PROPOSED VISITOR ACCOMMODATION
117 CONINGHAM ROAD
CONINGHAM

GEOTECHNICAL SUMMARY

In general accordance with AS1726 (2017) *Geotechnical Site Investigations*

SITE (SOIL TEST) CLASSIFICATION

In general accordance with AS2870 (2011) *Residential slabs and footings*

AND

WIND LOAD CLASSIFICATION

In general accordance with AS4055 (2021) *Wind loads for housing*

September 2024

Cover

View southwest and slightly uphill past the proposed house site (left centre) on 117 Coningham Road.

Photo: Bill Cromer, 2 June 2022.

Refer to this report as

Cromer, W. C. (2024). *Geotechnical summary, site classification and wind classification, proposed visitor accommodation at 117 Coningham Road, Coningham.* Unpublished report for M. Trendall by William C. Cromer Pty. Ltd., 7 September 2024.

Important Notes

Report Distribution

This report has been prepared by William C Cromer Pty Ltd (WCCPL) for use by stakeholders (including regulators, developers, designers and architects, engineers, contractors, builders, building surveyors and owner-occupiers) involved with the residential development of the property named above. It is to be used only to assist in managing any existing or potential geotechnical issues relating to the site and its development.

This report requires certification via a Form 55 certificate for WCCPL to validate its contents.

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Footings and foundations

In this report, foundations are (usually) natural materials into which man-made footings are placed to support man-made structures.

Limitations of this geotechnical report

Site investigations for geotechnical reports usually but not always involve digging test holes and taking samples, at locations thought appropriate based on site conditions and general experience. The reports only apply to the tested part(s) of the site, and if not specifically stated otherwise, results should not be extrapolated to untested areas.

The main aim of the investigations is to reasonably determine the nature of and variability in subsurface conditions at the time of inspection. The number and location of test sites, and the number and types of tests done and samples collected, will vary from site to site. Subsurface conditions may change laterally and vertically between test sites, so discrepancies may occur between what is described in the reports, and what is exposed by subsequent excavations. No responsibility is therefore accepted for (a) any differences between what is reported, and actual site and soil conditions for parts of an investigation site not assessed at the time of inspection, and (b) subsequent activities on site by others, and/or climate variability (eg rainfall), which may alter subsurface conditions at the sites from those assessed at the time of inspection.

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SUMMARY STATEMENTS

Geotechnical risk

Geotechnical risks to property for proposed visitor accommodation (a new house[1]) at 117 Coningham Road, Coningham range from Low and Very Low.

To maintain the risk levels during and after residential development a range of risk treatments is recommended.

AS2870 Site Classification

In accordance with Australian Standard 2870 (2011) *Residential slabs and footings* the area **abcd** in Attachment 2 on 117 Coningham Road, Coningham is classed as **Class S** provided all house footings extend below the soil profile. See Attachment 4 for important details.

Site works subsequent to the date of investigation in this report may alter this classification.

AS4055 Wind Classification

In accordance with Australian Standard 4055 (2021) *Wind loads for housing*, the following wind load classification is made for 117 Coningham Road, Coningham:

Wind Region	**A**
Terrain Category classification	**TC2.5**
Topographic classification	**T1**
Shielding classification	**PS**
Wind classification	**N2**
Max. Design Gust Wind Speed	**26m/s** [Serviceability limit state ($V_{h, s}$)]
	40m/s [Ultimate limit state ($V_{h, u}$)]

W. C. Cromer
Principal

7 September 2024

[1] The term "house" in this report means a dwelling for Visitor Accommodation.

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This report is and must remain accompanied by the following Attachments

Attachment 1. Maps (5 pages)

Map 1.1	Cadastre
Map 1.2	Aerial imagery
Map 1.3	Published geology
Map 1.4	Hillshading

Attachment 2. Site sketch showing test pit locations, and the area abcd to which the AS2870 site classification in Attachment 4 applies (2 pages)

Attachment 3. Photographs of test pits C, D, E and F (5 pages)

Attachment 4. Interpretation of site geology and soils, AS2870 site classification and Notes for Stakeholders (9 pages)

Attachment 5. Summary of geotechnical issues, risks and consequences to development site, and suggested risk treatment practices (2 pages)
Terminology used in geotechnical risk assessment (1 page), and
Examples of good and poor hillside engineering practices (2 pages)

Stakeholders (including regulators, developers, designers and architects, engineers, contractors, builders, building surveyors and owner-occupiers) are encouraged to read this report.

Attachment 1

(5 pages including this page)

Maps

Map 1.1	Cadastre
Map 1.2	Aerial imagery
Map 1.3	Published geology
Map 1.4	Hillshading

Sources: http://maps.thelist.tas.gov.au; Mineral Resources Tasmania

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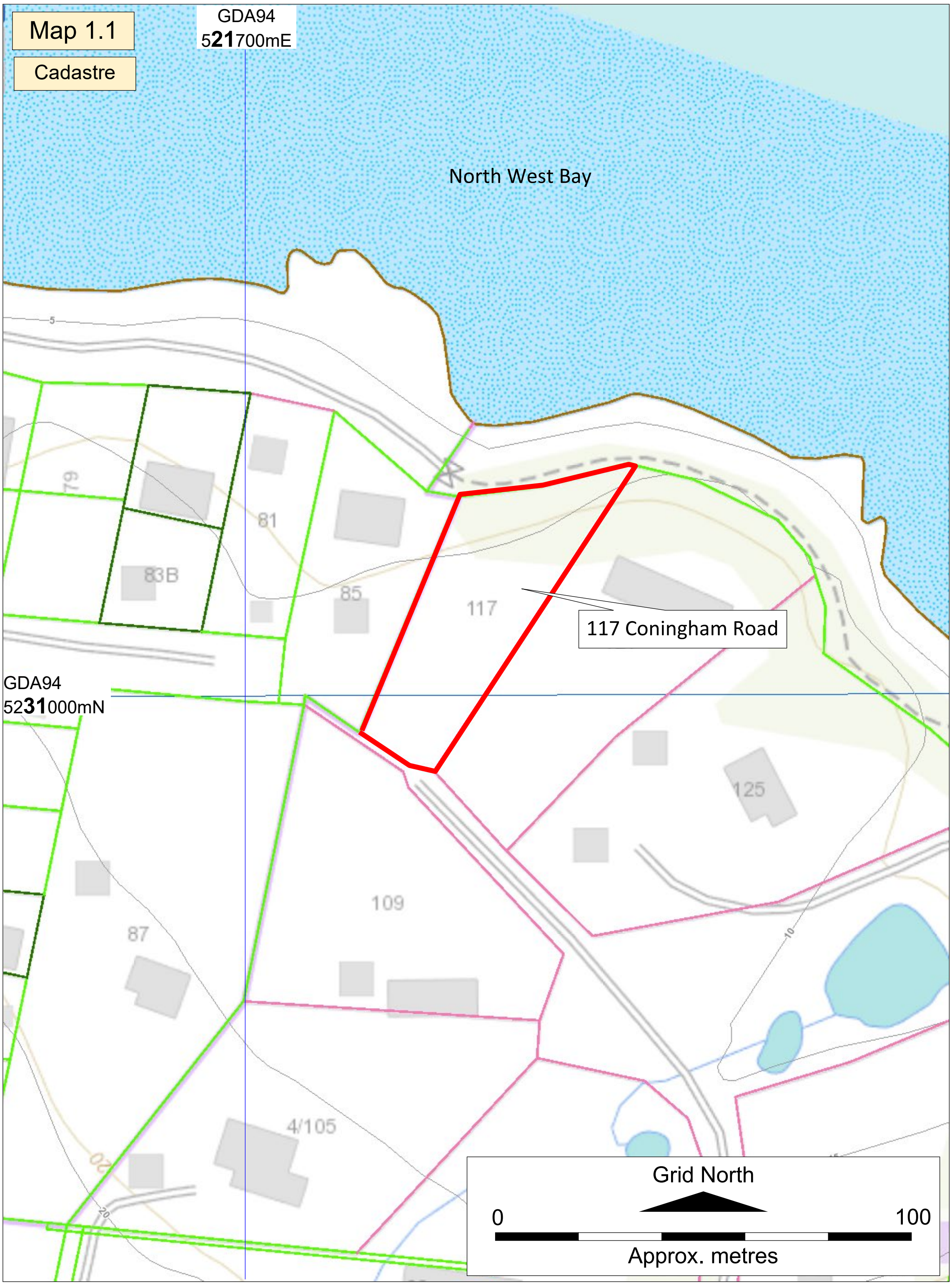
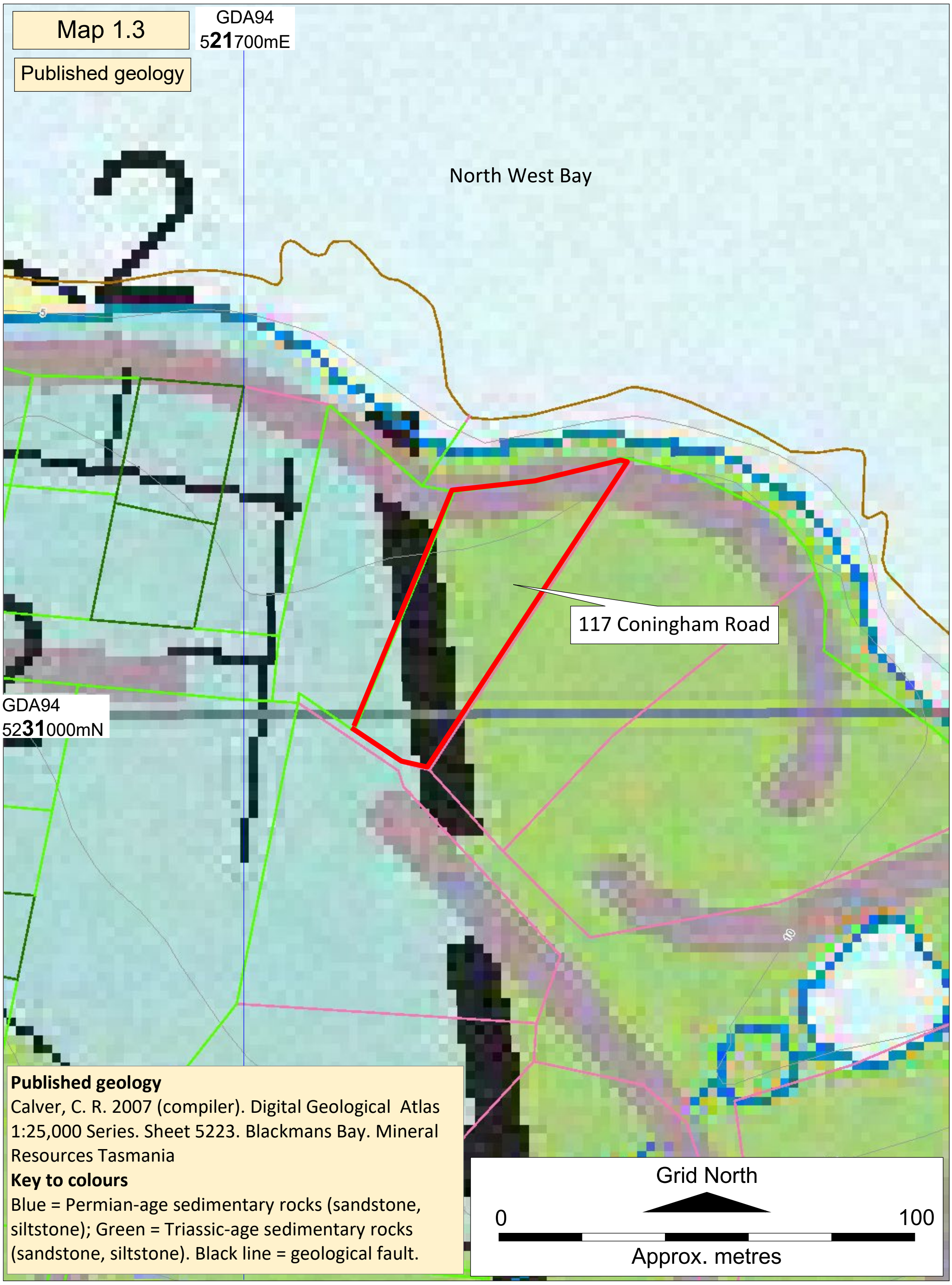
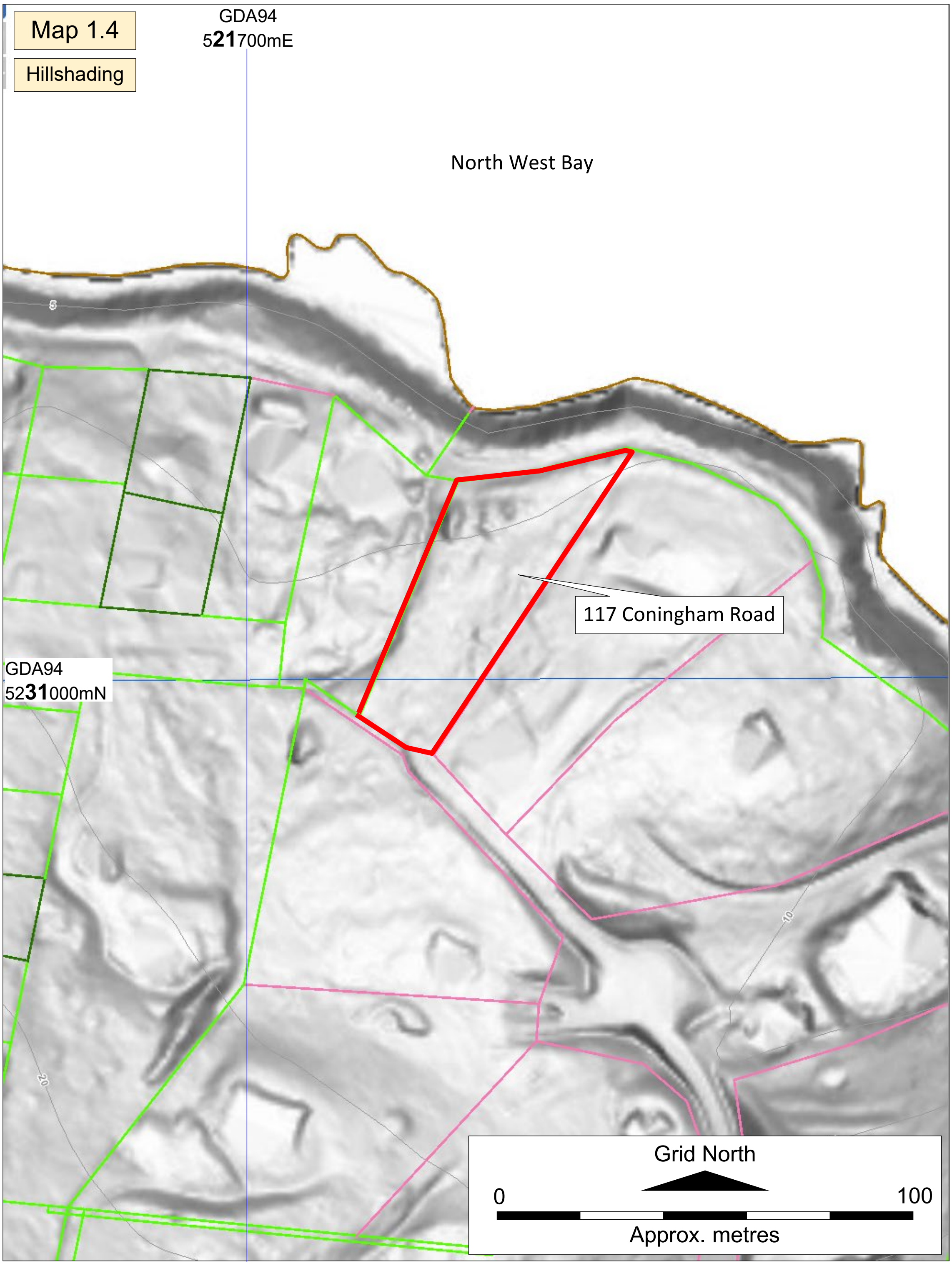

Map 1.1
Cadastre
GDA94
521700mE
North West Bay
GDA94
5231000mN
79
81
83B
85
117
117 Coningham Road
125
109
87
4/105
Grid North
0
100
Approx. metres


Map 1.2
Aerial imagery
GDA94
521700mE
North West Bay
117 Coningham Road
GDA94
5231000mN
Grid North
0
100
Approx. metres


Map 1.3
Published geology
GDA94
521700mE
North West Bay
117 Coningham Road
GDA94
5231000mN
Published geology
Calver, C. R. 2007 (compiler). Digital Geological Atlas 1:25,000 Series. Sheet 5223. Blackmans Bay. Mineral Resources Tasmania
Key to colours
Blue = Permian-age sedimentary rocks (sandstone, siltstone); Green = Triassic-age sedimentary rocks (sandstone, siltstone). Black line = geological fault.
Grid North
0
100
Approx. metres


Map 1.4
Hillshading
GDA94
521700mE
North West Bay
117 Coningham Road
GDA94
5231000mN
Grid North
0
100
Approx. metres

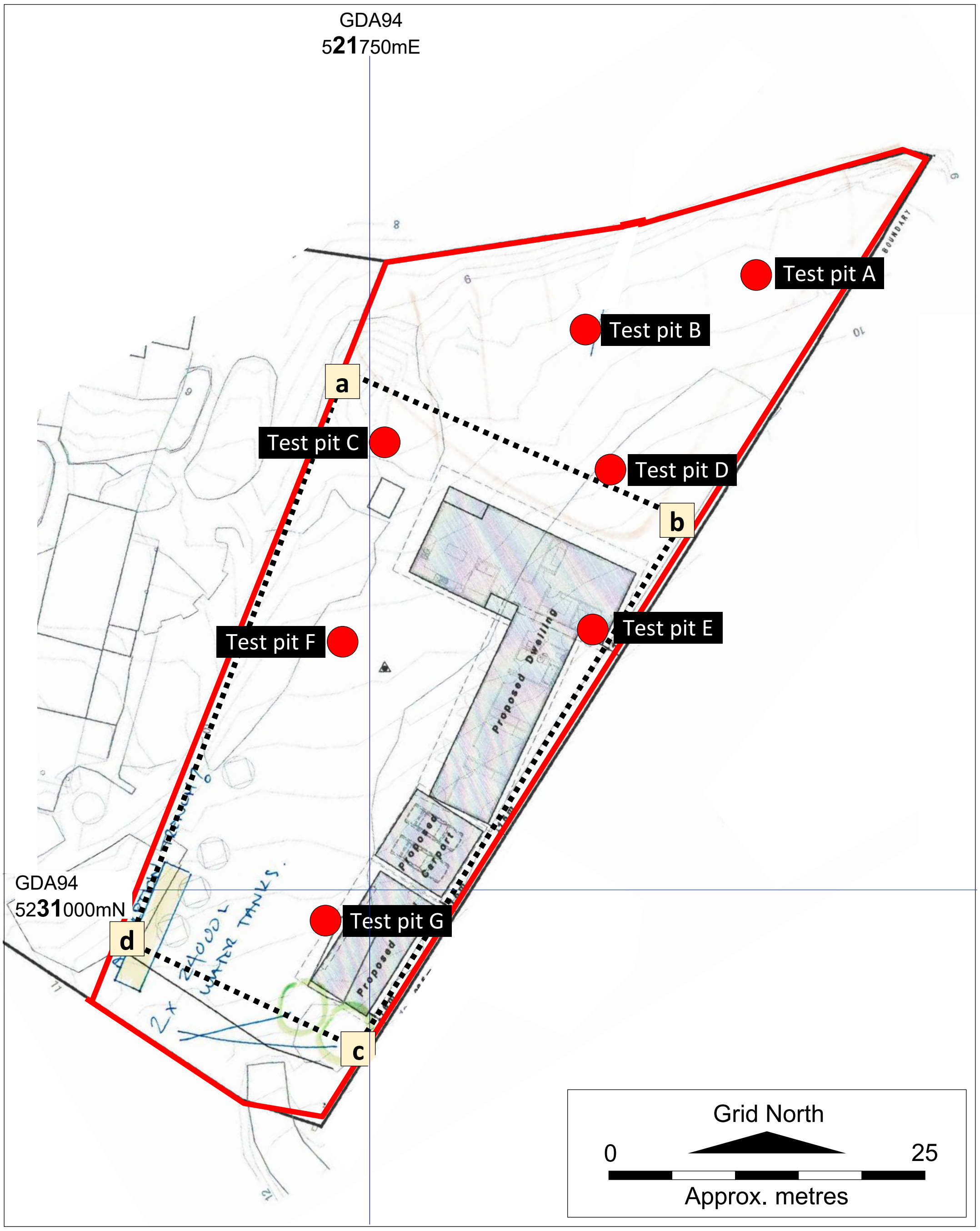
Attachment 2

(2 pages including this page)

Site sketch showing test pit locations, and the area abcd to which the AS2870 site classification in Attachment 4 applies

Source for site sketch: 1+2Architecture

Test pits C – G were mainly for AS2870 house site classification, and pits A and B were mainly for AS/NZS1547 wastewater assessment


GDA94
521750mE
GDA94
5231000mN
Test pit A
Test pit B
Test pit C
Test pit D
Test pit E
Test pit F
Test pit G
a
b
c
d
Grid North
0
25
Approx. metres

Attachment 3

(5 pages including this page)

Photographs of test pits C, D, E and F

There are three photos on a single page for each test pit. The main photo shows the soil profile in the test pit, a second inset photo shows the location of the test pit relative to site features, and a third inset photo shows the materials excavated from the test pit.

The name "Quinn" on the blackboard at each test pit refers to a former owner of the property, for which the original June 2022 site investigations were done.

The scale in the photos is graduated into red- and black-numbered segments each one metre long.

The numbers are decimetres.

See Table 4.1 in Attachment 4 for descriptions of Layers 1, 2, 3, etc in summary test pit logs.


QVINN
117
CONINGHAM
ROAD
2JUNE22
PIT C
Layer 1 (A1 horizon topsoil)
Layer 2 (A2 horizon topsoil)
Layer 3 (B horizon subsoil)
2JUNE22
PIT C


117
ROAD
2 JUNE 22
PIT D
Layer 1 (A1 horizon topsoil)
Layer 2 (A2 horizon topsoil)
Layer 4 (CB horizon


Layer 1 (A1 horizon topsoil)
Layer 2 (A2 horizon topsoil)
Layer 4 (CB horizon
QUINN
117
CONNINGHAM
ROAD
2JUNE 22
PIT E


QUINN
117
CONINGHAM
ROAD
2 JUNE 22
PIT F
ROAD
2 JUNE 22
PIT F
Layer 1 (A1 horizon topsoil)
Layer 2 (A2 horizon topsoil)
Layer 3 (B horizon subsoil)

Attachment 4

(9 pages including this page)

Interpretation of site geology and soils, AS2870 site classification, and Notes for Stakeholders

4.1 Site geology

4.1.1 Published geology

Published geological maps[2] of the district shows the property and environs underlain mostly by Triassic-age sedimentary rocks (principally sandstone and siltstone; coloured green on the Published Geology map in Attachment 1). A small section in the southwest corner is shown as underlain by Permian-age sedimentary rocks (coloured blue), faulted against the Triassic rocks.

4.1.2 Observed geology

No bedrock exposures occur on the property, but nearby, excellent exposures of sandstone and siltstone inferred to be both Permian and Triassic in age occur in the 8 – 10m high sea cliffs. The near-vertical fault separating the two ages of bedrock is well exposed in the cliff.

Material interpreted as extremely weathered to highly weathered sandstone and claystone bedrock (Table 4.1) was exposed in all but one of the seven test pits dug for coastal vulnerability and on-site wastewater assessments[3].

The bedrock is variably weathered: in pits D, E and G it was extremely weathered to silty and/or clayey sand (SC, CL; Layer 4 in Table 4.1).

4.2 Soils

4.2.1 Texture and thickness

Soils across the property are duplex (two-layered), comprising:

- <u>A1 and A2 horizons (topsoil; Layers 1 and 2 in Table 4.1; present in all seven pits)</u>
  SAND (SP): dark grey; 0 – 0.45m thick
  SAND (SP): light grey; 0.1 – 0.2m thick

- <u>B horizon (subsoil; Layer 3; present in 4 of seven pits)</u>
  Silty CLAY (CH): olive brown, light grey and orange; 0.3 – 0.5m thick

4.2.2 Soil reactivity[4]

To assess potential ground surface movement from reactive clayey materials, and to assist in site classification in terms of *AS2870:2011 Residential slabs and footings*, undisturbed clayey samples from the Layer 3 B horizons in test pits C and F were tested[5] for their shrink swell indices (Iss).

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[2] Calver, C.R. 2007 (compiler). Digital Geological Atlas 1:25 000 Scale Series. Sheet 5223. Blackmans Bay. Mineral Resources Tasmania.

[3] Reported separately. See Cromer, W. C. (2024). *Waterway and Coastal Protection, and Coastal Erosion Report, proposed new house, 117 Coningham Road, Coningham.* Unpublished report for M. Trendall by William C. Cromer Pty. Ltd., 25 June 2024, and Cromer, W. C. (2024). *Site and Soil Evaluation Report, and System Design for On-site Wastewater Management, proposed new house, 117 Coningham Road, Coningham.* Unpublished report for M. Trendall by William C. Cromer Pty. Ltd., 28 June 2024.

[4] Reactive materials contain clays which shrink and swell in volume when their moisture content decreases or increases respectively.

[5] Although William C. Cromer Pty. Ltd. is not NATA registered, testing is performed essentially in accordance with AS1289.7.1.1-1998. Methods of testing soils for engineering purposes. Method 7.1.1. Soil reactivity tests – Determination of the shrinkage index of a soil – Shrink-swell index. *Standards Australia*. From the Shrink-Swell index, the maximum ground surface movement can be estimated, and hence the site classification. Reactivity testing assists in site classification in accordance with AS2870:2011 *Residential slabs and footings.*

Table 4.1. Summary of test pits (Quinn & Risbey were the owners at the time the June 2022 site investigations were done).

Client Quinn & Risbey
Location 117 Coningham Road, Coningham
Date dug 2-Jun-22

Test pit	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Depth dug (m)	0.9	0.8	1.3	1.3	1.0	0.8	0.9
Easting (GDA94)	521782	521768	521752	521771	521772	521743	521742
Northing (GDA94)	5231050	5231045	5231035	5231033	5231020	5231020	5230997
Water inflow (depths in m)	None	None	None	None	None	None	None
Standing water level (m)	N/A	N/A	N/A	N/A	N/A	N/A	N/A

No.	**Layer**	**Details**	**USCS**	**Interpretation: Horizon**	**Interpretation: AS/NZS1547 soil category**	A	B	C	D	E	F	G
						Figures are depths to top and bottom of layer, in metres						
1	**SAND**	Dark grey; fine-medium grained; trace-some silt; D-M; MD	SP	Topsoil (A1 horizon)	2	0 to 0.2	0 to 0.3	0 to 0.45	0 to 0.4	0 to 0.25	0 to 0.2	0 to 0.15
2	**SAND**	Light grey; fine-medium grained; trace-some silt; D-M; MD	SP	Topsoil (A2 horizon)	3	0.2 to 0.35 D@0.3	0.3 to 0.5 D@0.4	0.45 to 0.55 D@0.5	0.4 to 0.55 D@0.55	0.25 to 0.35 D@0.3	0.2 to 0.3 D@0.3	0.15 to 0.35
3	**Silty CLAY**	olive brown, weakly mottled light grey and light orange; high plasticity; M<PL; VSt	CH	Subsoil (B horizon)	6	0.35 to 0.9 EAR	0.5 to 0.8 D@0.6	0.55 to 0.9 D@0.7 U50 (0.55 to 0.85)			0.3 to 0.65 D@0.6 U50 (0.3 to 0.6	
4	**Silty SAND**	Includes clayey sand; yellowish brown; nonplastic to low plasticity; D; D	SC, CL	CB horizon (extremely weathered bedrock	5				0.55 to 0.85 D@0.7	0.35 to 0.8 D@0.5		0.35 to 0.55
5	**SANDSTONE**	Yellowish orange; variably weathered (extremely to moderately); variable strength		Triassic-age bedrock	N/A		0.8 R		0.85 to 1.3 CR	0.8 to 1.0 CR	0.65 to 0.8 R	0.55 to 0.9 CR
6	**CLAYSTONE**	Silty; yellowish orange; highly weathered		Triassic-age bedrock	N/A			0.85 to 1.3 CR				

Notes and abbreviations

USCS = Unified Soil Classification System
Grey cells indicate a missing layer or layers in a test pit
Easting and Northing coordinates from Google Earth and hand-held GPS. Datum is GDA94.
Excavability Equipment = 1.8t excavator; 0.45m GP bucket; 4 teeth; Operator: Seaton Waterfield
EAR = end as required; NR = no refusal; CR = close to refusal; R = refusal.
Samples D = disturbed sample; U50 = Undisturbed 50mm diam drive tube sample
Weathering For rock only. F = fresh; SW = slightly weathered; MW = moderately weathered; HW = highly weathered;
EW = extremely weathered (ie soil properties; material can be remolded in the hand, with or without water)
Moisture D = dry; M = moist (M<=>PL = moisture less than, equal to or greater than Plastic Limit); W = wet.
Consistency Fb = Friable (crumbles to powder when scraped with thumbnail)
S = Soft (Easily penetrated by fist; 25 – 50kPa)
F = Firm (Easily penetrated by thumb; 50 – 100kPa)
St = Stiff (Indented with thumb; penetrated with difficulty; 100 – 200kPa)
VSt = Very stiff (Easily indented with thumbnail; 200 – 400kPa)
H = Hard (Indented by thumbnail with difficulty; >400kPa)
Rel density VL = Very loose (ravelling)
L = Loose (easy shovelling)
MD = Medium dense (hard shovelling)
D = Dense (picking)
VD = Very dense (hard picking)

Iss values of 2.6% and 1.2% from pits C and F respectively were obtained. These are low values so that ground surface movements from future possible soil moisture changes are unlikely to be significant.

Assume the Layer 3 subsoils exhibit Iss in the range 1 – 3%. Applying this range to all seven test pits (assuming Layers 1 and 2 are nonreactive, and Layer 4 where it occurs has Iss = 0.5%), the following ground surface movements (Ys) are estimated, with corresponding AS2870 site classifications:

Test pit A: Ys = 5 – 20mm; Class S – M
Test pit B: Ys = 0mm; Class S
Test pit C: Ys = 5 – 10mm; Class S
Test pit D: Ys = 5mm; Class S
Test pit E: Ys = 5mm; Class S
Test pit F: Ys = 5 – 15mm; Class S
Test pit G: Ys = 0mm; Class S

4.2.3 Soil dispersion

Selected samples of Layer 2 topsoil and Layer 3 subsoil were tested for dispersion. The topsoil is nondispersive (Emerson Class 7) and the Layer 3 subsoil is moderately-strongly dispersive (Emerson Classes 1 and 2).

4.3 Fill

No fill was observed on site, apart from a pile of loose sandstone boulders near the north northwestern boundary.

4.4 Bearing capacities of materials

A dynamic cone penetrometer (DCP) profile was done next to each of test pits A – F to attempt to assess the strength of soil.

The testing was done when soils were reasonably dry. Soil strength may decrease with increasing moisture content.

Profiles plotting hammer blows/100mm vs depth are presented in Figure 4.1. Published correlations between the DCP results and the soil property of allowable bearing capacity ("ABC") are presented in Table 4.2.

- The Layer 1 and 2 topsoil in all cases is of low strength, with DCP blows/100mm in the range 1 – 2 (ABC <100kPa).
- Strength generally (but not always) increases in the Layer 3 subsoil, with DCP blows/100mm typically in the 8 – 16 range (ABC 200 – 400kPa)

ABC more than about 100kPa is generally sufficient to support a house[6]. House footings should be placed beneath the Layer 1, 2 and 3 materials.

[6] Section 2.4.5 of AS2870 2011 *Residential slabs and footings* states:
"Determination of adequate bearing capacity shall be considered as follows:
(a) The design bearing capacity at foundation level shall be not less than 100 kPa for strip and pad footings and under the edge footings of footing slabs without tie bars between the edge footing and slab."
(b) "(b) The design bearing capacity at foundation level shall not be less than 50 kPa under all beams and slab panels and support thickenings for slab construction.
Determination of bearing capacity shall consider the weakest state of the foundation under normal site conditions. Local knowledge shall be used where available."

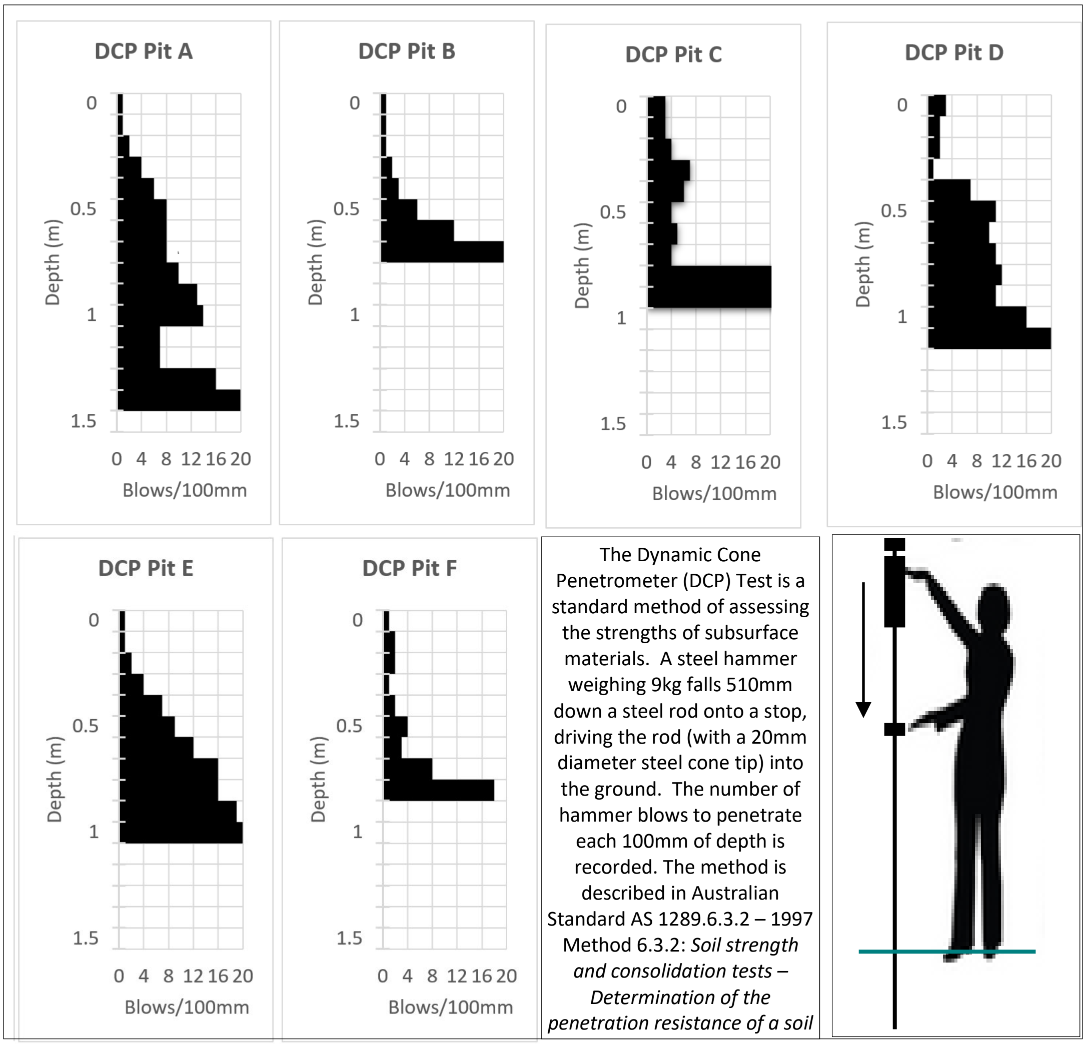

Figure 4.1 DCP profiles next to test pits A – F. See Figure 4.2 for published correlations between DCP values and some soil properties.

4.5 Groundwater

4.5.1 Temporary groundwater conditions

At the time of investigation, no shallow subsurface water was encountered in test pits.

Temporary shallow groundwater may be present in the soil profile after heavy rain.

4.5.2 Permanent groundwater

Permanent groundwater is expected to exist in fractured bedrock beneath the property and throughout the area, but at depths which will not affect residential subdivision.

4.6 Slope stability

There are no indications of slope instability on the property, and none is expected given the low slope angles and shallow presence of relatively stable bedrock.

There is a high likelihood of rockfalls/slumping on the adjacent sandstone/siltstone sea cliffs, but the cliffs are 10m away from the seaward property boundary, and the rate of coastal recession (including the possible effects of a rise in sea level of a metre or so by 2100,) is estimated to be about 1m/century[7]. Accordingly, the land is judged to be at very low risk of instability, and no management plan is required to address it.

Table 4.2. Published correlations between DCP values and some soil properties.

Blows/ 100mm	Allowable bearing capacity (kPa) Note 1	Typical material
<=1	<=50	Very soft to soft clays, very loose sands
1 – 2	50 – 100	Firm clays, loose sands
2 – 5	100 – 200	Stiff clays, medium dense sands
6 – 9	200 – 400	Very stiff clays, medium dense to dense sands
>=10	>400	Hard clays, dense to very dense sands

Reference: Look, B. (2014). *Handbook of Geotechnical Investigation and Design Tables* (2nd edition). CRC Press. The Netherlands. Table 5.15. The Table applies to shallow footings. Factor of Safety =3. For high and low plasticity clays the allowable bearing capacity may be lower and higher, respectively.

Notes

1. *Allowable bearing capacity* (ABC) is the Ultimate bearing capacity divided by a factor of safety (in the case of this Table, 3). *Ultimate bearing capacity* is the maximum average contact pressure between the soil and the footing which would not produce shear failure in the soil. In tis report it is assumed that ABC used here is the same as *Design Bearing Capacity* as defined in Section 1.8.14 of AS2870 2011 Residential slabs and footings: "The maximum bearing capacity that can be sustained by the foundation from the proposed footing system under service loads over the design range of soil moisture conditions."
2. Practitioners may prefer other published or unpublished correlations to those shown in this Table.

4.7 AS2870 site classification

In accordance with Australian Standard 2870 (2011) *Residential slabs and footings* the area **abcd** in Attachment 2 is classed as **Class S** provided all house footings are founded in Layers 4, 5, or 6 (Table 4.1) beneath the Layer 3 subsoil (where it exists).

If major site works occur on site this classification may need to be changed.

[7] Cromer, W. C. and Sharples, C. (2024). *Waterway and Coastal Protection, and Coastal Erosion Report, proposed Visitor Accommodation, 117 Coningham Road, Coningham.* Unpublished report for M. Trendall by William C. Cromer Pty. Ltd., 7 September 2024.

4.8 Notes for stakeholders[8]

4.8.1 Variability of subsurface conditions

Expect some but not significant variability in subsurface conditions at and near the proposed house site.

If significant variability is encountered, WCC should be immediately contacted for advice.

4.8. 2 Footings

House footings should avoid bearing on Layers 1, 2 and 3.

4.8.3 Excavations

As a general comment, it is preferable to minimise the depth of cut and fill, as shown in the hillside construction examples in Attachment 5.

4.8.4 Use of fill

On-site Layers 1 – 4 may be used as fill, but not to support weight-bearing loads unless of suitable nature and appropriately placed as controlled (structural) fill in an engineering sense[9].

4.8.5 Drainage

All roof and hardstand runoff should be piped away from the house and the adjacent wastewater land application area.

4.8.6 Good and poor hillside construction practices

Stakeholders are advised to read the AGS Geoguides[10], and in particular, the examples provided for good and bad hillside construction methods. The latter, and a geoguide on retaining walls, are included here as Attachment 5.

4.9 Geotechnical risk assessment

Table 4.3 assesses the proposed development of this property against a range of geotechnical issues, and where appropriate recommends treatment (management) of the associated risks.

The listed treatments are not necessarily exhaustive. Other treatments which achieve the same or better results may also be appropriate, separately or in combination with those listed.

[8] Stakeholders may include regulators, developers, designers and architects, engineers, contractors, builders, building surveyors and owner-occupiers, who should have read the Important Notes on page 2 of this report.

[9] See AS2870:2011 *Residential slabs and footings*, and AS3798:2007 *Guidelines on earthworks for commercial and residential developments*.

[10] AGS (2007e). *The Australian Geoguides for Slope Management and Maintenance*. Australian Geomechanics Vol 42 No 1 March 2007

Table 4.3. Geotechnical issues, risks and treatments for residential development on this property.

			Before treatment				After treatment		
	Issue #	Issue	Likelihood of occurrence	Consequences to property	Level of risk to property	Recommended risk treatment	Likelihood of occurrence	Consequences to property	Level of risk to property
Landslide/slope instability	1	Rotational or translational deep seated earth or debris slide.	Barely credible	Major	Very low	None	Barely credible	Major	Very low
	2	Rotational or translational shallow earth or debris slide.		Medium				Medium	
	3	Translational earth or debris slide, fall or topple: Very small scale; on steep, unsupported (artificial) excavations.	Unlikely	Minor	Low	Control stormwater discharge. Avoid or minimise excavations. Support excavations >0.8m high with engineered, drained retaining walls. Avoidusing fill as a weight-bearing material unless it is placed in a controlled (structural) manner.	Unlikely	Minor	Low
	4	Rotational or translational earth or debris slide: Very small to small scale; shallow, in fill (eg beneath or next to building, on the outside of access drive).							
	5	Earth or debris flow: Very small to small scale; shallow; in soil and/or uncontrolled fill.							
	6	Soil creep	Rare		Very low		Rare		Very low

Table 4.3 (continued). Geotechnical issues, risks and treatments for residential development on this property.

			Before treatment				After treatment		
	Issue #	Issue	Likelihood of occurrence	Consequences to property	Level of risk to property	Recommended risk treatment	Likelihood of occurrence	Consequences to property	Level of risk to property
Erosion, fill, drainage, subsurface conditions, coastal issues	7	Surface soil erosion	Possible	Minor	Low	As for Issues 3-6	Unlikely	Minor	Low
	8	Tunnel erosion (dispersive soils)							
	9	Foundation movement (eg settlement) due to low strength materials (eg uncontrolled fill, soft soils)	Unlikely	Minor to Medium		As for Issues 3 – 6. Also. design footings in accord with AS2870 - 2011 *Residential slabs and footings* and the site classification recommendation(s) in this report.			
	10	Foundation movement due to reactive or unstable soils	Possible		Moderate				
	11	Foundation movement due to tree removal or planting				Restrict tree planting to (and tree removal from) a distance from a building of 1.5x, 1x and 0.75x mature tree height for Class P, (H1, H2) and M sites respectively			
	12	Poor surface drainage	Unlikely	Minor	Low	Divert surface drainage away from buildings			
	13	Flooding or waterlogging				As for Issues 3 – 6, and 12			
	14	Shallow groundwater seepages				Divert seepages with interception drains behind any retaining walls, away from buildings			
	15	Site contamination from previous activities				Visual examination during construction.			
	16	Earthquake (magnitude <=4)	Likely	Insignificant		None	Likely	Insignificant	
	16	Earthquake (magnitude >4)	Unlikely	Minor			Unlikely	Minor	
	17	Coastal erosion	Almost certain	Insignificant			Almost certain	Insignificant	
	18	Sea level rise	Likely				Likely		

Notes

1. The risk assessments are qualitative and colour-coded in accordance with Appendix C of Practice Note Guidelines for Landslide Risk Management AGS (2007c)

2. Further reading: AGS (2007c). Practice Notes Guidelines for Landslide Risk Management, and AGS (2007e) *Australian Geoguides for Slope Management and Maintenance*. Australian Geomechanics Vol 42 No 1 March 2007

Attachment 5

(6 pages including this page)

Some AGS guidelines for hillside construction (1 page)

AGS Geoguide LR8 illustrating good and poor hillside engineering practices (2 pages)

AGS Geoguide LR6 Retaining walls (2 pages)

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.	

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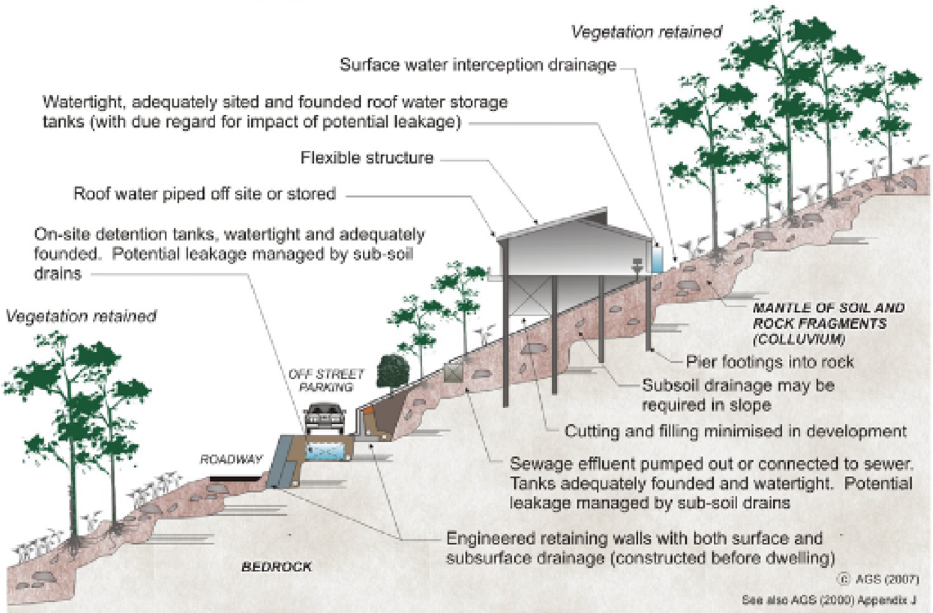
Good and poor hillside construction practices

AGS Geoguide LR8 (Construction Practice)

HILLSIDE CONSTRUCTION PRACTICE

Sensible development practices are required when building on hillsides, particularly if the hillside has more than a low risk of instability (GeoGuide LR7). Only building techniques intended to maintain, or reduce, the overall level of landslide risk should be considered. Examples of good hillside construction practice are illustrated below.

EXAMPLES OF GOOD HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES GOOD?

Roadways and parking areas - are paved and incorporate kerbs which prevent water discharging straight into the hillside (GeoGuide LR5).

Cuttings - are supported by retaining walls (GeoGuide LR6).

Retaining walls - are engineer designed to withstand the lateral earth pressures and surcharges expected, and include drains to prevent water pressures developing in the backfill. Where the ground slopes steeply down towards the high side of a retaining wall, the disturbing force (see GeoGuide LR6) can be two or more times that in level ground. Retaining walls must be designed taking these forces into account.

Sewage - whether treated or not is either taken away in pipes or contained in properly founded tanks so it cannot soak into the ground.

Surface water - from roofs and other hard surfaces is piped away to a suitable discharge point rather than being allowed to infiltrate into the ground. Preferably, the discharge point will be in a natural creek where ground water exits, rather than enters, the ground. Shallow, lined, drains on the surface can fulfil the same purpose (GeoGuide LR5).

Surface loads - are minimised. No fill embankments have been built. The house is a light weight structure. Foundation loads have been taken down belowthe level at which a landslide is likely to occur and, preferably, to rock. This sort of construction is probably not applicable to soil slopes (GeoGuide LR3). If you are uncertain whether your site has rock near the surface, or is essentially a soil slope, you should engage a geotechnical practitioner to find out.

Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing can result in a rise in water table with a consequent increase in the likelihood of a landslide (GeoGuide LR5). An exception may have to be made to this rule on steep rock slopes where trees have little effect on the water table, but their roots pose a landslide hazard by dislodging boulders.

Possible effects of ignoring good construction practices are illustrated on page 2. Unfortunately, these poor construction practices are not as unusual as you might think and are often chosen because, on the face of it, they will save the developer, or owner, money. You should not lose sight of the fact that the cost and anguish associated with any one of the disasters illustrated, is likely to more than wipe out any apparent savings at the outset.

ADOPT GOOD PRACTICE ON HILLSIDE SITES

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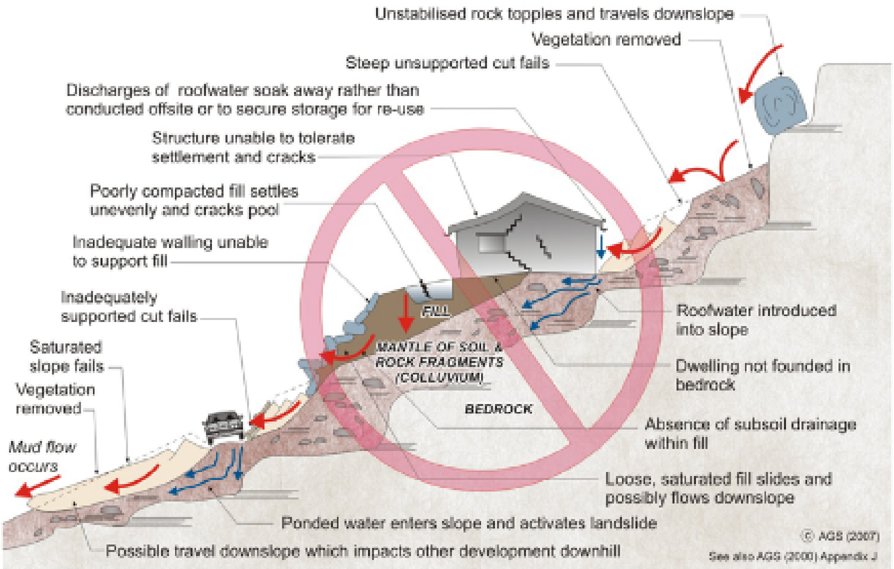
AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF POOR HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES POOR?

Roadways and parking areas - are unsurfaced and lack proper table drains (gutters) causing surface water to pond and soak into the ground.

Cut and fill - has been used to balance earthworks quantities and level the site leaving unstable cut faces and added large surface loads to the ground. Failure to compact the fill properly has led to settlement, which will probably continue for several years after completion. The house and pool have been built on the fill and have settled with it and cracked. Leakage from the cracked pool and the applied surface loads from the fill have combined to cause landslides.

Retaining walls - have been avoided, to minimise cost, and hand placed rock walls used instead. Without applying engineering design principles, the walls have failed to provide the required support to the ground and have failed, creating a very dangerous situation.

A heavy, rigid, house - has been built on shallow, conventional, footings. Not only has the brickwork cracked because of the resulting ground movements, but it has also become involved in a man-made landslide.

Soak-away drainage - has been used for sewage and surface water run-off from roofs and pavements. This water soaks into the ground and raises the water table (GeoGuide LR5). Subsoil drains that run along the contours should be avoided for the same reason. If felt necessary, subsoil drains should run steeply downhill in a chevron, or herring bone, pattern. This may conflict with the requirements for effluent and surface water disposal (GeoGuide LR9) and if so, you will need to seek professional advice.

Rock debris - from landslides higher up on the slope seems likely to pass through the site. Such locations are often referred to by geotechnical practitioners as "debris flow paths". Rock is normally even denser than ordinary fill, so even quite modest boulders are likely to weigh many tonnes and do a lot of damage once they start to roll. Boulders have been known to travel hundreds of metres downhill leaving behind a trail of destruction.

Vegetation - has been completely cleared, leading to a possible rise in the water table and increased landslide risk (GeoGuide LR5).

DON'T CUT CORNERS ON HILLSIDE SITES - OBTAIN ADVICE FROM A GEOTECHNICAL PRACTITIONER

More information relevant to your particular situation may be found in other Australian GeoGuides:

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- GeoGuide LR11 - Record Keeping

The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to help you understand why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local council approval (if required) to remove, reduce, or minimise the risk they represent. The GeoGuides have been prepared by the Australian Geomechanics Society, a specialist technical society within Engineers Australia, the national peak body for all engineering disciplines in Australia, whose members are professional geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments' National Disaster Mitigation Program.

AUSTRALIAN GEOGUIDE LR6 (RETAINING WALLS)

RETAINING WALLS

Retaining walls are used to support cuts and fills. Some are built in the open and backfill is placed behind them (gravity walls). Others are inserted into the ground (cast *in situ* or driven piles) and the ground is subsequently excavated on one side. Retaining walls, like all man-made structures, have a finite life. Properly engineered walls should last 50 years, or more, without needing significant repairs. However, not all walls fit this category. Some, particularly those built by inexperienced tradesmen without engineering input, can deflect and even fail because they are unable to withstand the pressures that develop in the ground around them or because the materials from which they are built deteriorate with time. Design of retaining walls more than 900mm high should be undertaken by a geotechnical practitioner or structural engineer and normally require local council approval.

Retaining walls have to withstand the weight of the ground on the high side, any water pressure forces that develop, any additional load (surcharge) on the ground surface and sometimes swelling pressures from expansive clays. These forces are resisted by the wall itself and the ground on the low side. Engineers calculate the forces that the retained ground, the water, and the surcharge impose on a wall (the disturbing force) as well as the maximum force that the wall and ground on the low side can provide to resist them (the restoring force). The ratio of the restoring force to the disturbing force is called the "factor of safety" (GeoGuide LR1). Permanent retaining walls designed in accordance with accepted engineering standards will normally have a factor of safety in the range 1.5 to 2.

Never add surcharge to the high side of a wall (e.g. place fill, erect a structure, stockpile bulk materials, or park vehicles) unless you know the wall has been designed with that purpose in mind.

Never more than lightly water plants on the high side of a retaining wall.

Never excavate at the toe of a retaining wall.

Any of these actions will reduce the factor of safety of the wall and could lead to failure. If in doubt about any aspect of an existing retaining wall, or changes you would like to make near one, seek advice from a geotechnical practitioner, or a structural engineer. This GeoGuide sets out basic inspection requirements for retaining walls and identifies some common signs that might indicate all is not well. GeoGuide LR11 provides information about records that should be kept.

GRAVITY WALLS

Gravity walls are so called because they rely on their own weight (the force of gravity) to hold the ground behind in place.

Formed concrete and reinforced blockwork walls (Figure 1) - should be built so the backfill can drain. They should be inspected at least once a year. Look for signs of tilting, bulging, cracking, or a drop in ground level on the high side, as any of these may indicate that the wall has started to fail. Look for rust staining, which may indicate that the steel reinforcement is deteriorating and the wall is losing structural strength ("concrete cancer"). Ensure that weep holes are clear and that water is able to drain at all times, as high water pressures behind the wall can lead to sudden and catastrophic failure.

Concrete "crib" walls (Figure 2) - should be filled with clean gravel, or "blue metal" with a nominated grading. Sometimes soil is used to reduce cost, but this is undesirable, from an engineering perspective, unless internal drainage is incorporated in the wall's construction. Without backfill drainage, a soil filled crib wall is likely to have a lower factor of safety than is required. Crib walls should be inspected as for formed concrete walls. In addition, you should check that material is not being lost through the structure of the wall, which has large gaps through it.

Timber "crib" walls - should be checked as for concrete crib walls. In addition, check the condition of the timber. Once individual elements show signs of rotting, it is necessary to have the wall replaced. If you are uncertain seek advice from a geotechnical practitioner, or a structural engineer.

Masonry walls: natural stone, brick, or interlocking blocks (Figure 3) - more than about 1m high, should be wider at the bottom than at the top and include specific measures to permit drainage of the backfill. They should be checked as for formed concrete walls. Natural stone walls should be inspected for signs of deterioration of the individual blocks: strength loss, corners becoming rounded, cracks appearing, or debris from the blocks collecting at the foot of the wall.

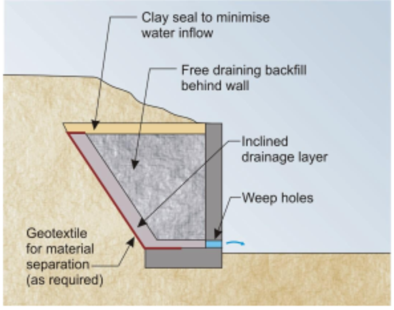


Figure 1- Typical formed concrete wall

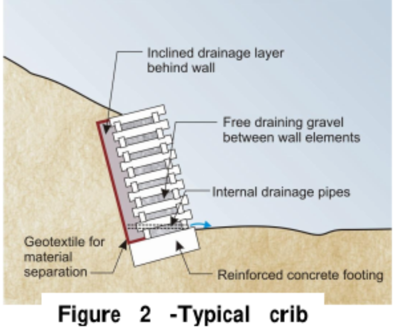


Figure 2 -Typical crib

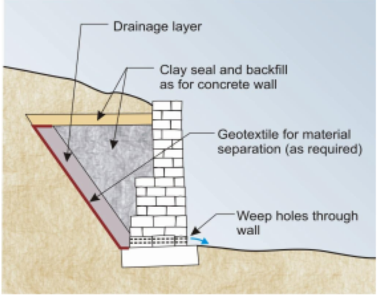


Figure 3 -Typical masonry wall

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AUSTRALIAN GEOGUIDE LR6 (RETAINING WALLS)

Old Masonry walls (Figure 4) - Many old masonry retaining walls have not been built in accordance with modern design standards and often have a low "factor of safety" (GeoGuide LR1). They may therefore be close to failure and a minor change in their condition, or loading, could initiate collapse. You need to take particular care with such structures and seek professional advice sooner rather than later. Although masonry walls sometimes deflect significantly over long periods of time collapse, when it occurs, is usually sudden and can be catastrophic. Familiarity with a particular situation can instil a false sense of confidence.

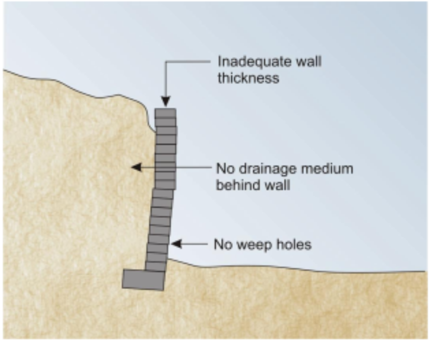

Figure 4 - Poorly built masonry wall

Reinforced soil walls (Figure 5) - are made of compacted select fill in which layers of reinforcement are buried to form a "reinforced soil zone". The reinforcement is all important, because it holds the soil "wall" together. Reinforcement may be steel strip, or mesh, or a variety of geosynthetic ("plastic") products. The facing panels are there to protect the soil "wall" from erosion and give it a finished appearance.

Most reinforced soil walls are proprietary products. Construction should be carried out strictly in accordance with the manufacturer's instructions. Inspection and maintenance should be the same as for formed concrete and concrete block walls. If unusual materials such as timber, or used tyres, are used as a facing it should be checked to see that it is not rotting, or perishing.

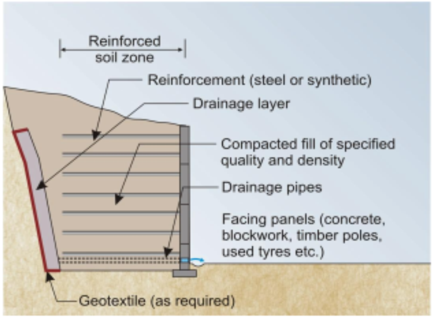

Figure 5 - Typical reinforced soil wall

OTHER WALLS

Cantilevered and anchored walls (Figure 6) - rely on earth pressure on the low side, rather than self-weight, to provided the restoring force and an adequate factor of safety. These walls may comprise:

- a line of touching bored piers (contiguous bored pile wall) or
- sprayed concrete panels between bored piers (shotcrete wall) or
- horizontal timber or concrete planks spanning between upright timber or steel soldier piles or
- steel sheet piles.

Depending on the form of construction and ground conditions, walls in excess of 3 m height normally require at least one row of permanent ground anchors.

INSPECTION

All walls should be inspected at least once a year, looking for tilting and other signs of deterioration. Concrete walls should be inspected for cracking and rust stains as for formed concrete gravity walls. Contiguous bored pile walls can have gaps between the piles - look for loss of soil from behind which can become a major difficulty if it is not corrected. Timber walls should be inspected for rot, as for timber crib walls. Steel sheet piles should be inspected for signs of rusting. In addition, you should make sure that ground anchors are maintained as described in GeoGuide LR4 under the heading "Rock bolts and rock anchors".

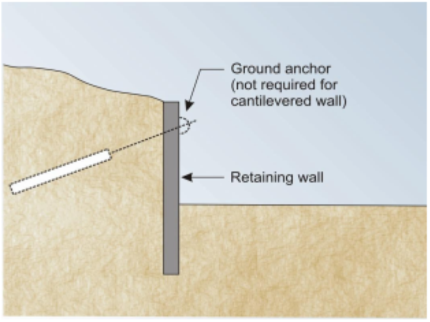

Figure 6 - Typical cantilevered or anchored wall

One of the most important issues for walls is that their internal drainage systems are operational. Frequently verify that internal drainage pipes and surface interception drains around the wall are not blocked nor have become inoperative.

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