. SITE SLOPE RISK ASSESSMENT

The Australian Geomechanics Society guideline for Landslide Risk Management (2007) states that the landslide risk of a site is assessed based on the likelihood of a failure mode and the consequence of that failure mode (See Appendix B). A qualitative measure is presented for the risk to property and a quantitate approach is proposed for loss of life. The slope stability of a site depends on subsurface materials and their strength, slope angle and surface/sub-surface drainage. AGS (2007) guidelines consider a risk of 10^{-5} per annum for persons most at risk on new development and risk of 10^{-4} is considered tolerable for existing slopes/developments, if risk treatment options will be employed to maintain or reduce the level of risk. Acceptable risks are usually considered to be one order of magnitude smaller than tolerable risks (10^{-6} per annum for new development and 10^{-5} for existing slopes/developments.

The site subsurface materials at the location of the retaining wall comprise moderately depth fill. Minor slope/retaining failure/movement on the existing timber retaining wall was observed during the site inspection. No sign of slope instability was observed on site below and above the retaining wall. The survey plan and ground features in the site observed during the inspection, depth of fill materials, and our site inspection observations were used in the slope risk assessment for the site.

Applying the Geomechanics Society Guideline for slope risk assessment to the site surface and subsurface conditions at its existing condition, the risk to property is assessed to be low to very low. Shallow soil layer failure is considered as the potential mode of failure with the possible likelihood (one in thousand per annum or less) and insignificant to minor consequence to the property.

The proposed development includes the construction of a new retaining in front of the existing retaining wall while keeping the existing retaining wall. No major excavation will occur during the construction except for the construction of a few piles (450mm piles) which does not increase the risk of slope instability to the site. The risk analysis summary is presented in Table 2.

Table 2. Geotechnical Hazards and Risk Analysis Summary

Failure Modes/Possible Hazard	Assessed Likelihood	Expected Consequences to Property	Assessed Risk to Property	Assessed Risk to Life	Comments
Existing fill/retaining wall slope failure	Possible (10^{-3})	minor (5%)	Very Low to medium (5×10^{-5})	4×10^{-6}/annum*	This level of risk to life and property is still UNACCEPTABLE. To have an ACCEPTABLE level, the recommendations in this report to be followed.
New retaining wall slope failure	Rare (10^{-5})	Minor (5%)	Very low (5×10^{-7})	4×10^{-8}/annum*	Using engineer design retailing wall the risk will be reduced to the acceptable level

*Assuming annual probability 10^{-3} , temporal probability 0.04, spatial probability 0.2, and vulnerability to the life of 0.2

** Assuming annual probability 10^{-5} , temporal probability 0.04, spatial probability 0.2, and vulnerability to the life of 0.2

Assuming the *possible* likelihood for the failure mode and minor consequence, a very low to medium risk level is assessed to the property before and during the construction. Implementing the specific engineering treatment such as supporting the existing fill and retaining wall by an engineered designed retaining wall will reduce the risk. Taking into consideration all the specific engineering controls, the proposed development is considered to have "*an acceptable risk level*" for loss of property. The proposed development where undertaken in accordance with the specific engineering controls is considered to have "*an acceptable risk level*" for loss of life. It is also assumed that the required fencing/exclusion zone will be set up on-site during the retaining wall construction. Temporary propping of the existing retaining is recommended if any sign of further failure is observed. Adequate drainage to be provided for the retaining structure.

Having taken into consideration the above and following the guidelines for hillside construction attached to this report (See Appendix D), an acceptable risk is achievable for both the property and the life for the site's during/after the retaining wall construction.

4. FOOTING AND RETAINING WALL

Australian Standard AS 2870-2011, Residential Slabs and Footings can be adopted for the design of the proposed footing and retaining wall for a site class "P". Engineer-designed foundations should be designed to support the load of the proposed development. An allowable bearing capacity of 60 kPa can be adopted for the retaining wall footing design. The lateral earth pressure parameters presented in Table 3 can be adopted for the retaining wall design.

Table 3. Retaining Wall Design Parameters

Unit #	**Unit weight (kN/m^3)**	**Active Earth Pressure Coefficient**	**At Rest Earth Pressure Coefficient**	**Passive Earth Pressure Coefficient/Ultimate Passive Resistance**
1- Fill	19	0.39	0.56	2.56

Free-draining granular backfills and appropriate subsurface drainage are to be considered in the design and construction of the retaining walls to ensure dissipation of the water pressure occurs. Otherwise, the retaining walls are to be designed against water pressure.

5. RECOMMENDATIONS ON EXCAVATION AND EARTHWORK

The excavation in fill materials can be achieved using conventional earth working plants such as small to medium excavators fitted with a digging bucket and with no vibration occurring during the excavation. We expect major excavation for the foundation works. The excavation class based on SANS 1200D is assessed as soft for the fill materials. The proposed development does not produce any major vibration and noise pollution on-site during the foundation works. The excavation in the fill materials (to 2m) to be battered with a slope not steeper than 1H:1V.

If any fill layer is required during the construction for raising up the foundations, suitable granular fill materials with proper compaction (controlled/rolled) is required to ensure that excessive surface settlement does not occur. All fill brought onto the site (if required) is to be certified as ‘clean fill’ with a VENM certificate or similar documentation in accordance with EPA guidelines. The required backfill density and minimum frequency of compaction tests as outlined in AS 3798 should be followed for any site filling. If required, the suitable fill materials to be placed in loose layers of 200mm and compacted to 95% of standard maximum dry density.

6. GENERAL RECOMMENDATIONS

- ✓ Utilize a stormwater drainage system to collect surface water and drainage from behind the retaining walls.

- ✓ Exercise caution during excavations near any footings or easements. If the excavation is within the zone of influence of any existing footing or easement, it must not go deeper than 100mm above the base of the existing footing. The zone of influence is determined by projecting a line upward at a 45° angle from the horizontal, starting from the invert of the existing footing or easement.

- ✓ All on-site earthworks must comply with Australian Standard AS3798, which provides guidelines for earthworks in commercial and residential developments.

7. LIMITATIONS AND CONDITIONS OF THE REPORT

This report is the copyright of KFM Geotech Pty Ltd and any unauthorized reproduction and usage by any person or third party other than the client for whom this investigation was commissioned is strictly prohibited. The results of this investigation should not be used for any other purpose other than that for which it is specifically intended.

This Geotechnical Site Investigation report has been prepared based only on the information provided at the time of this investigation and may not be valid if site conditions change. The findings presented in the report reflect the sub-surface conditions specifically at the designated sampling and testing locations, and only to the depths probed during the investigation and at the time of assessment. It's important to note that sub-surface conditions are subject to abrupt changes influenced by geological processes and human activities. These alterations might occur subsequent to KFM Geotech fieldwork.

KFM Geotech recommendations are formulated based on the observed conditions during the investigation. However, the accuracy of these recommendations may be impacted by undetected variations in ground conditions across the site, extending beyond the sampled areas. Additionally, budget constraints imposed by external parties or limitations in site accessibility may further constrain the scope of advice provided. We recommend that the foundation excavation for any type to be inspected by a qualified geotechnical engineer to confirm the subsurface conditions and advice recommended in this report.

If the construction phase recommendations presented in this report are not implemented, the general recommendations may become inapplicable and KFM accepts no responsibility whatsoever for the performance of the building where recommendations are not implemented in full and properly tested, inspected, and documented.
During the earthworks, if site conditions significantly differ from those indicated in this report, KFM Geotech to be contacted to provide further advice.

8. REFERENCES

- Australian Standard (AS 2870-2011), Residential Slabs and Footings
- Australian Standard (AS 1726-2017), Geotechnical Site Investigations
- Australian Standard (AS 3600-2009), Concrete structures
- Australian Standard (AS 4678-2002), Earth-retaining structures
- Australian Standard (AS 2159.2009), Piling-Design and installation
- Australian Standard (AS 3798-1996), Guidelines on earthworks for commercial and residential developments

For and on behalf of

KFM Geotech Pty Ltd

Dr. Mohammad Hossein Bazyar

Managing Director

Appendix A

BH Logs

Boring Log

Project: 78 Mccarrs Creek Road, Church Point NSW 2105	**Project Number**: KFMGR-240309	**Client:** Mr. Iman Ahmadian	**Boring No. BH1** **Page 1 of 1**
Logged By: SK	**Drilling Date:** 11/12/2024	**Drilling Type:** Hand Auger	**Driller:** SK

Depth (m)	Sample Type	Sample Number	Graphic Log	USCS	Lithology **Soil Group Name:** type, color, grain size, other descriptors	Density/ Consistency	Moisture Content	DCP (blows per 100mm penetration)
0.0 0.5			▨		**Fil:** gravel,sand, dark brown, trace rootlets	PC	M	0 2 1 1 1 3 11
1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0			▨	SP	Hand auger terminated at 070 m Potential Natural			12 8 6 5 5 5 5 5 6 10 6 6 4 5

Consistency		**Density**		**Moisture**		**Compaction**	
S:	Soft	**VL:**	Very Loose	**D:**	Dry	**PC:**	Poorly Compacted
F:	Firm	**L:**	Loose	**M:**	Moist	**MC:**	Moderatly Compacted
St:	Stiff	**MD:**	Medium Dense	**W:**	Wet	**WC:**	Well Compacted
Vst:	Very Stiff	**D:**	Dense				
H:	Hard	**VD:**	Very Dense	B	Bouncing	R	Refusal

Boring Log

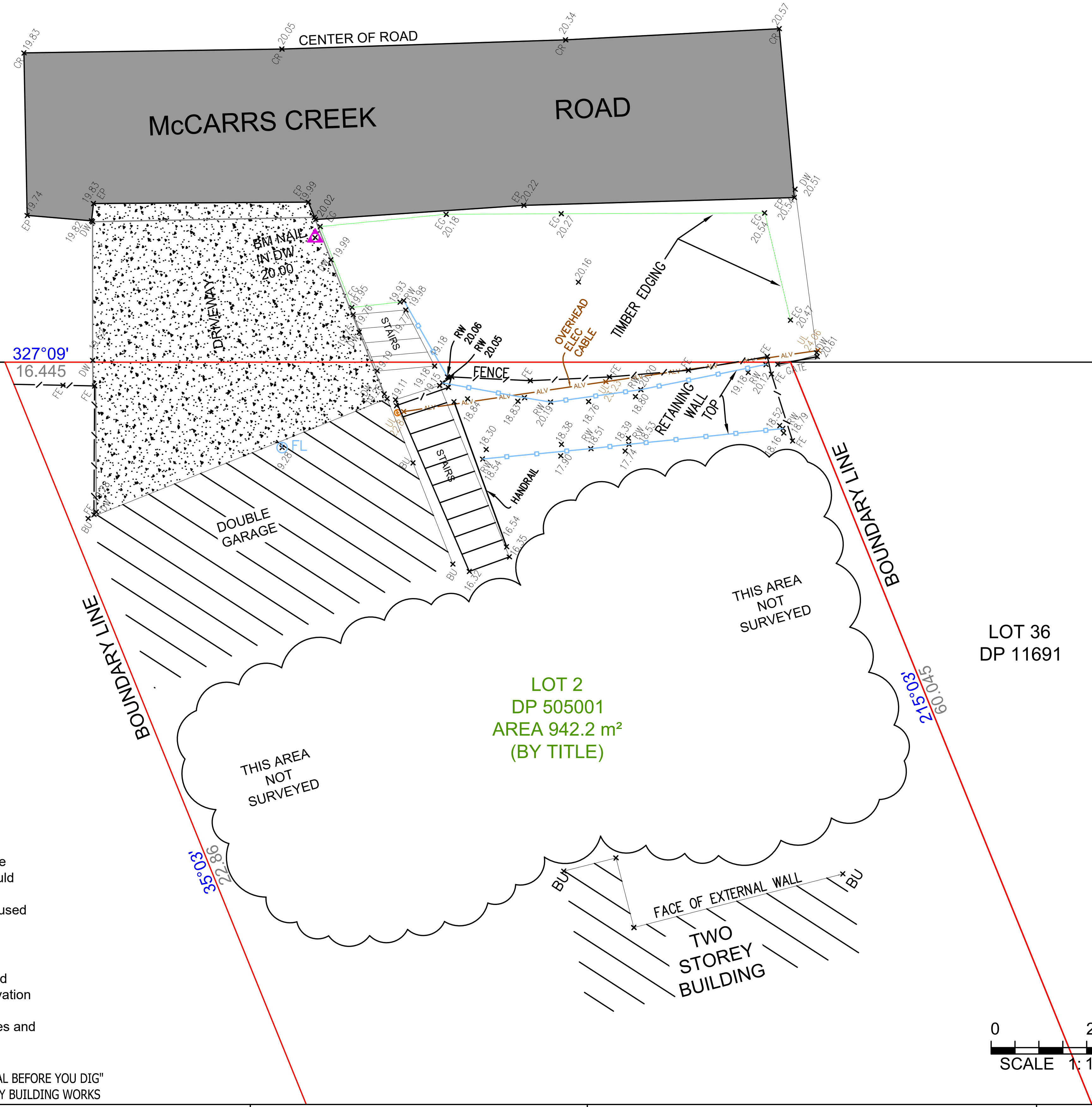
Project: 78 Mccarrs Creek Road, Church Point NSW 2105	**Project Number**: KFMGR-240309	**Client:** Mr. Iman Ahmadian	**Boring No. BH2** **Page 1 of 1**
Logged By: SK	**Drilling Date:** 11/12/2024	**Drilling Type:** Hand Auger	**Driller:** MT

Depth (m)	Sample Type	Sample Number	Graphic Log	USCS	**Lithology** **Soil Group Name:** type, color, grain size, other descriptors	Density/ Consistency	Moisture Content	DCP (blows per 100mm penetration)
0.0 0.5			▨		**Fil:** Silty sand, dark brown, trace rootlets	PC	M	1 2 2 2 1 2 3 5 3
1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0			▨		Hand auger terminated at 0.9 m Potential Natural Soil			3 4 5 7 4 6 4 6 21 9 6 6

Consistency		**Density**		**Moisture**		**Compaction**	
S:	Soft	**VL:**	Very Loose	**D:**	Dry	**PC:**	Poorly Compacted
F:	Firm	**L:**	Loose	**M:**	Moist	**MC:**	Moderatly Compacted
St:	Stiff	**MD:**	Medium Dense	**W:**	Wet	**WC:**	Well Compacted
Vst:	Very Stiff	**D:**	Dense				
H:	Hard	**VD:**	Very Dense	B	Bouncing	R	Refusal

DCP Results

	Number of Blows for 100mm Penetration			
Depth (mm)	DCP1	DCP2	DCP3 (1.3m lower than DCP1 and DCP2)	DCP4 (1.3m lower than DCP1 and DCP2)
0.0-100mm	0	1	1	0
100-200mm	2	2	2	3
200-300mm	1	2	3	2
300-400mm	1	2	4	2
400-500mm	1	1	2	3
500-600mm	3	2	3	2
600-700mm	11	3	2	2
700-800mm	12	5	3	7
800-900mm	8	3	5	B
900-1000mm	6	3	5	
1000-1100mm	5	4	6	
1100-1200mm	5	5	5	
1200-1300mm	5	7		
1300-1400mm	5	4		
1400-1500mm	5	6		
1500-1600mm	6	4		
1600-1700mm	10	6		
1700-1800mm	6	21		
1800-1900mm	6	9		
1900-2000mm	4	6		
2000-2100mm	5	6		



21.01.2025

SAM PYRUZ DATE
REGISTERED LAND SURVEYOR NSW

IMPORTANT NOTE:
This plan is prepared for 78 Mccarrs Creek Road from a combination of field survey and existing records for the purpose of designing new constructions on the land and should not be used for any other purpose.
The clouded area has not been surveyed and should not be used for any design or construction purpose.

A services search of the area surveyed above has not been undertaken. Visible services shown hereon have been located where possible by field survey. Prior to any demolition, excavation or construction on the site, the relevant authority should be contacted for possible location of further underground services and detailed locations of all services.

YOU ARE ADVISED TO CONTACT "DIAL BEFORE YOU DIG"
AT 1100 PRIOR TO COMMENCING ANY BUILDING WORKS

LEGEND

×	SURVEY SHOT
⊘	ELE POST
ⓘ FL	FLOOR LEVEL
△	ELEVATION BENCH MARK
-▫-▫-	RETAINING WALL
—/—/—	FENCE

0 2 3 4 6 8 10
SCALE 1: 100 @ A3

CONTOUR INTERVAL: MAJOR 0.0 MINOR 0.0

HORIZONTAL ORIGIN		VERTICAL DATUM	
COORD. SYSTEM XXX	MARK ADOPTED: PM XXXX COORDINATES: E XXX XXX.XXX N X XXX XXX.XXX	DATUM ASSUEMD	BM ADOPTED: PM XXXX RL: XX.XXX

REVISION	DATE	DESCRIPTION	CCAD REF	APPROVED
00	01-2025	ORIGINAL ISSUE	****	*****

FARD Mapping Solutions
Survey . Utility . Mapping

m: 0437 936 980
www.fardmappingsolutions.com.au
e: admin@fardmapping.com.au

PROJECT: RETAINING WALL RECONSTRUCTION

DETAILS & BOUNDARY SURVEY

CLIENT: 78 McCARRS CREEK ROAD

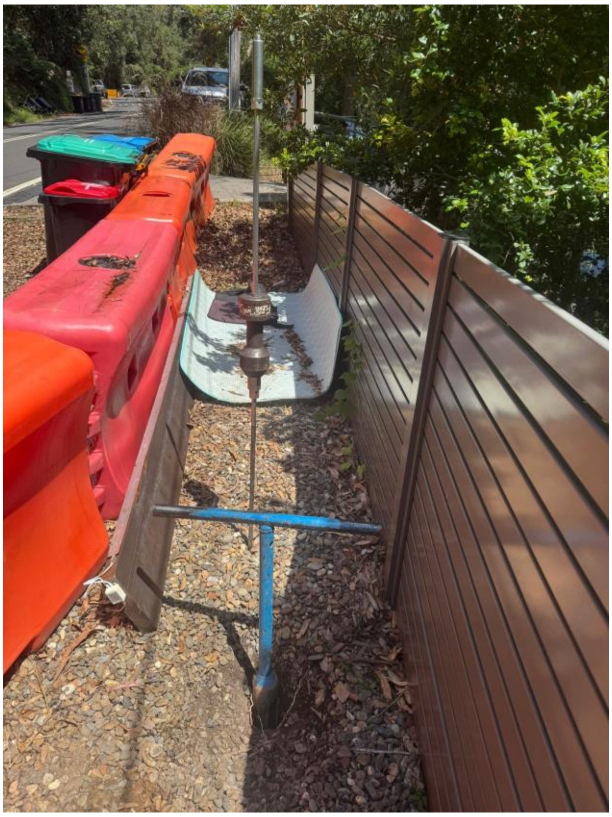
SURVEYED	DRAWN	CHECKED	PASSED
A.F.	A.F.	S.F.	A.F.

SCALE 1:100
SHEET 1 OF 1
DRAWING NUMBER: FMA241218 CHURCH.DWG
REV: 01
A3

N

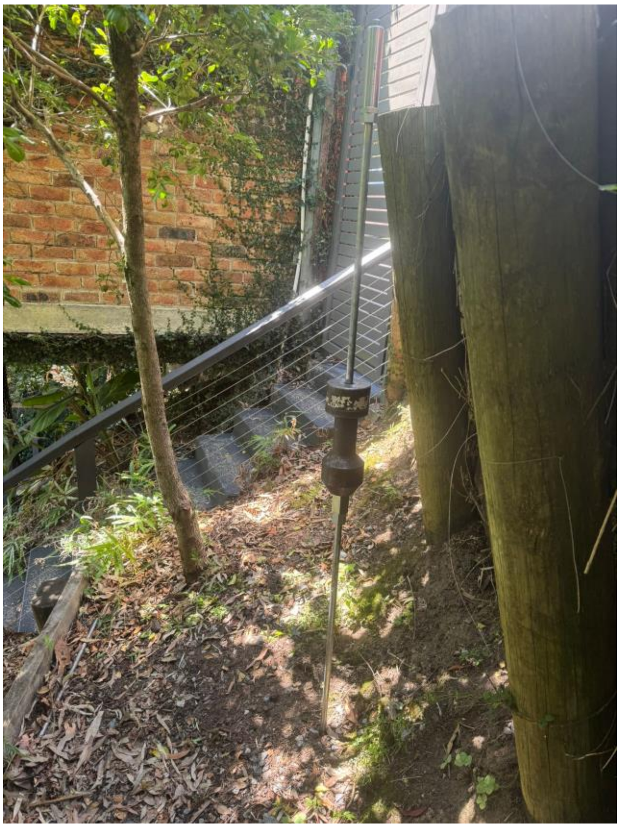
Appendix B

Site Photographs



BH1/DCP1

BH2/DCP2



DCP3

DCP4

Appendix C

Landslide Risk Assessment Matrix

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		**CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)**				
	Indicative Value of Approximate Annual Probability	**1: CATASTROPHIC 200%**	**2: MAJOR 60%**	**3: MEDIUM 20%**	**4: MINOR 5%**	**5: INSIGNIFICANT 0.5%**
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.

(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

Risk Level		**Example Implications** (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

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

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		**Implied Indicative Landslide Recurrence Interval**		**Description**	**Descriptor**	**Level**
Indicative Value	**Notional Boundary**					
10^{-1}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-6}$	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		**Description**	**Descriptor**	**Level**
Indicative Value	**Notional Boundary**			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

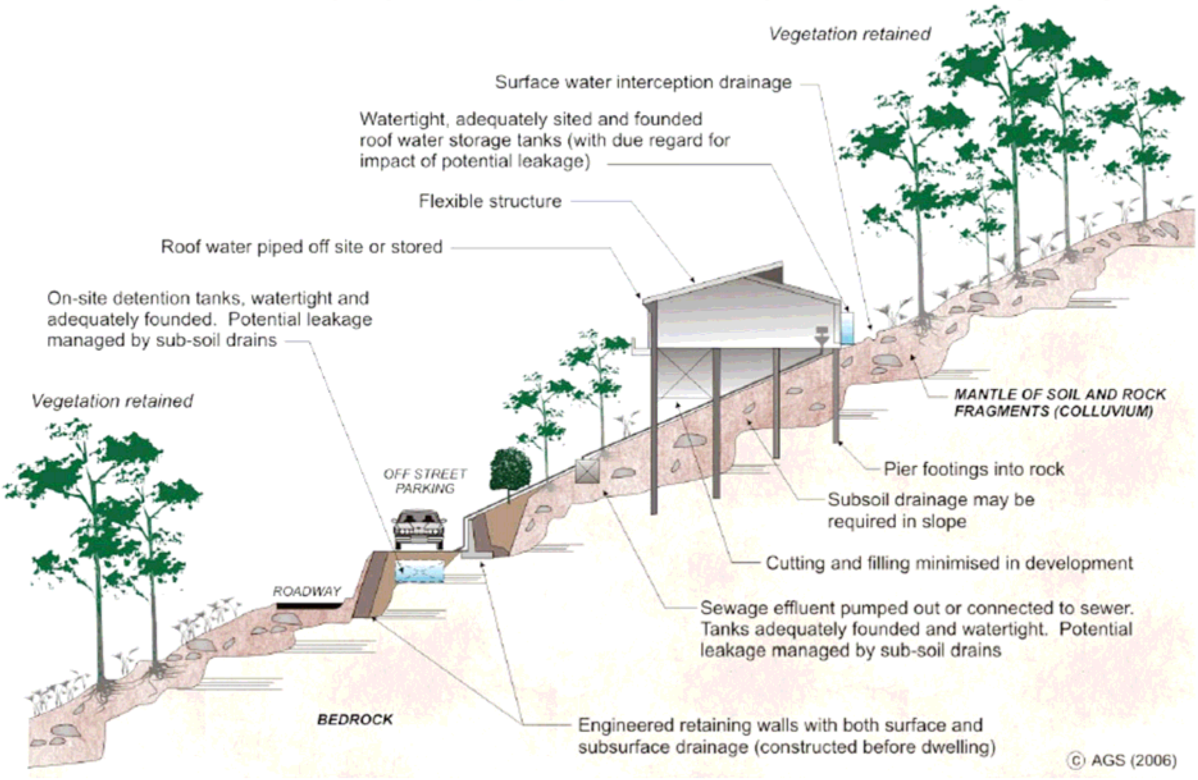
APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

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

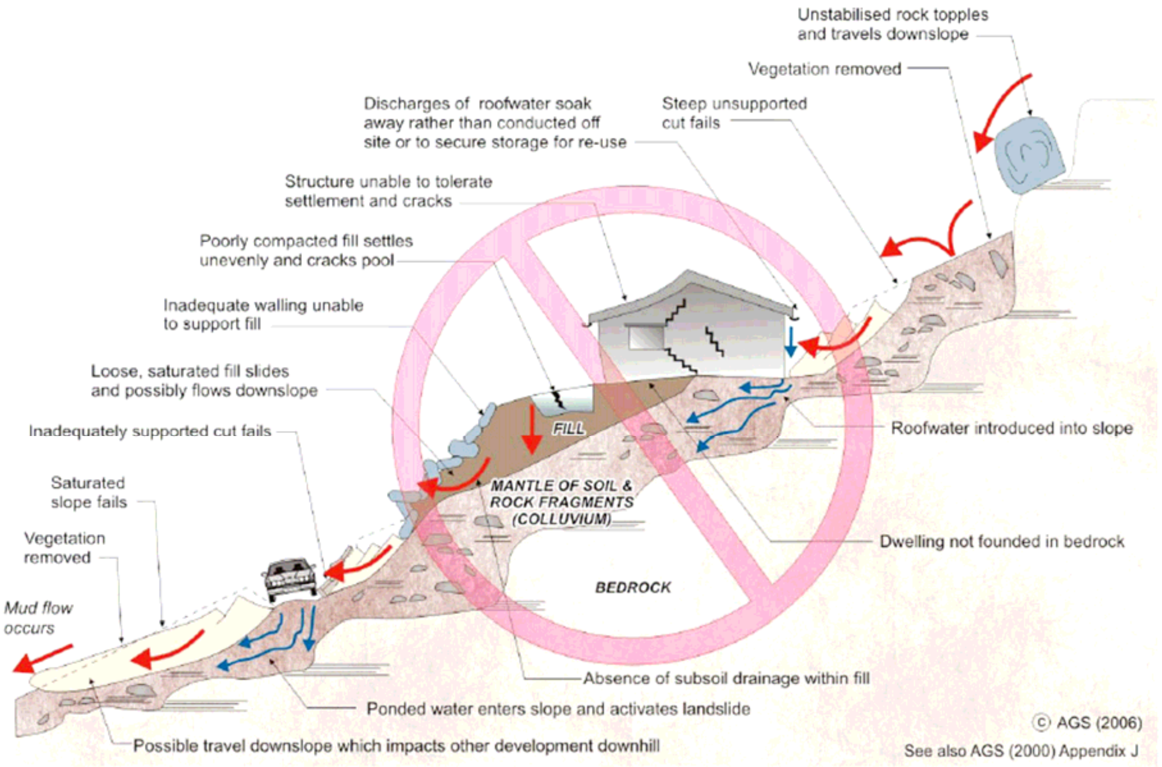
Appendix D

Hillside Construction Guideline

EXAMPLES OF GOOD HILLSIDE PRACTICE



EXAMPLES OF POOR HILLSIDE PRACTICE



Foundation Maintenance and Footing Performance: A Homeowner's Guide

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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 2870-2011, 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, which may experience only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes

Notes

1. Where controlled fill has been used, the site may be classified A to E according to the type of fill used.
2. Filled sites. Class P is used for sites which include soft fills, such as clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soil subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise.
3. Where deep-seated moisture changes exist on sites at depths of 3 m or greater, further classification is needed for Classes M to E (M-D, H1-D, H2-D and E-D).

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

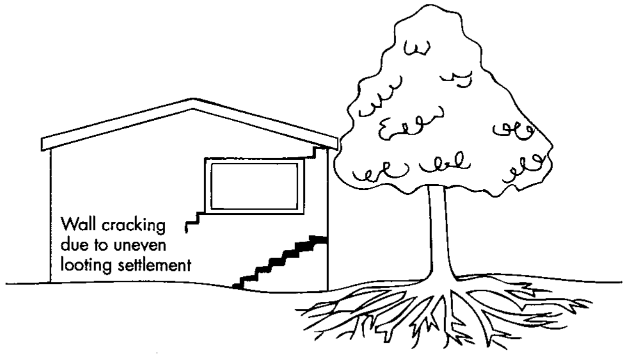
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the 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.

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.

Trees can cause shrinkage and damage



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

Movement caused by tree roots

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

Complications caused by the structure itself

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

Effects on full masonry structures

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

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

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

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

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

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

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

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

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

Water Service and Drainage

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

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem. Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

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

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870-2011.

AS 2870-2011 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/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.

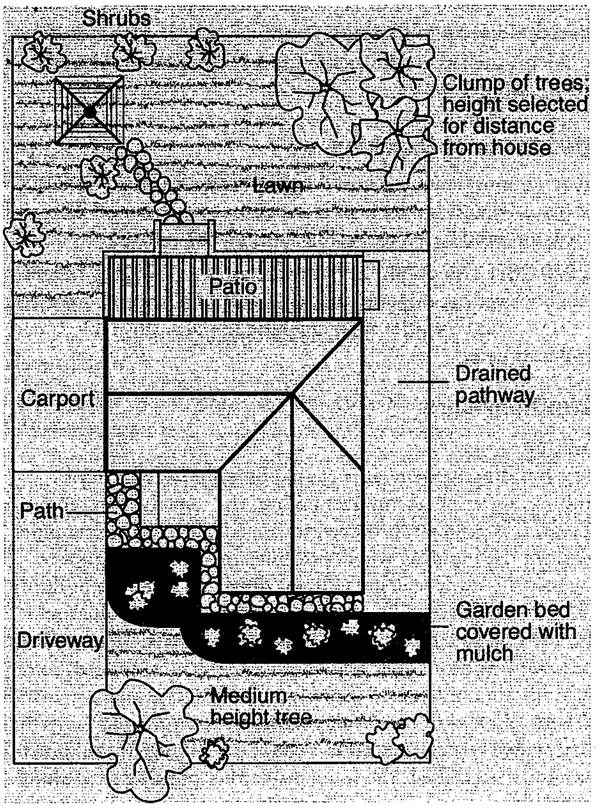
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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 should

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 depends on number of cracks	4

Gardens for a reactive site



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.

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

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Tel (03) 9545 8400 1300 788 000 www.publish.csiro.au
Email: publishing.sales@csiro.au