Report on:

GEOTECHNICAL AND ENVIRONMENTAL STUDY PROPOSED CHILDCARE CENTRE 21 BERKSHIRE ROAD, FORRESTFIELD

WAE250028-01 001 R Rev0

Submitted to:

West Property Group

23 June 2025

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Standard Geotechnical Definitions, Recommendations, Requirements and Limitations

1. INTRODUCTION

This report presents the outcomes of Galt Environmental and Galt Geotechnics' (Galt's) geotechnical and environmental study for the proposed childcare centre, at 21 Berkshire Road, Forrestfield ("the site").

This report is to be read in conjunction with the appended "Geotechnical Definitions, Recommendations, Requirements and Limitations". 'Clause GDR1', etc. refer to this Appendix, found at the back of this report.

2. KEY FINDINGS

The site is underlain by a thin cover of gravelly sand/sandy gravel (typically 0.5 m) over medium plasticity clay. Groundwater was not encountered within the investigated depth (3 m) and is expected to be deep at the site. Based on this, a site classification of "Class S" applies to the site in accordance with AS2870-2011.

Standard site preparation measures are expected to apply, but we note that nuclear density gauge testing will be required to test compaction at this site. The use of a penetrometer for compaction control is not appropriate.

On site disposal of stormwater is not possible due to the clayey soils at the site. Stormwater must be captured and disposed via council drainage.

The concentrations of all contaminants of potential concern were either below the laboratory limit of reporting (LOR) and/or conformed to the adopted assessment criteria. Based on these findings, we consider that the site is suitable for use as a childcare centre.

3. SITE DESCRIPTION

Table 1: Summary of Site

Item	Comment
Site Extent	The site is bounded by Berkshire Road and residential developments on all other sides (Refer Figure 1)
Site Area	3,750 m^2
Current Site Surface Elevation[1]	RL 54 m AHD at the west to RL 56 m AHD to the east.
Vegetation	Mature trees are present across the site.
Current Land Use	Residential
Existing Infrastructure	Single-storey house and associated outbuildings.
Site History[2]	The existing house has been present at the site since at least 1953. Extensions appear to have been undertaken in the 1980s.

NOTES: ***1.*** *Site elevation based on publicly available data (Landgate)*

2. *Site history based on historical aerial imagery (Landgate)*

4. PROPOSED DEVELOPMENT

A concept layout of the proposed development is presented in Appendix A.

Table 2: Summary of Proposed Development

Item	Comment
Proposed Development	Childcare (single storey).
Basements Proposed	Nil.
Proposed Finished Elevation	Assumed at or close to existing ground level.
Cut/Fill	Nil or as required to create flat areas (< 0.5 m cut/fill)
Assumed Foundation Type	Shallow footings with slabs on ground.
Assumed Retaining Walls	Nil or very low retained heights.
Assumed Stormwater Disposal	Council drainage.
Assumed Sewage Disposal	Reticulated sewer.

5. PROJECT OBJECTIVES

The objectives of the study were to:

- assess subsurface soil and groundwater conditions across the site;
- provide recommendations on suitable footing systems for the proposed development;
- provide allowable bearing pressure and settlement estimates for shallow foundations;
- provide a site classification(s) in accordance with AS 2870-2011 “Residential Slabs and Footings”;
- provide recommendations and geotechnical design parameters for earth retaining structures, including temporary support;
- assess the appropriate site subsoil class for the site in accordance with AS 1170.4-2007
- recommend appropriate site preparation procedures including compaction criteria;
- assess the permeability of the soils at the site for potential on-site disposal of stormwater by infiltration;
- provide a subgrade California bearing ratio (CBR) value for pavement thickness design by others;
- comment on any environmental issues or contaminants that may impact the proposed development, in accordance with WAPC planning bulletin 7/2009.

6. FIELDWORK

Fieldwork was carried out on 6 June 2025 and is summarised below.

Table 3: Summary of Fieldwork

Type	Results Appendix	Summary	GDR Clause	Equipment Used	No. Tests	Depth Range (m)
Site Plan	Figure 1	-	-	Hand held GPS[1]	-	-
Photographs	B	-	-	-	-	-
Machine Auger Boreholes (BH)	C	Section 9	GDR3.3	EVH Scout on utility	4	3.0
Dynamic Cone Penetrometer (DCP)[2]	C	N/A	GDR3.4	Hand operated DCP	4	0.6 – 1.0
Environmental Grab Samples	-	-	-	-	4	0.0 – 0.2

NOTES: ***1.*** *Hand held GPS is accurate to ±5 m.*

2. *DCP Tests carried out adjacent to boreholes, results are shown on borehole logs.*

Infiltration testing was proposed but based on very thin sand cover (<0.5 m) and underlying clayey soils, the testing was not possible.

7. LABORATORY TESTING

Table 4: Summary of Laboratory Testing Undertaken

Type	Testing Done?	Results Summary	Results Appendix
Geotechnical Index Tests	Yes	Attached Table 1	C
Environmental Chain of Custody	Yes	-	D
Heavy metals, pesticides, and asbestos identification	Yes	-	F

8. SITE CONDITIONS

8.1. Geology

Table 5: Summary of Geology Mapping

Map Sheet	Map Scale	Mapped Soils	Site Findings
Armadale/Perth	1:50,000	Mgs1 – Pebbly silt – strong brown silt with common pebbles of fine to coarse-grained, sub-rounded granite, some dolerite and rare sandstone, variable sand cover (colluvium).	Colluvial sandy gravel/gravelly sand, with some sandy fill in areas (likely site derived), over clay. In general accordance with the geological mapping.

8.2. Groundwater

Table 6: Summary of Groundwater Levels

Item	Date	Depth Range (m)	Elevation Range (m AHD)	Comment
Perth Groundwater Atlas				The Perth Groundwater Atlas does not extend to this site.
Perth Groundwater Map (2019) (Gnangara-Jandakot Mound)	2019	37-39	17	May not be strictly applicable to this area.
Site observations	2025	-	-	Maximum drilled depth 3.0 m.
Recommended Design	-	-		True groundwater is at significant depth at this site. Perched groundwater over the clay is likely during and following heavy rainfall events.

NOTES: ***1.*** *Elevation range for site observations is based on depth and site levels during fieldwork*

9. GROUND MODEL

The subsurface conditions can be summarised as:

- UNIT A – Gravelly SAND/Sandy GRAVEL (SM/GM) – fine to coarse grained sand/gravel, with non-plastic/low-plasticity fines, brown to dark brown, typically dense, present from the site surface to a typical depth of around 0.5 m (0.3 m to 0.8 m); overlying
- UNIT B – CLAY (CI-CH) – typically medium plasticity, orange-brown, with gravel, gravel content decreasing with depth, very stiff.

The generalised subsurface units are described in the table with geotechnical design parameters.

Table 7: Geotechnical Model Units and Design Parameters

Unit Name	Material Type	γ_{bulk} (kN/m^3)	ϕ' (°)	c' (kPa)	s_u (kPa)	E_v (MPa)	ν	k_0	Wall Friction=0		Wall Friction=0.5ϕ	
									k_a	k_p	k_a	k_p
A	Gravelly SAND/Sandy GRAVEL Dense	19	36	0	-	50	0.3	0.36	0.26	3.85	0.22	7.63
B	CLAY Very Stiff	19	25	10	150	75	0.25	Refer to GDR11.2.2 Cohesive Soils with drained properties, fines content >35% and PI of 20%.				

NOTES:

1. *These units are a generalisation of results from individual tests, which should be referred to for more information.*
2. *Topsoil is not included as a discrete unit.*
3. *For all earth pressure coefficients (retaining wall design) refer to clause GDR11.2. Unit weights for retaining structure design should be as per GDR11.2 or 1 kN/m^3 greater than the values in the table above.*

γ_{bulk} – bulk unit weight
ϕ' – effective friction angle
s_u – undrained shear strength
c'– effective cohesion
E_v – vertical elastic modulus
ν – Poisson's Ratio
k_a – coefficient of active earth pressure (Coulomb – AS4678-2002, Appendix E)
k_p – coefficient of passive earth pressure (Coulomb – AS4678-2002, Appendix E)
k_0 – coefficient of at-rest earth pressure (Jaky)

10. GEOTECHNICAL ASSESSMENT

10.1. Summary

Table 8: Summary of Geotechnical Assessment

Type	Clause	Parameter	Comment
Site Suitability	-	-	We consider the site to be geotechnically suitable for the proposed development. Standard site preparation measures will apply but no unusual conditions were encountered. Stormwater disposal via infiltration is **not suitable.** Stormwater should be captured and diverted to council drainage. Surface drainage should be carefully considered due to the relatively impermeable nature of subsurface soils.
Construction Methodology and Suitability	-	-	Shallow footings in accordance with AS2870-2011 will be suitable for this site. Mass retaining will be suitable for retaining above groundwater.
Site Classification (AS2870)	GDR5	Class S	The removal of the large existing trees (or leaving some in place) may have an impact on foundation performance. We refer you to CSIRO Pamphlet BTF 18-2011 (Appendix G).
Site Subsoil Class (AS1170.4)	-	Ce	-
Site Preparation	GDR6	-	**GDR6.2.1 Common Measures** followed by **GDR6.2.4 Clayey Sites** We also refer you to guidance in the following sections for clayey sites: **GDR6.3 Guidance on Sites with Cohesive Soils**; and **GDR14 Drainage Control**
Footing Preparation and Testing	GDR6.4	-	Footings at this site must be tested using a nuclear density gauge (Refer to **GDR7.3 Nuclear Density Gauge**)
Topsoil Strip	GDR6.2.1	Thickness = 50 mm	Expected thickness of topsoil strip (average).
Compaction Control	GDR7	-	The upper unit should be compacted in accordance with “clayey/silty gravel” as per GDR7. The deeper clay unit to be compacted in accordance with “fine grained soils” (if required). Compaction control at this site may be done using a nuclear density gauge (NDG). Refer to **GDR7.3 Nuclear Density Gauge**
Approved Fill	GDR8	-	Approved fill at this site is to comprise **Granular Fill** as per **GDR8 Approved Fill and Conformance Testing** The existing near-surface gravelly soils are suitable for re-use as fill (other than any topsoil). This fill may be considered as Granular Fill as per **GDR8 Approved Fill and Conformance Testing** We do not recommend re-use of the deeper clayey soils, where possible.
Shallow Footings	GDR9	q_{all} = 200 kPa	Refer to footing tables in Section 10.2.
Earth Pressure Coefficients	GDR11	Refer parameters in Section 9	-
Excavations, batters and slopes	GDR12	1V:2H (temporary) 1V:3H (permanent)	Excavations should be readily achievable to 2 m with a 20T excavator with a toothed bucket (or similar). The clayey soils are likely to become desiccated in dry periods and become more difficult to excavate. The batter angles given are for slopes up to 2 m high and above groundwater. Refer to **GDR12 Excavations, Batters and Slopes** for more information.
Pavement Subgrades	GDR16	CBR = 12%	This CBR value applies to the gravelly near-surface material present at the site. A geotechnical engineer should inspect the car park and access areas during earthworks to confirm that the pavement will have a consistent subgrade.

NOTES: ***1.*** *q_{all} – allowable bearing pressure (maximum for all footings, refer to footing tables for further details)*

10.2. Shallow Footings

Table 9: Isolated Pad Footing Allowable Bearing Pressures and Estimated Settlements

d_e (m)	b (m)	q_{all} (kPa)	s (mm)
0.5	0.5	200	<5
0.5	1.0	200	5 – 10
0.5	1.5	200	5 – 10
0.5	2.0	200	10 – 15
1.0	1.0	200	5 – 10
1.0	2.0	200	10 – 15
1.0	3.0	200	10 – 15

NOTES:
1. *d_e – minimum embedment depth (below finished ground level or floor slab)*
2. *b – Footing width (footings assumed approximately square)*
3. *q_{all} – allowable bearing pressure (peak). Limited to keep estimated settlements less than 25 mm.*
4. *s – estimated settlement (excludes shrink/swell from site class)*
5. *Refer to GDR9*

Table 10: Isolated Strip Footing Allowable Bearing Pressures and Estimated Settlements

d_e (m)	b (m)	q_{all} (kPa)	s (mm)
0.5	0.5	150	5 – 10
0.5	1.0	200	10 – 15
0.5	1.5	200	10 – 15
0.5	2.0	200	15 – 20
1.0	1.0	200	10 – 15
1.0	2.0	200	15 – 20
1.0	3.0	200	20 – 25

NOTES:
1. *d_e – minimum embedment depth (below finished ground level or floor slab)*
2. *b – Footing width (footings assumed long relative to breadth)*
3. *q_{all} – allowable bearing pressure (peak). Limited to keep estimated settlements less than 25 mm.*
4. *s – estimated settlement (excludes shrink/swell from site class)*
5. *Refer to GDR9*

11. ENVIRONMENTAL ASSESSMENT

11.1. Assessment Criteria

Environmental laboratory results were compared against the following guidelines:

- Health screening levels for residential sites (HSLs D) and;
- Health investigation levels for residential sites (HILs D).

The laboratory certificates of analysis along with the chain of custody documentation are presented in Appendix E. Laboratory analytical results compared against the relevant assessment criteria is shown in Appendix F.

11.2. Laboratory Results

Laboratory results indicate that the concentrations of all contaminants of potential concern (COPC) were either below the laboratory limit of reporting (LOR) and/or conformed to the adopted assessment criteria.

11.3. Summary

Based the results of the environmental assessment, we consider it unlikely that soil at the site is impacted by contaminants at concentrations that would pose a risk to human health or the environment. Furthermore, we consider that the site is suitable for use as a childcare centre.

12. CLOSURE

GALT GEOTECHNICS

Sean Coffey CPEng

Geotechnical Engineer

Brad Palmer

Environmental Scientist

https://galtgeo.sharepoint.com/sites/wae250028/shared documents/01 westpg si/03 correspondence/wae250028-01 001 r rev0.docx

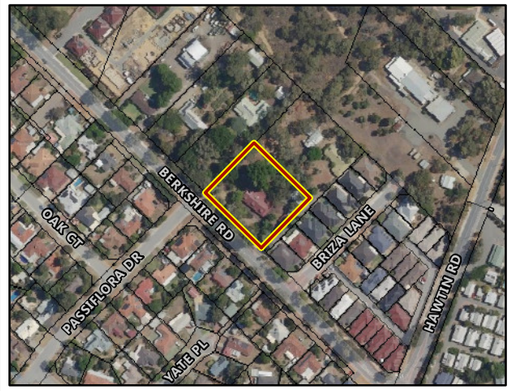
Attached Table 1: Summary of Geotechnical Index Test Results

Test Name	Sample Depth (m)	Soil Class (AS1726 2017)	Gravel (%)	Sand (%)	Fines (%)	LL (%)	PI (%)	LS (%)	MMDD (t/m^3)	OMC (%)	CBR (%)	CBR Swell (%)
BH01	0.2 – 0.4	GM	54	34	12	NO	NP	1.5	2.04	10.0	50	0.0
BH04	1.2 – 1.5	CI	17	45	38	36	18	8.5	-	-	-	-

Notes

1. *Particle size distribution (by mass)*
   - *Gravel: 2.36 mm – 63 mm*
   - *Sand: 0.075 mm – 2.36 mm*
   - *Fines: <0.075 mm*
2. *FMC: Field moisture content*
3. *Atterberg Limits*
   - *LL: Liquid limit*
   - *PI: Plasticity index*
   - *LS: Linear shrinkage*
   - *NO: Not obtainable*
   - *NP: Non-plastic*
4. *Org: Organic content (by mass)*
5. *Modified compaction*
   - *MMDD: Modified maximum dry density*
   - *OMC: Optimum moisture content*
6. *CBR: California bearing ratio*
   - *Remoulding dry density ratio: 95% MMDD*
   - *Surcharge: 4.5 kg*
   - *Soaking: 4-day soaked*

Figures



Legend

- Site Boundary
- Borehole / Dynamic Cone Penetration Test
- Grab Sample

N

0 6.5 13 19.5 26 32.5
Meters

NOTES

Aerial Imagery and Cadastre sourced from Landgate/SLIP

SCALE	1:400	(A3)
DRAWN	CED	
DATE DRAWN	12/6/2025	
CHECKED	_	
DATE CHECKED	_	
PROJECTION	GDA 1994 MGA Zone 50	

Galt Environmental Pty Ltd
ACN : 161 708 998
Tel : +61 (0)8 6272-0200
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Osborne Park WA 6017

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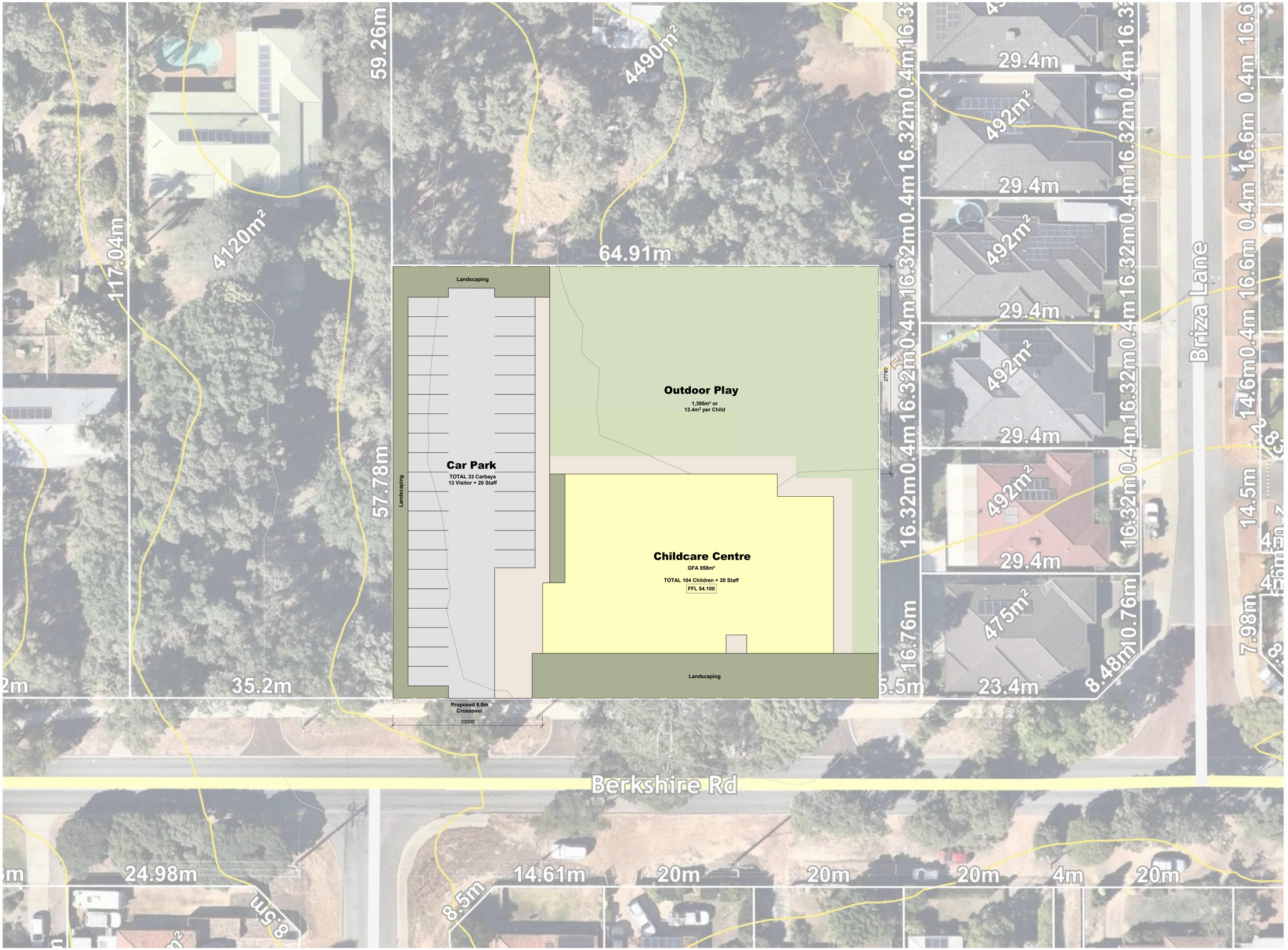
CLIENT	**WEST PROPERTY GROUP**
PROJECT	PROPOSED CHILDCARE CENTRE
LOCATION	21 BERKSHIRE ROAD FORRESTFIELD
TITLE	SITE & LOCATION PLAN

Job No	Fig No	Rev
WAE250028-01	FIGURE 1	**A**

Appendices

Appendix A: Supplied Information



SITE PLAN
SCALE: 1 : 200

SITE CRITERIA

1. Site Area
a. Site Area — **3,750m²**

2. Landscaping
a. Required 10% of Site Area — **375m²**
b. Provided
Soft — 1,732m² (46.2%)
Hard — 340m²
Total — 2,072m²

3. Floor Area (GFA)
a. Childcare Centre — 858m²
b. Bin Store — 18m²
Total — 876m²

4. Carparking
i. Cars Required
a. 1:1 Staff — 20 Staff Cars
b. 1:8 Parent — 13 Visitors Cars
Total Car required — **33 Cars**

ii. Cars Provided — **33 Cars**

CHILD CARE CRITERIA

1. Centre capacity — **104 Places**
a. Number of places

2. Landscaping
a. Required 7m² : 1 child — **728m²**
b. Provided — 1,395m²
Total m² provided per child — 13.4m²

Landscaping
A. Soft Landscaping
Defined as vegetative landscaping.

Gross Floor Area : GFA
A. All Floor Areas on this plan are shown as GROSS FLOOR AREA.
Unless otherwise noted as Nett Floor Area
B. Definition of Gross Floor Area is defined as:
i/ GROSS FLOOR AREA OF TENANCY:
Gross Floor Area of an individual Tenancy is defined as the area contained between the centre line of common tenancy walls and the outside edge of external walls.
ii/ GROSS FLOOR AREA OF A BUILDING:
Gross Floor Area of a Building is defined as the total area contained between the outside edge of external walls

Nett Floor Area : NFA
A. Nett Floor Area of a Tenancy on this plan is defined as the area between external or tenancy dividing walls.
B. This area is inclusive of toilets if the toilets are exclusive to the Tenancy.

SITE DESIGN CHECKLIST

- ☐ 1. SEWER MAINS LOCATION TO BE DETERMINED
- ☐ 2. FIRE MAINS PRESSURE TEST REQUIRED
- ☐ 3. FIRE TANKS OR PUMPS TO BE DETERMINED
- ☐ 4. WESTERN POWER TRANSFORMER LOCATION TO BE DETERMINED
- ☐ 5. CROSSOVER & ACCESS TO STREET TO BE DETERMINED BY LOCAL AUTHORITY
- ☐ 6. FULL FEATURE SITE SURVEY REQUIRED
- ☐ 7. DIAL BEFORE YOU DIG REQUIRED
- ☐ 8. BUSHFIRE ATTACK LEVEL (BAL) TO BE DETERMINED
- ☐ 9. STREET POWER POLES TO BE DETERMINED
- ☐ 10. SITE ZONING & USE TO BE DETERMINED

NOTE: Any of the following items that do not have an 'X' in the provided square require determination.

LEGEND

- BUILDING FOOTPRINT - CHILDCARE FACILITY
- OUTDOOR PLAY AREA
- EXTENT OF PAVING
- EXTENT OF LANDSCAPING
- EXTENT OF BITUMEN PAVING

PRELIMINARY

meyer shircore architects

PROPOSED CHILDCARE CENTRE
LOCATION : LOT 500 (HN 21) BERKSHIRE ROAD, FORRESTFIELD
FOR : BLOKK PROPERTY AUSTRALIA

Member Australian Institute of Architects

0 2 4 6 8 10 20

DATE: APRIL 2024
REVISION: SK002
SHEET: A - 1001
SCALE: As indicated @B1

PROJECT NUMBER **25-9572**

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PO Box 1294 Subiaco WA 6904
t: 08 9381 8511 e: msa@meyershircore.com.au

Appendix B: Site Photographs

Photograph 1: Looking at mature trees near Berkshire Road

Photograph 2: Borehole drilling underway

Photograph 3: Looking at existing building at the site.

Photograph 4: Looking at existing asphalt pavement and outbuildings.

Photograph 5: Looking at existing trees and damaged concrete pavement.

Photograph 6: Looking towards Berkshire Road – Large tree at property boundary

Appendix C: Borehole Reports

BOREHOLE: BH01

Project Name: WAE250028
Client: West Property Group
Project: Proposed Childcare Facility
Location: 21 Berkshire Rd Forrestfield

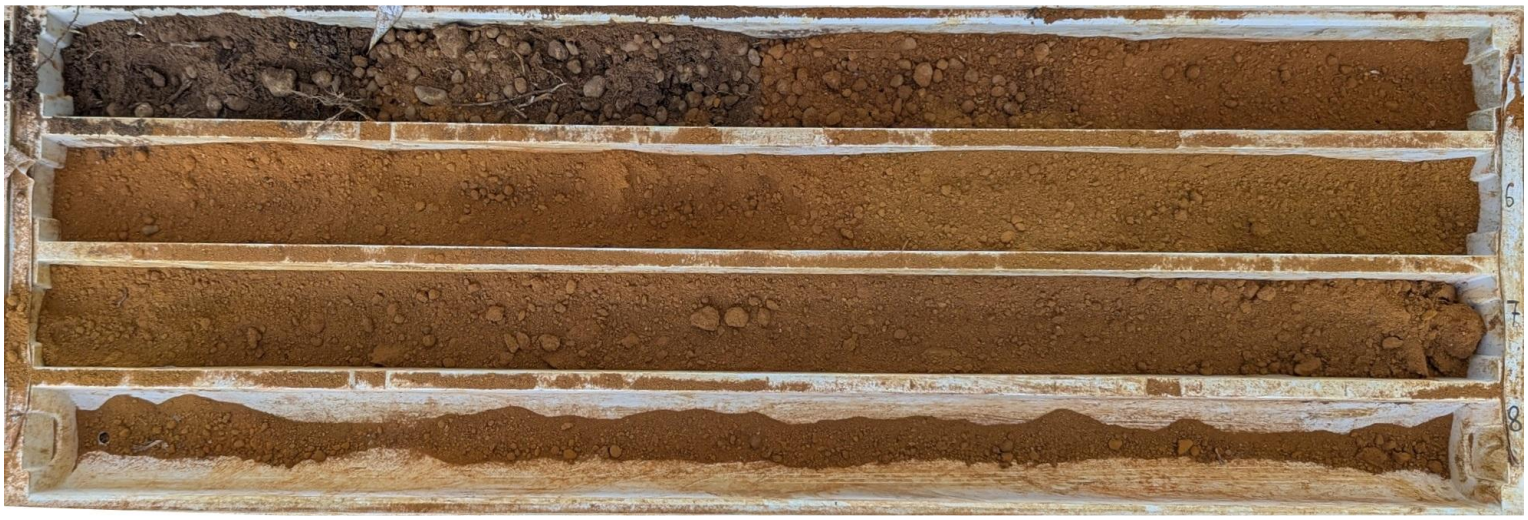
Contractor: GBI
Drill Rig: EVH Scout 1750
Inclination: -90

Date: 06/06/2025
Logged By: SD
Date Checked: 20/06/2025
Checked By: SC

Drill Method	Penetration Resistance	Water Level	Depth (m)	Sample Information: Sample Number	Sample Information: Sample Type	Graphic Log	Soil Class	Soil/Rock Material Description	Moisture Condition	Consistency Density	DCP	Additional Remarks
ADV			0				SM/GM	TOPSOIL: Gravelly SAND/Sandy GRAVEL: fine grained, brown, fine to medium grained, rounded to sub-rounded gravel, trace to with fines	D	D	3 9 8 9	Grass and rootlets at surface pisolitic gravel
			0.5				CI	CLAY: medium plasticity, orange/brown, with fine to medium grained, sub-angular to angular gravel, gravel content decreasing with depth.	D	VSt	15+	
			1									
			1.5									
			2									
			2.5									
			3					3.0				

Borehole terminated at 3.0 m, target depth
Groundwater not encountered

Notes:



Depth Range: 0.0 - 3.0 m

PROJECT	WAE250028	**PROJECT NO.**	Proposed Childcare Facility
CLIENT	West Property Group	**LOG:**	BH01
LOCATION	Forrestfield, WA	**FIGURE NO.**	Appendix

BOREHOLE: BH02

Project Name: WAE250028
Client: West Property Group
Project: Proposed Childcare Facility
Location: 21 Berkshire Rd Forrestfield

Contractor: GBI
Drill Rig: EVH Scout 1750
Inclination: -90

Date: 06/06/2025
Logged By: SD
Date Checked: 20/06/2025
Checked By: SC

Drill Method	Penetration Resistance	Water Level	Depth (m)	Sample Information: Sample Number	Sample Information: Sample Type	Graphic Log	Soil Class	Soil/Rock Material Description	Moisture Condition	Consistency Density	DCP	Additional Remarks
ADV			0				SM/GM	TOPSOIL: Gravelly SAND/Sandy GRAVEL: fine grained, brown, fine to medium grained, rounded to sub-rounded gravel, trace to with fines	M	MD	6	pisolitic gravel
								0.3			6	
								CLAY: medium plasticity, orange/brown, with fine to medium grained, sub-angular to angular gravel, gravel content decreasing with depth.			7	
			0.5								10	
											13	
							CI		M	VSt	10	
											7	
			1								6	
											4	
								1.2				
			1.5									
			2						D			
			2.5									
			3					3.0				

Borehole terminated at 3.0 m, target depth
Groundwater not encountered

Notes:

Depth Range: 0.0 - 3.0 m

Galt GEOTECHNICS

PROJECT	WAE250028	**PROJECT NO.**	Proposed Childcare Facility
CLIENT	West Property Group	**LOG:**	BH02
LOCATION	Forrestfield, WA	**FIGURE NO.**	Appendix

BOREHOLE: BH03

Project Name: WAE250028
Client: West Property Group
Project: Proposed Childcare Facility
Location: 21 Berkshire Rd Forrestfield

Contractor: GBI
Drill Rig: EVH Scout 1750
Inclination: -90

Date: 06/06/2025
Logged By: SD
Date Checked: 20/06/2025
Checked By: SC

Drill Method	Penetration Resistance	Water Level	Depth (m)	Sample Information: Sample Number	Sample Information: Sample Type	Graphic Log	Soil Class	Soil/Rock Material Description	Moisture Condition	Consistency Density	DCP	Additional Remarks
ADV			0				SM/GM	TOPSOIL: Gravelly SAND/Sandy GRAVEL: fine grained, dark brown, fine to medium grained, rounded to sub-rounded gravel, trace to with fines	M	MD D	4	
								0.3			6	
								CLAY: medium plasticity, orange/brown, with fine to medium grained, sub-angular to angular gravel, gravel content decreasing with depth.			4	
			0.5								5	
											9	
											8	
			1								9	
											9	
											8	
			1.5				CI		M	VSt		
			2									
			2.5									
			3					3.0				

Borehole terminated at 3.0 m, target depth
Groundwater not encountered

Notes:

Depth Range: 0.0 - 3.0 m

PROJECT	WAE250028	**PROJECT NO.**	Proposed Childcare Facility
CLIENT	West Property Group	**LOG:**	BH03
LOCATION	Forrestfield, WA	**FIGURE NO.**	Appendix

BOREHOLE: BH04

Project Name: WAE250028
Client: West Property Group
Project: Proposed Childcare Facility
Location: 21 Berkshire Rd Forrestfield

Contractor: GBI
Drill Rig: EVH Scout 1750
Inclination: -90

Date: 06/06/2025
Logged By: SD
Date Checked: 20/06/2025
Checked By: SC

Drill Method	Penetration Resistance	Water Level	Depth (m)	Sample Information: Sample Number	Sample Information: Sample Type	Graphic Log	Soil Class	Soil/Rock Material Description	Moisture Condition	Consistency Density	DCP	Additional Remarks
ADV			0					FILL: Gravelly SAND 0.1	D	MD		Basecourse/Roadbase
							SP	Gravelly SAND: fine grained, orange/brown, fine to medium grained, sub-angular to rounded gravel, with low plasticity fines	D	MD	16 14 8 7 8 9 15+	
			0.5					0.8				
			1				CI-CH	CLAY: medium to high plasticity, orange/brown, with fine to medium grained, sub-angular to angular gravel, gravel content decreasing with depth.	D	VSt H		
			1.5									
			2									
			2.5									
			3					3.0				

Borehole terminated at 3.0 m, target depth
Groundwater not encountered

Notes:

Depth Range: 0.0 - 3.0 m

Galt GEOTECHNICS

PROJECT	WAE250028	**PROJECT NO.**	Proposed Childcare Facility
CLIENT	West Property Group	**LOG:**	BH04
LOCATION	Forrestfield, WA	**FIGURE NO.**	Appendix

Appendix D: Geotechnical Laboratory Test Results

WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

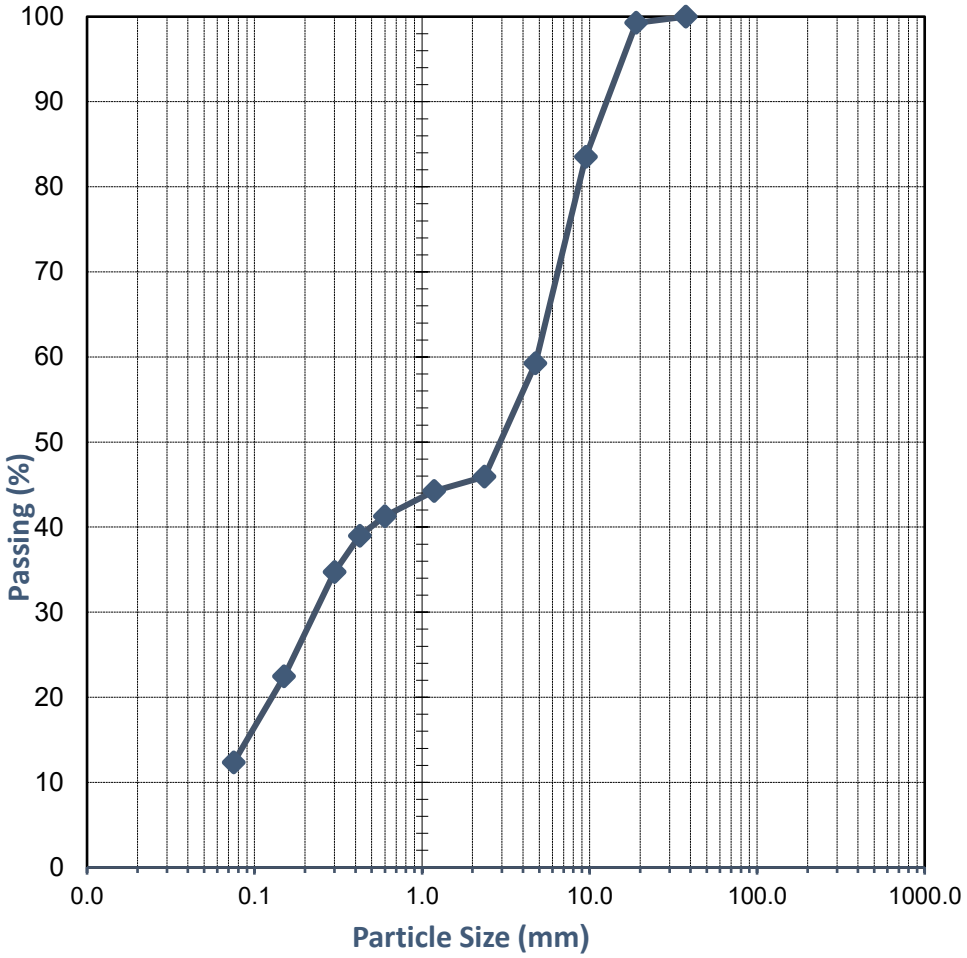
TEST REPORT - AS 1289.3.6.1

Client:	West Property Group	*Ticket No.*	S17703
Client Address:	-	*Report No.*	WG25.10449_1_PSD
Project:	Proposed Childcare Centre	*Sample No.*	WG25.10449
Location:	21 Berkshire Road, Forrestfield	*Date Sampled:*	Not Specified
Sample Identification:	BH01 (0.2-0.4m)	*Date Tested:*	11/06 - 12/06/2025

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	100
19.0	99
9.5	84
4.75	59
2.36	46
1.18	44
0.600	41
0.425	39
0.300	35
0.150	22
0.075	12



Comments:

Approved Signatory: Cody O'Neill

Name: Cody O'Neill

Date: 12/June/2025

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.1.1, 3.2.1, 3.3.1 & 3.4.1

Client:	West Property Group	*Ticket No.*	S17703
Client Address:	-	*Report No.*	WG25.10449_1_PI
Project:	Proposed Childcare Centre	*Sample No.*	WG25.10449
Location:	21 Berkshire Road, Forrestfield	*Date Sampled:*	Not Specified
Sample Identification:	BH01 (0.2-0.4m)	*Date Tested:*	12/06/2025

TEST RESULTS - Consistency Limits (Casagrande)

Sampling Method:	**Sampled by Client, Tested as Received**
History of Sample:	**Oven Dried <50°C**
Method of Preparation:	**Dry Sieved**

AS 1289.3.1.1	**Liquid Limit (%)**	**Not Obtainable**
AS 1289.3.2.1	**Plastic Limit (%)**	**Non-Plastic**
AS 1289.3.3.1	**Plasticity Index (%)**	**Non-Plastic**
AS 1289.3.4.1	**Linear Shrinkage (%)**	**1.5**
AS 1289.3.4.1	**Length of Mould (mm)**	**250**
AS 1289.3.4.1	**Condition of Dry Specimen:**	**-**

Comments:

Approved Signatory:

Name: Cody O'Neill

Date: 13/June/2025

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.5.2.1

Client:	West Property Group	*Ticket No.*	S17703
Client Address:	-	*Report No.*	WG25.10449_1_MMDD
Project:	Proposed Childcare Centre	*Sample No.*	WG25.10449
Location:	21 Berkshire Road, Forrestfield	*Date Sampled:*	Not Specified
Sample Identification:	BH01 (0.2-0.4m)	*Date Tested:*	11/06/2025

TEST RESULTS - Modified Maximum Dry Density

Sampling Method: Sampled by Client, Tested as Received

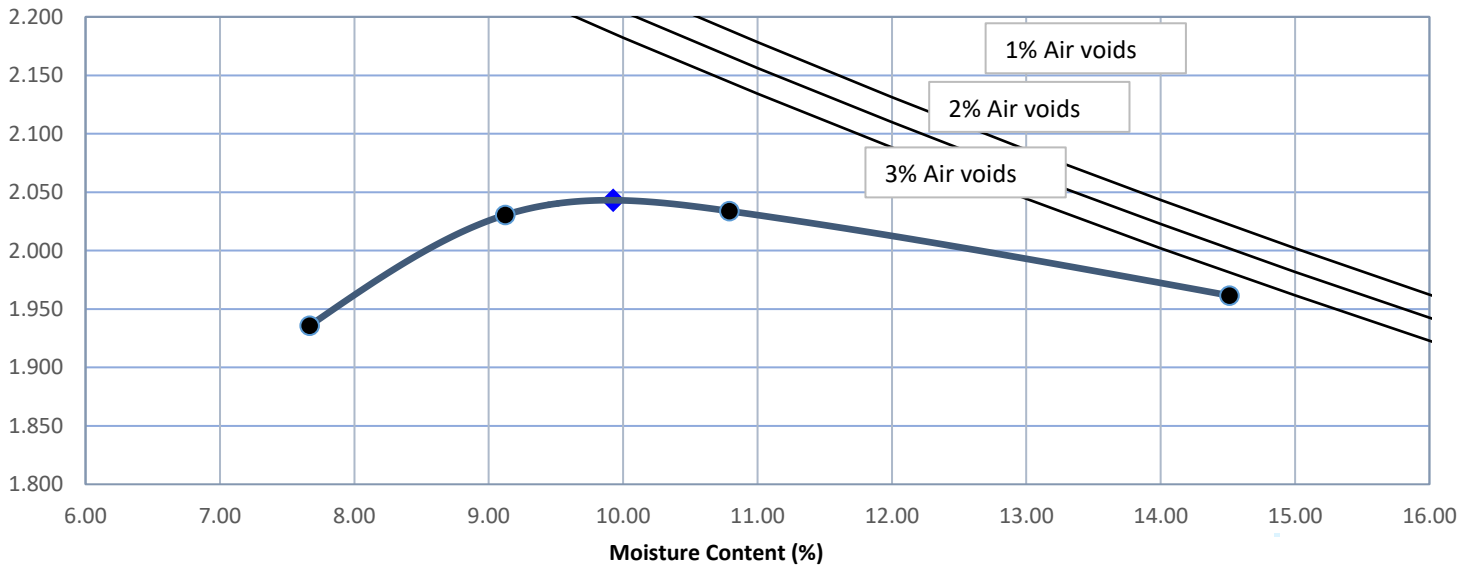
Sample Curing Time (Hours): >2

Method used to Determine Liquid Limit: Visual / Tactile Assessment by Competent Technician

Material + 19.0mm (%): 0 **Material + 37.5mm (%)** -

Moisture Content (%)	**7.7**	**9.1**	**10.8**	**14.5**	
Dry Density (t/m³)	**1.936**	**2.031**	**2.034**	**1.962**	

Dry Density (t/m³)



Modified Maximum Dry Density (t/m³) **2.04**

Optimum Moisture Content (%) **10.0**

Comments: *The above air void lines are derived from a calculated apparent particle density of 2.903 t/m³*

Approved Signatory:

Name: Connor Budimir

Date: 13/June/2025

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.6.1.1

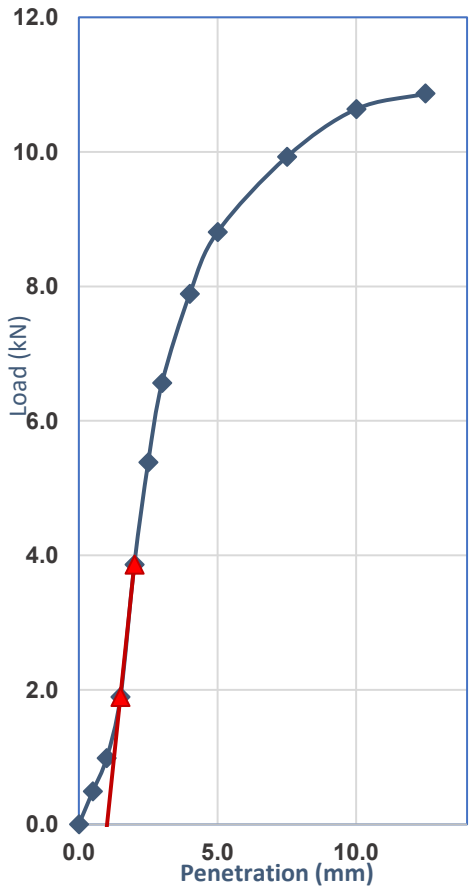
Client:	West Property Group	*Ticket No.*	S17703
Client Address:	-	*Report No.*	WG25.10449_1_SCBR
Project:	Proposed Childcare Centre	*Sample No.*	WG25.10449
Location:	21 Berkshire Road, Forrestfield	*Date Sampled:*	Not Specified
Sample Identification:	BH01 (0.2-0.4m)	*Date Tested:*	11/06 - 17/06/2025

TEST RESULTS - CALIFORNIA BEARING RATIO

Sample Description: Sandy Gravel

Sampling Method: Sampled by Client, Tested as Received

Load Penetration Curve



Compaction Details			
Compaction Method	AS 1289.5.2.1	Hammer Type	Modified
Plasticity Determined by	Estimated	Curing Time (Hours)	>2
% Retained 19.0mm	0	Excluded/Replaced	Excluded
Maximum Dry Density (t/m^3)	2.04	Optimum Moisture (%)	10.0
Target Dry Density Ratio (%)	95	Target Moisture Ratio (%)	100

Specimen Conditions At Compaction			
Dry Density (t/m3)	1.94	Moisture Content (%)	10.0
Density Ratio (%)	95.0	Moisture Ratio (%)	101.0

Specimen Conditions After Soak			
Soaked or Unsoaked	Soaked	Soaking Period (days)	4
Surcharges Applied (kg)	4.50	Measured Swell (%)	0.0
Dry Density (t/m³)	1.94	Dry Density Ratio (%)	95.0
Moisture Content (%)	13.8	Moisture Ratio (%)	139.5

Specimen Conditions After Test			
Top 30mm Moisture (%)	12.7	Remaining Depth (%)	13.6

Correction applied to Penetration: 1mm

Determined at a Penetration of: 2.5mm

California Bearing Ratio (CBR): 50%

Comments:

Approved Signatory:

Name: Madhav Basnet

Date: 18/June/2025

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

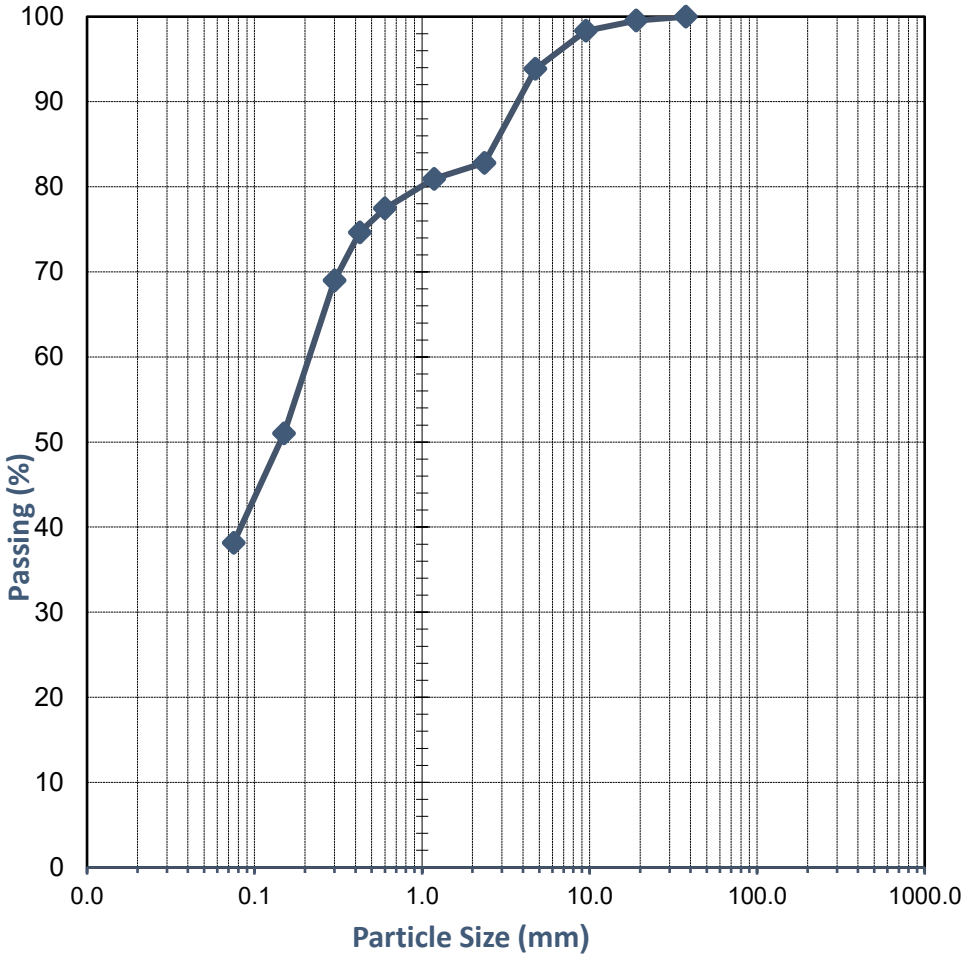
TEST REPORT - AS 1289.3.6.1

Client:	West Property Group	*Ticket No.*	S17703
Client Address:	-	*Report No.*	WG25.10450_1_PSD
Project:	Proposed Childcare Centre	*Sample No.*	WG25.10450
Location:	21 Berkshire Road, Forrestfield	*Date Sampled:*	Not Specified
Sample Identification:	BH04 (1.2-1.5m)	*Date Tested:*	11/06 - 12/06/2025

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	100
19.0	100
9.5	98
4.75	94
2.36	83
1.18	81
0.600	77
0.425	75
0.300	69
0.150	51
0.075	38



Comments:

Approved Signatory: Cody O'Neill

Name: Cody O'Neill

Date: 12/June/2025

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.1.1, 3.2.1, 3.3.1 & 3.4.1

Client:	West Property Group	*Ticket No.*	S17703
Client Address:	-	*Report No.*	WG25.10450_1_PI
Project:	Proposed Childcare Centre	*Sample No.*	WG25.10450
Location:	21 Berkshire Road, Forrestfield	*Date Sampled:*	Not Specified
Sample Identification:	BH04 (1.2-1.5m)	*Date Tested:*	12/06/2025

TEST RESULTS - Consistency Limits (Casagrande)

Sampling Method:	**Sampled by Client, Tested as Received**
History of Sample:	**Oven Dried <50°C**
Method of Preparation:	**Dry Sieved**

AS 1289.3.1.1	**Liquid Limit (%)**	**36**
AS 1289.3.2.1	**Plastic Limit (%)**	**18**
AS 1289.3.3.1	**Plasticity Index (%)**	**18**
AS 1289.3.4.1	**Linear Shrinkage (%)**	**8.5**
AS 1289.3.4.1	**Length of Mould (mm)**	**250**
AS 1289.3.4.1	**Condition of Dry Specimen:**	**-**

Comments:

Approved Signatory:

Name: Cody O'Neill

Date: 13/June/2025

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Appendix E: Environmental Laboratory Certificates of Analysis

Galt Environment P/L
50 Edward Street
Osborne Park
WA 6017

NATA Accredited
Accreditation Number 2377
Site Number 2370 & 2554

Accredited for compliance with ISO/IEC 17025 – Testing
NATA is a signatory to the ILAC Mutual Recognition Arrangement for the mutual recognition of the equivalence of testing, medical testing, calibration, inspection, proficiency testing scheme providers and reference materials producers reports and certificates.

Attention: **- ALL SRA/Results**

Report **1229833-S**
Project name BERKSHIRE RD FORESTFIELD
Project ID WAE250028
Received Date Jun 06, 2025

Client Sample ID			**BH01/0.0**	**BH02/0.0**	**BH03/0.0**	**BH04/0.0**
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins Sample No.			**L25-Jn0020556**	**L25-Jn0020557**	**L25-Jn0020558**	**L25-Jn0020559**
Date Sampled			**Jun 06, 2025**	**Jun 06, 2025**	**Jun 06, 2025**	**Jun 06, 2025**
Test/Reference	LOR	Unit				
OCOP in Soil						
Aldrin	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
alpha-BHC (HCH)	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
beta-BHC (HCH)	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
delta-BHC (HCH)	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Bifenthrin	0.2	mg/kg	< 0.2	< 0.2	< 0.2	< 0.2
Bromophos Ethyl	0.05	mg/kg	< 0.05	< 0.05	< 0.05	< 0.05
Chlordane	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Chlorpyrifos	0.02	mg/kg	< 0.02	< 0.02	< 0.02	< 0.02
Dieldrin	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
p.p-DDD	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
p.p-DDE	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
p.p-DDT	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
o.p-DDT	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Endosulfan I	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Endosulfan II	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Endosulfan Sulfate	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Endrin	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Heptachlor	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Heptachlor Epoxide	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Hexachlorobenzene (HCB)	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Lindane	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Methoxychlor	0.2	mg/kg	< 0.2	< 0.2	< 0.2	< 0.2
Oxychlordane	0.01	mg/kg	< 0.01	< 0.01	< 0.01	< 0.01
Diazinon	0.2	mg/kg	< 0.2	< 0.2	< 0.2	< 0.2
Ethion	0.05	mg/kg	< 0.05	< 0.05	< 0.05	< 0.05
Fenitrothion	0.1	mg/kg	< 0.1	< 0.1	< 0.1	< 0.1
Malathion	0.1	mg/kg	< 0.1	< 0.1	< 0.1	< 0.1
Trifluralin	0.2	mg/kg	< 0.2	< 0.2	< 0.2	< 0.2
Metals M8						
Arsenic	2	mg/kg	3.3	2.9	< 2	< 2
Cadmium	0.1	mg/kg	< 0.1	< 0.1	0.1	0.1
Chromium	1	mg/kg	20	51	12	17
Copper	1	mg/kg	2.9	3.0	10	50
Lead	1	mg/kg	8.4	21	25	24
Mercury	0.02	mg/kg	0.03	0.02	0.06	0.03

Client Sample ID			BH01/0.0	BH02/0.0	BH03/0.0	BH04/0.0
Sample Matrix			Soil	Soil	Soil	Soil
Eurofins Sample No.			L25-Jn0020556	L25-Jn0020557	L25-Jn0020558	L25-Jn0020559
Date Sampled			Jun 06, 2025	Jun 06, 2025	Jun 06, 2025	Jun 06, 2025
Test/Reference	LOR	Unit				
Metals M8						
Nickel	1	mg/kg	2.0	3.6	2.5	15
Zinc	5	mg/kg	12	12	93	40
% Moisture	1	%	9.3	14	35	3.9

Client Sample ID			GS01	GS02	QC101
Sample Matrix			Soil	Soil	Soil
Eurofins Sample No.			L25-Jn0020560	L25-Jn0020561	L25-Jn0020563
Date Sampled			Jun 06, 2025	Jun 06, 2025	Jun 06, 2025
Test/Reference	LOR	Unit			
OCOP in Soil					
Aldrin	0.01	mg/kg	< 0.01	< 0.01	< 0.01
alpha-BHC (HCH)	0.01	mg/kg	< 0.01	< 0.01	< 0.01
beta-BHC (HCH)	0.01	mg/kg	< 0.01	< 0.01	< 0.01
delta-BHC (HCH)	0.01	mg/kg	< 0.01	< 0.01	< 0.01
Bifenthrin	0.2	mg/kg	< 0.2	< 0.2	< 0.2
Bromophos Ethyl	0.05	mg/kg	< 0.05	< 0.05	< 0.05
Chlordane	0.01	mg/kg	< 0.01	< 0.01	< 0.01
Chlorpyrifos	0.02	mg/kg	< 0.02	< 0.02	< 0.02
Dieldrin	0.01	mg/kg	< 0.01	< 0.01	< 0.01
p.p-DDD	0.01	mg/kg	< 0.01	< 0.01	< 0.01
p.p-DDE	0.01	mg/kg	< 0.01	< 0.01	< 0.01
p.p-DDT	0.01	mg/kg	< 0.01	< 0.01	< 0.01
o.p-DDT	0.01	mg/kg	< 0.01	< 0.01	< 0.01
Endosulfan I	0.01	mg/kg	< 0.01	< 0.01	< 0.01
Endosulfan II	0.01	mg/kg	< 0.01	< 0.01	< 0.01
Endosulfan Sulfate	0.01	mg/kg	< 0.01	< 0.01	< 0.01
Endrin	0.01	mg/kg	< 0.01	< 0.01	< 0.01
Heptachlor	0.01	mg/kg	< 0.01	< 0.01	< 0.01
Heptachlor Epoxide	0.01	mg/kg	< 0.01	< 0.01	< 0.01
Hexachlorobenzene (HCB)	0.01	mg/kg	< 0.01	< 0.01	< 0.01
Lindane	0.01	mg/kg	< 0.01	< 0.01	< 0.01
Methoxychlor	0.2	mg/kg	< 0.2	< 0.2	< 0.2
Oxychlordane	0.01	mg/kg	< 0.01	< 0.01	< 0.01
Diazinon	0.2	mg/kg	< 0.2	< 0.2	< 0.2
Ethion	0.05	mg/kg	< 0.05	< 0.05	< 0.05
Fenitrothion	0.1	mg/kg	< 0.1	< 0.1	< 0.1
Malathion	0.1	mg/kg	< 0.1	< 0.1	< 0.1
Trifluralin	0.2	mg/kg	< 0.2	< 0.2	< 0.2
Metals M8					
Arsenic	2	mg/kg	< 2	< 2	3.7
Cadmium	0.1	mg/kg	< 0.1	< 0.1	< 0.1
Chromium	1	mg/kg	3.3	15	40
Copper	1	mg/kg	2.6	5.5	2.7
Lead	1	mg/kg	2.5	17	16
Mercury	0.02	mg/kg	< 0.02	< 0.02	< 0.02
Nickel	1	mg/kg	< 1	1.4	2.9
Zinc	5	mg/kg	23	31	11

Client Sample ID			GS01	GS02	QC101
Sample Matrix			Soil	Soil	Soil
Eurofins Sample No.			L25-Jn0020560	L25-Jn0020561	L25-Jn0020563
Date Sampled			Jun 06, 2025	Jun 06, 2025	Jun 06, 2025
Test/Reference	LOR	Unit			
% Moisture	1	%	5.1	15	14

Sample History

Where samples are submitted/analysed over several days, the last date of extraction is reported.

If the date and time of sampling are not provided, the Laboratory will not be responsible for compromised results should testing be performed outside the recommended holding time.

Description	Testing Site	Extracted	Holding Time
OCOP in Soil	Welshpool	Jun 09, 2025	14 Days
- Method: ARL003 - OCOP and PCB in Soil			
Metals M8	Welshpool	Jun 09, 2025	28 Days
- Method: LTM-MET-3040 Metals in Waters, Soils & Sediments by ICP-MS			
% Moisture	Welshpool	Jun 09, 2025	14 Days
- Method: ARL135 Moisture in Solids			

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Tauranga 3112
+64 9 525 0568
IANZ# 1402

Company Name: Galt Environment P/L
Address: 50 Edward Street
Osborne Park
WA 6017

Project Name: BERKSHIRE RD FORESTFIELD
Project ID: WAE250028

Order No.: WAE250028
Report #: 1229833
Phone: 08 6272 0200
Fax: 08 9285 8444

Received: Jun 6, 2025 4:00 PM
Due: Jun 13, 2025
Priority: 5 Day
Contact Name: - ALL SRA/Results

Eurofins Analytical Services Manager : Natalie Hill

Sample Detail						Asbestos Absence /Presence	Metals M8	Moisture Set	Asbestos in Soils (ASC NEPM 2013)	OCOP in Soil	OCOP in Water
Perth Laboratory - NATA # 2377 Site # 2370 & 2554						X	X	X	X	X	X
External Laboratory											
No	**Sample ID**	**Sample Date**	**Sampling Time**	**Matrix**	**LAB ID**						
1	BH01/0.0	Jun 06, 2025		Soil	L25-Jn0020556		X	X	X	X	
2	BH02/0.0	Jun 06, 2025		Soil	L25-Jn0020557		X	X	X	X	
3	BH03/0.0	Jun 06, 2025		Soil	L25-Jn0020558		X	X	X	X	
4	BH04/0.0	Jun 06, 2025		Soil	L25-Jn0020559		X	X	X	X	
5	GS01	Jun 06, 2025		Soil	L25-Jn0020560		X	X	X	X	
6	GS02	Jun 06, 2025		Soil	L25-Jn0020561		X	X	X	X	
7	GS03	Jun 06, 2025		Building Materials	L25-Jn0020562	X					
8	QC101	Jun 06, 2025		Soil	L25-Jn0020563		X	X		X	
9	QC301	Jun 06, 2025		Water	L25-Jn0020564		X				X
Test Counts						1	8	7	6	7	1

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Internal Quality Control Review and Glossary

General

1. Laboratory QC results for Method Blanks, Duplicates, Matrix Spikes, and Laboratory Control Samples follow guidelines delineated in the National Environment Protection (Assessment of Site Contamination) Measure 1999, as amended May 2013. They are included in this QC report where applicable. Additional QC data may be available on request.
2. Unless otherwise stated, all soil/sediment/solid results are reported on a dry weight basis.
3. Unless otherwise stated, all biota/food results are reported on a wet weight basis on the edible portion.
4. For CEC results where the sample's origin is unknown or environmentally contaminated, the results should be used advisedly.
5. Actual LORs are matrix dependent. Quoted LORs may be raised where sample extracts are diluted due to interferences.
6. Results are uncorrected for matrix spikes or surrogate recoveries except for PFAS compounds where annotated.
7. SVOC analysis on waters is performed on homogenised, unfiltered samples unless noted otherwise.
8. Samples were analysed on an 'as received' basis.
9. Information identified in this report with **blue** colour indicates data provided by customers that may have an impact on the results.
10. This report replaces any interim results previously issued.

Holding Times

Please refer to the 'Sample Preservation and Container Guide' for holding times (QS3001).

For samples received on the last day of holding time, notification of testing requirements should have been received at least 6 hours before sample receipt deadlines as stated on the SRA.

If the Laboratory did not receive the information in the required timeframe, and despite any other integrity issues, suitably qualified results may still be reported.

Holding times apply from the sampling date; therefore, compliance with these may be outside the laboratory's control.

For VOCs containing vinyl chloride, styrene and 2-chloroethyl vinyl ether, the holding time is seven days; however, for all other VOCs, such as BTEX or C6-10 TRH, the holding time is 14 days.

Units

mg/kg: milligrams per kilogram	**mg/L:** milligrams per litre	**ppm:** parts per million
µg/L: micrograms per litre	**ppb:** parts per billion	**%:** Percentage
org/100 mL: Organisms per 100 millilitres	**NTU:** Nephelometric Turbidity Units	**MPN/100 mL:** Most Probable Number of organisms per 100 millilitres
CFU: Colony Forming Unit	**Colour:** Pt-Co Units (CU)	

Terms

APHA	American Public Health Association
CEC	Cation Exchange Capacity
COC	Chain of Custody
CP	Client Parent - QC was performed on samples pertaining to this report
CRM	Certified Reference Material (ISO17034) - reported as percent recovery.
Dry	Where moisture has been determined on a solid sample, the result is expressed on a dry weight basis.
Duplicate	A second piece of analysis from the same sample and reported in the same units as the result to show comparison.
LOR	Limit of Reporting.
LCS	Laboratory Control Sample - reported as percent recovery.
Method Blank	In the case of solid samples, these are performed on laboratory-certified clean sands and in the case of water samples, these are performed on de-ionised water.
NCP	Non-Client Parent - QC performed on samples not pertaining to this report, QC represents the sequence or batch that client samples were analysed within.
RPD	Relative Percent Difference between two Duplicate pieces of analysis.
SPIKE	Addition of the analyte to the sample and reported as percentage recovery.
SRA	Sample Receipt Advice
Surr - Surrogate	The addition of a similar compound to the analyte target is reported as percentage recovery. See below for acceptance criteria.
TBTO	Tributyltin oxide (*bis*-tributyltin oxide) - individual tributyltin compounds cannot be identified separately in the environment; however, free tributyltin was measured, and its values were converted stoichiometrically into tributyltin oxide for comparison with regulatory limits.
TCLP	Toxicity Characteristic Leaching Procedure
TEQ	Toxic Equivalency Quotient or Total Equivalence
QSM	US Department of Defense Quality Systems Manual Version 6.0
US EPA	United States Environmental Protection Agency
WA DWER	Sum of PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFBS, PFHxS, PFOS, 6:2 FTSA, 8:2 FTSA

QC - Acceptance Criteria

The acceptance criteria should only be used as a guide and may be different when site-specific Sampling Analysis and Quality Plan (SAQP) have been implemented.

RPD Duplicates: Global RPD Duplicates Acceptance Criteria is ≤30%; however, the following acceptance guidelines are equally applicable:

Results <10 times the LOR:	No Limit
Results between 10-20 times the LOR:	RPD must lie between 0-50%
Results >20 times the LOR:	RPD must lie between 0-30%

NOTE: pH duplicates are reported as a range, not as RPD

Surrogate Recoveries: Recoveries must lie between 20-130% for Speciated Phenols & 50-150% for PFAS. SVOCs recoveries 20 – 150%, VOC recoveries 50 – 150%

PFAS field samples containing surrogate recoveries above the QC limit designated in QSM 6.0, where no positive PFAS results have been reported or reviewed, and no data was affected.

QC Data General Comments

1. Where a result is reported as less than (<), higher than the nominated LOR, this is due to either matrix interference, extract dilution required due to interferences or contaminant levels within the sample, high moisture content or insufficient sample provided.
2. Duplicate data shown within this report that states the word "BATCH" is a Batch Duplicate from outside of your sample batch but within the laboratory sample batch at a 1:10 ratio. The Parent and Duplicate data shown are not data from your samples.
3. pH and Free Chlorine analysed in the laboratory - Analysis on this test must begin within 30 minutes of sampling. Therefore, laboratory analysis is unlikely to be completed within holding time.Analysis will begin as soon as possible after sample receipt.
4. Recovery Data (Spikes & Surrogates) - where chromatographic interference does not allow the determination of recovery, the term "INT" appears against that analyte.
5. For Matrix Spikes and LCS results, a dash "-" in the report means that the specific analyte was not added to the QC sample.
6. Duplicate RPDs are calculated from raw analytical data; thus, it is possible to have two sets of data.

Quality Control Results

Test	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Method Blank							
OCOP in Soil							
Aldrin	mg/kg	< 0.01			0.01	Pass	
alpha-BHC (HCH)	mg/kg	< 0.01			0.01	Pass	
beta-BHC (HCH)	mg/kg	< 0.01			0.01	Pass	
delta-BHC (HCH)	mg/kg	< 0.01			0.01	Pass	
Bifenthrin	mg/kg	< 0.2			0.2	Pass	
Bromophos Ethyl	mg/kg	< 0.05			0.05	Pass	
Chlordane	mg/kg	< 0.01			0.01	Pass	
Chlorpyrifos	mg/kg	< 0.02			0.02	Pass	
Dieldrin	mg/kg	< 0.01			0.01	Pass	
p.p-DDD	mg/kg	< 0.01			0.01	Pass	
p.p-DDE	mg/kg	< 0.01			0.01	Pass	
p.p-DDT	mg/kg	< 0.01			0.01	Pass	
o.p-DDT	mg/kg	< 0.01			0.01	Pass	
Endosulfan I	mg/kg	< 0.01			0.01	Pass	
Endosulfan II	mg/kg	< 0.01			0.01	Pass	
Endosulfan Sulfate	mg/kg	< 0.01			0.01	Pass	
Endrin	mg/kg	< 0.01			0.01	Pass	
Heptachlor	mg/kg	< 0.01			0.01	Pass	
Heptachlor Epoxide	mg/kg	< 0.01			0.01	Pass	
Hexachlorobenzene (HCB)	mg/kg	< 0.01			0.01	Pass	
Lindane	mg/kg	< 0.01			0.01	Pass	
Methoxychlor	mg/kg	< 0.2			0.2	Pass	
Oxychlordane	mg/kg	< 0.01			0.01	Pass	
Diazinon	mg/kg	< 0.2			0.2	Pass	
Ethion	mg/kg	< 0.05			0.05	Pass	
Fenitrothion	mg/kg	< 0.1			0.1	Pass	
Malathion	mg/kg	< 0.1			0.1	Pass	
Trifluralin	mg/kg	< 0.2			0.2	Pass	
Method Blank							
Metals M8							
Arsenic	mg/kg	< 2			2	Pass	
Cadmium	mg/kg	< 0.1			0.1	Pass	
Chromium	mg/kg	< 1			1	Pass	
Copper	mg/kg	< 1			1	Pass	
Lead	mg/kg	< 1			1	Pass	
Mercury	mg/kg	< 0.02			0.02	Pass	
Nickel	mg/kg	< 1			1	Pass	
Zinc	mg/kg	< 5			5	Pass	
LCS - % Recovery							
OCOP in Soil							
Aldrin	%	68			60-120	Pass	
alpha-BHC (HCH)	%	63			60-120	Pass	
beta-BHC (HCH)	%	68			60-120	Pass	
delta-BHC (HCH)	%	64			60-120	Pass	
Dieldrin	%	77			60-120	Pass	
p.p-DDD	%	65			60-120	Pass	
p.p-DDE	%	76			60-120	Pass	
p.p-DDT	%	79			60-120	Pass	
o.p-DDT	%	95			60-120	Pass	
Endosulfan II	%	76			60-120	Pass	

Test	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Endosulfan Sulfate	%	72			60-120	Pass	
Endrin	%	90			60-120	Pass	
Heptachlor	%	64			60-120	Pass	
Heptachlor Epoxide	%	71			60-120	Pass	
Lindane	%	64			60-120	Pass	
Methoxychlor	%	80			60-120	Pass	
Oxychlordane	%	73			60-120	Pass	
LCS - % Recovery							
Metals M8							
Arsenic	%	104			80-120	Pass	
Cadmium	%	103			80-120	Pass	
Chromium	%	98			80-120	Pass	
Copper	%	87			80-120	Pass	
Lead	%	97			80-120	Pass	
Mercury	%	101			80-120	Pass	
Nickel	%	95			80-120	Pass	
Zinc	%	97			80-120	Pass	

Test	Lab Sample ID	QA Source	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Spike - % Recovery									
OCOP in Soil				Result 1					
Aldrin	L25-Jn0020557	CP	%	68			60-120	Pass	
alpha-BHC (HCH)	L25-Jn0020557	CP	%	65			60-120	Pass	
beta-BHC (HCH)	L25-Jn0020557	CP	%	85			60-120	Pass	
delta-BHC (HCH)	L25-Jn0020557	CP	%	68			60-120	Pass	
Dieldrin	L25-Jn0020557	CP	%	72			60-120	Pass	
p.p-DDD	L25-Jn0020557	CP	%	66			60-120	Pass	
p.p-DDE	L25-Jn0020557	CP	%	100			60-120	Pass	
p.p-DDT	L25-Jn0020557	CP	%	74			60-120	Pass	
o.p-DDT	L25-Jn0020557	CP	%	86			60-120	Pass	
Endosulfan II	L25-Jn0020557	CP	%	72			60-120	Pass	
Endosulfan Sulfate	L25-Jn0020557	CP	%	66			60-120	Pass	
Endrin	L25-Jn0020557	CP	%	100			60-120	Pass	
Heptachlor	L25-Jn0020557	CP	%	67			60-120	Pass	
Heptachlor Epoxide	L25-Jn0020557	CP	%	67			60-120	Pass	
Lindane	L25-Jn0020557	CP	%	66			60-120	Pass	
Methoxychlor	L25-Jn0020557	CP	%	68			60-120	Pass	
Oxychlordane	L25-Jn0020557	CP	%	72			60-120	Pass	
Spike - % Recovery									
Metals M8				Result 1					
Arsenic	L25-Jn0020557	CP	%	105			75-125	Pass	
Chromium	L25-Jn0020557	CP	%	90			75-125	Pass	
Copper	L25-Jn0020557	CP	%	110			75-125	Pass	
Lead	L25-Jn0020557	CP	%	117			75-125	Pass	
Nickel	L25-Jn0020557	CP	%	116			75-125	Pass	
Zinc	L25-Jn0020557	CP	%	114			75-125	Pass	

Test	Lab Sample ID	QA Source	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Duplicate									
OCOP in Soil				Result 1	Result 2	RPD			
Aldrin	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
alpha-BHC (HCH)	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
beta-BHC (HCH)	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
delta-BHC (HCH)	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Bifenthrin	L25-Jn0020556	CP	mg/kg	< 0.2	< 0.2	<1	30%	Pass	

Test	Lab Sample ID	QA Source	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Duplicate									
OCOP in Soil				Result 1	Result 2	RPD			
Bromophos Ethyl	L25-Jn0020556	CP	mg/kg	< 0.05	< 0.05	<1	30%	Pass	
Chlordane	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Chlorpyrifos	L25-Jn0020556	CP	mg/kg	< 0.02	< 0.02	<1	30%	Pass	
Dieldrin	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
p.p-DDD	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
p.p-DDE	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
p.p-DDT	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
o.p-DDT	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Endosulfan I	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Endosulfan II	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Endosulfan Sulfate	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Endrin	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Heptachlor	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Heptachlor Epoxide	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Hexachlorobenzene (HCB)	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Lindane	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Methoxychlor	L25-Jn0020556	CP	mg/kg	< 0.2	< 0.2	<1	30%	Pass	
Oxychlordane	L25-Jn0020556	CP	mg/kg	< 0.01	< 0.01	<1	30%	Pass	
Diazinon	L25-Jn0020556	CP	mg/kg	< 0.2	< 0.2	<1	30%	Pass	
Ethion	L25-Jn0020556	CP	mg/kg	< 0.05	< 0.05	<1	30%	Pass	
Fenitrothion	L25-Jn0020556	CP	mg/kg	< 0.1	< 0.1	<1	30%	Pass	
Malathion	L25-Jn0020556	CP	mg/kg	< 0.1	< 0.1	<1	30%	Pass	
Trifluralin	L25-Jn0020556	CP	mg/kg	< 0.2	< 0.2	<1	30%	Pass	
Duplicate									
Metals M8				Result 1	Result 2	RPD			
Arsenic	L25-My0039989	NCP	mg/kg	4.3	4.6	5.0	30%	Pass	
Cadmium	L25-My0069467	NCP	mg/kg	23	24	3.0	30%	Pass	
Chromium	L25-My0069467	NCP	mg/kg	330	350	5.0	30%	Pass	
Copper	L25-My0069467	NCP	mg/kg	610	650	6.0	30%	Pass	
Lead	L25-My0069467	NCP	mg/kg	1000	1000	1.0	30%	Pass	
Mercury	L25-My0069467	NCP	mg/kg	0.25	0.26	6.0	30%	Pass	
Nickel	L25-My0069467	NCP	mg/kg	450	460	2.0	30%	Pass	
Zinc	L25-My0069467	NCP	mg/kg	1900	2000	5.0	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
% Moisture	L25-Jn0020954	NCP	%	2.6	2.6	<1	30%	Pass	

Comments

Sample Integrity

Custody Seals Intact (if used)	N/A
Attempt to Chill was evident	Yes
Sample correctly preserved	Yes
Appropriate sample containers have been used	Yes
Sample containers for volatile analysis received with minimal headspace	N/A
Samples received within HoldingTime	Yes
Some samples have been subcontracted	No

Qualifier Codes/Comments

Code	Description
Q08	The matrix spike recovery is outside of the recommended acceptance criteria. An acceptable recovery was obtained for the laboratory control sample indicating a sample matrix interference.

Authorised by:

Natalie Hill	Analytical Services Manager
Sean Sangster	Senior Analyst-Metal
Douglas Todd	Senior Analyst-Sample Properties
Rhys Thomas	Senior Analyst-Asbestos
Patrick Patfield	Senior Analyst-Organic

Kim Rodgers
General Manager

Final Report – this report replaces any previously issued Report

- Indicates Not Requested

* Indicates NATA accreditation does not cover the performance of this service

Measurement uncertainty of test data is available on request

Eurofins shall not be liable for loss, cost, damages or expenses incurred by the client, or any other person or company, resulting from the use of any information or interpretation given in this report. In no case shall Eurofins be liable for consequential damages including, but not limited to, lost profits, damages for failure to meet deadlines and lost production arising from this report. This document shall not be reproduced except in full and relates only to the items tested. Unless indicated otherwise, the tests were performed on the samples as received.

Galt Environment P/L
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WA 6017

NATA Accredited
Accreditation Number 2377
Site Number 2370 & 2554

Accredited for compliance with ISO/IEC 17025 – Testing
NATA is a signatory to the ILAC Mutual Recognition Arrangement for the mutual recognition of the equivalence of testing, medical testing, calibration, inspection, proficiency testing scheme providers and reference materials producers reports and certificates.

Attention: **- ALL SRA/Results**

Report **1229833-W**
Project name BERKSHIRE RD FORESTFIELD
Project ID WAE250028
Received Date Jun 06, 2025

Client Sample ID			**QC301**
Sample Matrix			**Water**
Eurofins Sample No.			**L25-Jn0020564**
Date Sampled			**Jun 06, 2025**
Test/Reference	LOR	Unit	
OCOP in Water			
Aldrin	0.001	ug/L	< 0.001
alpha-BHC (HCH)	0.001	ug/L	< 0.001
beta-BHC (HCH)	0.001	ug/L	< 0.001
delta-BHC (HCH)	0.001	ug/L	< 0.001
Bifenthrin	0.05	ug/L	< 0.05
Bromophos Ethyl	0.005	ug/L	< 0.005
Chlordane	0.002	ug/L	< 0.002
Chlorothalonil	0.01	ug/L	< 0.01
Chlorpyrifos	0.005	ug/L	< 0.005
Diazinon	0.01	ug/L	< 0.01
Dieldrin	0.001	ug/L	< 0.001
Endosulfan I	0.001	ug/L	< 0.001
Endosulfan II	0.001	ug/L	< 0.001
Endosulfan Sulfate	0.001	ug/L	< 0.001
Endrin	0.01	ug/L	< 0.01
Ethion	0.01	ug/L	< 0.01
Fenitrothion	0.01	ug/L	< 0.01
Fipronil	0.02	ug/L	< 0.02
Hexachlorobenzene (HCB)	0.001	ug/L	< 0.001
Heptachlor Epoxide	0.001	ug/L	< 0.001
Heptachlor	0.001	ug/L	< 0.001
Lindane	0.001	ug/L	< 0.001
Malathion	0.01	ug/L	< 0.01
Methoxychlor	0.02	ug/L	< 0.02
o.p-DDT	0.001	ug/L	< 0.001
Oxychlordane	0.001	ug/L	< 0.001
p.p-DDD	0.001	ug/L	< 0.001
p.p-DDE	0.001	ug/L	< 0.001
p.p-DDT	0.001	ug/L	< 0.001
Parathion Ethyl	0.02	ug/L	< 0.02
Parathion Methyl	0.02	ug/L	< 0.02
Trifluralin	0.01	ug/L	< 0.01
Vinclozolin	0.02	ug/L	< 0.02

Client Sample ID			QC301
Sample Matrix			**Water**
Eurofins Sample No.			**L25-Jn0020564**
Date Sampled			**Jun 06, 2025**
Test/Reference	LOR	Unit	
Metals M8			
Arsenic	0.001	mg/L	< 0.001
Cadmium	0.0001	mg/L	< 0.0001
Chromium	0.001	mg/L	< 0.001
Copper	0.001	mg/L	< 0.001
Lead	0.001	mg/L	< 0.001
Mercury	0.0001	mg/L	< 0.0001
Nickel	0.001	mg/L	< 0.001
Zinc	0.005	mg/L	< 0.005

Sample History

Where samples are submitted/analysed over several days, the last date of extraction is reported.

If the date and time of sampling are not provided, the Laboratory will not be responsible for compromised results should testing be performed outside the recommended holding time.

Description	Testing Site	Extracted	Holding Time
OCOP in Water	Welshpool	Jun 09, 2025	7 Days
- Method: ARL No. 002 - OCOP and PCB in Water			
Metals M8	Welshpool	Jun 09, 2025	28 Days
- Method: LTM-MET-3040 Metals in Waters, Soils & Sediments by ICP-MS			

eurofins

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Project Name: BERKSHIRE RD FORESTFIELD
Project ID: WAE250028

Order No.: WAE250028
Report #: 1229833
Phone: 08 6272 0200
Fax: 08 9285 8444

Received: Jun 6, 2025 4:00 PM
Due: Jun 13, 2025
Priority: 5 Day
Contact Name: - ALL SRA/Results

Eurofins Analytical Services Manager : Natalie Hill

Sample Detail						Asbestos Absence /Presence	Metals M8	Moisture Set	Asbestos in Soils (ASC NEPM 2013)	OCOP in Soil	OCOP in Water
Perth Laboratory - NATA # 2377 Site # 2370 & 2554						X	X	X	X	X	X
External Laboratory											
No	**Sample ID**	**Sample Date**	**Sampling Time**	**Matrix**	**LAB ID**						
1	BH01/0.0	Jun 06, 2025		Soil	L25-Jn0020556		X	X	X	X	
2	BH02/0.0	Jun 06, 2025		Soil	L25-Jn0020557		X	X	X	X	
3	BH03/0.0	Jun 06, 2025		Soil	L25-Jn0020558		X	X	X	X	
4	BH04/0.0	Jun 06, 2025		Soil	L25-Jn0020559		X	X	X	X	
5	GS01	Jun 06, 2025		Soil	L25-Jn0020560		X	X	X	X	
6	GS02	Jun 06, 2025		Soil	L25-Jn0020561		X	X	X	X	
7	GS03	Jun 06, 2025		Building Materials	L25-Jn0020562	X					
8	QC101	Jun 06, 2025		Soil	L25-Jn0020563		X	X		X	
9	QC301	Jun 06, 2025		Water	L25-Jn0020564		X				X
Test Counts						1	8	7	6	7	1

Internal Quality Control Review and Glossary

General

1. Laboratory QC results for Method Blanks, Duplicates, Matrix Spikes, and Laboratory Control Samples follow guidelines delineated in the National Environment Protection (Assessment of Site Contamination) Measure 1999, as amended May 2013. They are included in this QC report where applicable. Additional QC data may be available on request.
2. Unless otherwise stated, all soil/sediment/solid results are reported on a dry weight basis.
3. Unless otherwise stated, all biota/food results are reported on a wet weight basis on the edible portion.
4. For CEC results where the sample's origin is unknown or environmentally contaminated, the results should be used advisedly.
5. Actual LORs are matrix dependent. Quoted LORs may be raised where sample extracts are diluted due to interferences.
6. Results are uncorrected for matrix spikes or surrogate recoveries except for PFAS compounds where annotated.
7. SVOC analysis on waters is performed on homogenised, unfiltered samples unless noted otherwise.
8. Samples were analysed on an 'as received' basis.
9. Information identified in this report with **blue** colour indicates data provided by customers that may have an impact on the results.
10. This report replaces any interim results previously issued.

Holding Times

Please refer to the 'Sample Preservation and Container Guide' for holding times (QS3001).

For samples received on the last day of holding time, notification of testing requirements should have been received at least 6 hours before sample receipt deadlines as stated on the SRA.

If the Laboratory did not receive the information in the required timeframe, and despite any other integrity issues, suitably qualified results may still be reported.

Holding times apply from the sampling date; therefore, compliance with these may be outside the laboratory's control.

For VOCs containing vinyl chloride, styrene and 2-chloroethyl vinyl ether, the holding time is seven days; however, for all other VOCs, such as BTEX or C6-10 TRH, the holding time is 14 days.

Units

mg/kg: milligrams per kilogram	**mg/L:** milligrams per litre	**ppm:** parts per million
µg/L: micrograms per litre	**ppb:** parts per billion	**%:** Percentage
org/100 mL: Organisms per 100 millilitres	**NTU:** Nephelometric Turbidity Units	**MPN/100 mL:** Most Probable Number of organisms per 100 millilitres
CFU: Colony Forming Unit	**Colour:** Pt-Co Units (CU)	

Terms

APHA	American Public Health Association
CEC	Cation Exchange Capacity
COC	Chain of Custody
CP	Client Parent - QC was performed on samples pertaining to this report
CRM	Certified Reference Material (ISO17034) - reported as percent recovery.
Dry	Where moisture has been determined on a solid sample, the result is expressed on a dry weight basis.
Duplicate	A second piece of analysis from the same sample and reported in the same units as the result to show comparison.
LOR	Limit of Reporting.
LCS	Laboratory Control Sample - reported as percent recovery.
Method Blank	In the case of solid samples, these are performed on laboratory-certified clean sands and in the case of water samples, these are performed on de-ionised water.
NCP	Non-Client Parent - QC performed on samples not pertaining to this report, QC represents the sequence or batch that client samples were analysed within.
RPD	Relative Percent Difference between two Duplicate pieces of analysis.
SPIKE	Addition of the analyte to the sample and reported as percentage recovery.
SRA	Sample Receipt Advice
Surr - Surrogate	The addition of a similar compound to the analyte target is reported as percentage recovery. See below for acceptance criteria.
TBTO	Tributyltin oxide (*bis*-tributyltin oxide) - individual tributyltin compounds cannot be identified separately in the environment; however, free tributyltin was measured, and its values were converted stoichiometrically into tributyltin oxide for comparison with regulatory limits.
TCLP	Toxicity Characteristic Leaching Procedure
TEQ	Toxic Equivalency Quotient or Total Equivalence
QSM	US Department of Defense Quality Systems Manual Version 6.0
US EPA	United States Environmental Protection Agency
WA DWER	Sum of PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFBS, PFHxS, PFOS, 6:2 FTSA, 8:2 FTSA

QC - Acceptance Criteria

The acceptance criteria should only be used as a guide and may be different when site-specific Sampling Analysis and Quality Plan (SAQP) have been implemented.

RPD Duplicates: Global RPD Duplicates Acceptance Criteria is ≤30%; however, the following acceptance guidelines are equally applicable:

Results <10 times the LOR:	No Limit
Results between 10-20 times the LOR:	RPD must lie between 0-50%
Results >20 times the LOR:	RPD must lie between 0-30%

NOTE: pH duplicates are reported as a range, not as RPD

Surrogate Recoveries: Recoveries must lie between 20-130% for Speciated Phenols & 50-150% for PFAS. SVOCs recoveries 20 – 150%, VOC recoveries 50 – 150%

PFAS field samples containing surrogate recoveries above the QC limit designated in QSM 6.0, where no positive PFAS results have been reported or reviewed, and no data was affected.

QC Data General Comments

1. Where a result is reported as less than (<), higher than the nominated LOR, this is due to either matrix interference, extract dilution required due to interferences or contaminant levels within the sample, high moisture content or insufficient sample provided.
2. Duplicate data shown within this report that states the word "BATCH" is a Batch Duplicate from outside of your sample batch but within the laboratory sample batch at a 1:10 ratio. The Parent and Duplicate data shown are not data from your samples.
3. pH and Free Chlorine analysed in the laboratory - Analysis on this test must begin within 30 minutes of sampling. Therefore, laboratory analysis is unlikely to be completed within holding time.Analysis will begin as soon as possible after sample receipt.
4. Recovery Data (Spikes & Surrogates) - where chromatographic interference does not allow the determination of recovery, the term "INT" appears against that analyte.
5. For Matrix Spikes and LCS results, a dash "-" in the report means that the specific analyte was not added to the QC sample.
6. Duplicate RPDs are calculated from raw analytical data; thus, it is possible to have two sets of data.

Quality Control Results

Test	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Method Blank							
OCOP in Water							
Aldrin	ug/L	< 0.001			0.001	Pass	
alpha-BHC (HCH)	ug/L	< 0.001			0.001	Pass	
beta-BHC (HCH)	ug/L	< 0.001			0.001	Pass	
delta-BHC (HCH)	ug/L	< 0.001			0.001	Pass	
Bifenthrin	ug/L	< 0.05			0.05	Pass	
Bromophos Ethyl	ug/L	< 0.005			0.005	Pass	
Chlordane	ug/L	< 0.002			0.002	Pass	
Chlorothalonil	ug/L	< 0.01			0.01	Pass	
Chlorpyrifos	ug/L	< 0.005			0.005	Pass	
Diazinon	ug/L	< 0.01			0.01	Pass	
Dieldrin	ug/L	< 0.001			0.001	Pass	
Endosulfan I	ug/L	< 0.001			0.001	Pass	
Endosulfan II	ug/L	< 0.001			0.001	Pass	
Endosulfan Sulfate	ug/L	< 0.001			0.001	Pass	
Endrin	ug/L	< 0.01			0.01	Pass	
Ethion	ug/L	< 0.01			0.01	Pass	
Fenitrothion	ug/L	< 0.01			0.01	Pass	
Fipronil	ug/L	< 0.02			0.02	Pass	
Hexachlorobenzene (HCB)	ug/L	< 0.001			0.001	Pass	
Heptachlor Epoxide	ug/L	< 0.001			0.001	Pass	
Heptachlor	ug/L	< 0.001			0.001	Pass	
Lindane	ug/L	< 0.001			0.001	Pass	
Malathion	ug/L	< 0.01			0.01	Pass	
Methoxychlor	ug/L	< 0.02			0.02	Pass	
o.p-DDT	ug/L	< 0.001			0.001	Pass	
Oxychlordane	ug/L	< 0.001			0.001	Pass	
p.p-DDD	ug/L	< 0.001			0.001	Pass	
p.p-DDE	ug/L	< 0.001			0.001	Pass	
p.p-DDT	ug/L	< 0.001			0.001	Pass	
Parathion Ethyl	ug/L	< 0.02			0.02	Pass	
Parathion Methyl	ug/L	< 0.02			0.02	Pass	
Trifluralin	ug/L	< 0.01			0.01	Pass	
Vinclozolin	ug/L	< 0.02			0.02	Pass	
Method Blank							
Metals M8							
Arsenic	mg/L	< 0.001			0.001	Pass	
Cadmium	mg/L	< 0.0001			0.0001	Pass	
Chromium	mg/L	< 0.001			0.001	Pass	
Copper	mg/L	< 0.001			0.001	Pass	
Lead	mg/L	< 0.001			0.001	Pass	
Mercury	mg/L	< 0.0001			0.0001	Pass	
Nickel	mg/L	< 0.001			0.001	Pass	
Zinc	mg/L	< 0.005			0.005	Pass	
LCS - % Recovery							
OCOP in Water							
Aldrin	%	120			60-120	Pass	
alpha-BHC (HCH)	%	97			60-120	Pass	
beta-BHC (HCH)	%	111			60-120	Pass	
Dieldrin	%	111			60-120	Pass	
Endrin	%	108			60-120	Pass	

Test	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Hexachlorobenzene (HCB)	%	106			60-120	Pass	
Heptachlor Epoxide	%	113			60-120	Pass	
Heptachlor	%	104			60-120	Pass	
Lindane	%	108			60-120	Pass	
p.p-DDD	%	100			60-120	Pass	
p.p-DDE	%	112			60-120	Pass	
p.p-DDT	%	113			60-120	Pass	
LCS - % Recovery							
Metals M8							
Arsenic	%	103			80-120	Pass	
Cadmium	%	104			80-120	Pass	
Chromium	%	98			80-120	Pass	
Copper	%	90			80-120	Pass	
Lead	%	97			80-120	Pass	
Mercury	%	97			80-120	Pass	
Nickel	%	95			80-120	Pass	
Zinc	%	100			80-120	Pass	
CRM - % Recovery							
Metals M8							
Mercury	%	95			70-130	Pass	

Test	Lab Sample ID	QA Source	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Spike - % Recovery									
Metals M8				Result 1					
Arsenic	L25-My0042795	NCP	%	86			75-125	Pass	
Cadmium	L25-My0042795	NCP	%	84			75-125	Pass	
Chromium	L25-My0042795	NCP	%	78			75-125	Pass	
Copper	L25-Jn0020758	NCP	%	86			75-125	Pass	
Lead	L25-My0042795	NCP	%	77			75-125	Pass	
Mercury	L25-My0042795	NCP	%	76			75-125	Pass	
Nickel	L25-Jn0020758	NCP	%	93			75-125	Pass	
Zinc	L25-My0042795	NCP	%	78			75-125	Pass	

Test	Lab Sample ID	QA Source	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Duplicate									
Metals M8				Result 1	Result 2	RPD			
Arsenic	L25-My0042796	NCP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Cadmium	L25-My0042796	NCP	mg/L	< 0.0001	< 0.0001	<1	30%	Pass	
Chromium	L25-My0042796	NCP	mg/L	0.002	0.002	2.0	30%	Pass	
Copper	L25-My0042796	NCP	mg/L	0.005	0.005	2.0	30%	Pass	
Lead	L25-My0042796	NCP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Mercury	L25-My0042796	NCP	mg/L	< 0.0001	< 0.0001	<1	30%	Pass	
Zinc	L25-My0042796	NCP	mg/L	0.013	0.012	2.0	30%	Pass	

Comments

Sample Integrity

Custody Seals Intact (if used)	N/A
Attempt to Chill was evident	Yes
Sample correctly preserved	Yes
Appropriate sample containers have been used	Yes
Sample containers for volatile analysis received with minimal headspace	N/A
Samples received within HoldingTime	Yes
Some samples have been subcontracted	No

Authorised by:

Natalie Hill	Analytical Services Manager
Patrick Patfield	Senior Analyst-Organic
Sean Sangster	Senior Analyst-Metal

Kim Rodgers
General Manager

Final Report – this report replaces any previously issued Report

- Indicates Not Requested

* Indicates NATA accreditation does not cover the performance of this service

Measurement uncertainty of test data is available on request

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Certificate of Analysis

Galt Environment P/L
50 Edward Street
Osborne Park
WA 6017

NATA Accredited
Accreditation Number 2377
Site Number 2370 & 2554

Accredited for compliance with ISO/IEC 17025–Testing
NATA is a signatory to the ILAC Mutual Recognition Arrangement for the mutual recognition of the equivalence of testing, medical testing, calibration, inspection, proficiency testing scheme providers and reference materials producers reports and certificates.

Attention:	- ALL SRA/Results
Report	1229833-AIS
Project Name	BERKSHIRE RD FORESTFIELD
Project ID	WAE250028
Received Date	Jun 06, 2025
Date Reported	Jun 16, 2025

Methodology:

Asbestos Fibre Identification	Conducted in accordance with the Australian Standard AS 5370:2024* Sampling and qualitative identification of asbestos in bulk materials (ISO 22262-1:2012, MOD), formerly AS 4964-2004 and in-house Method LTM-ASB-8020 by polarised light microscopy (PLM) and dispersion staining (DS) techniques. *NOTE: Positive Trace Analysis results indicate the sample contains detectable respirable fibres.*
Man-made vitreous fibre (MMVF)	Fibres exhibiting isotropic characteristics, including glass fibres, glass wool, rock wool, slag wool, ceramic fibres and bio-soluble fibres. NOTE: previously known as "synthetic mineral fibre" (SMF). Simple analytical procedures such as polarised light microscopy cannot detect or reliably identify asbestos in some types of commercial products containing asbestos, either because the fibres are below the resolution of optical microscopy or because the matrix material adheres too strongly to the fibres. For these types of products, electron microscopy may be necessary.
Subsampling Soil Samples	The sample submitted is dried and passed through a 10 mm sieve followed by a 2 mm sieve. All fibrous matter greater than 10 mm and greater than 2 mm and the material passing through the 2 mm sieve are retained and analysed for the presence of asbestos. If the sub 2mm fraction is greater than approximately 30 g to 60 g, then a subsampling routine based on ISO 3082:2017(E) is employed. *NOTE: Depending on the nature and size of the soil sample, the sub-2 mm residue material may need to be subsampled for trace analysis, in accordance with AS 5370:2024*.*
Bonded asbestos-containing material (ACM)	The material is first examined, and any fibres are isolated for identification by PLM and DS. Where required, interfering matrices may be removed by disintegration using a range of heat, chemical or physical treatments, possibly in combination. The resultant material is then further examined in accordance with AS 5370:2024*. *NOTE: Even after disintegration, it may be difficult to detect the presence of asbestos in some asbestos-containing bulk materials using PLM and DS. This is due to the low grade or small length or diameter of the asbestos fibres present in the material or to the fact that very fine fibres have been distributed intimately throughout the materials. Vinyl/asbestos floor tiles, some asbestos-containing sealants and mastics, asbestos-containing epoxy resins and some ore samples are examples of these types of material, which are difficult to analyse.*
Limit of Reporting (LOR)	The performance limitation of the AS 5370:2024* method for non-homogeneous samples is around 0.1 g/kg (equivalent to 0.01% (w/w)). Where no asbestos is found by PLM and DS, including Trace Analysis, this is considered to be at the nominal reporting limit of 0.01% (w/w). The NEPM screening level of 0.001% (w/w) is intended as an on-site determination, not a laboratory limit of reporting, per se. Examination of large sample size (e.g., 500 mL) may improve the likelihood of detecting asbestos, particularly AF, to aid assessment against the NEPM criteria. Gravimetric determinations to this level of accuracy are outside of AS 5370:2024*, and hence, NATA Accreditation does not cover the performance of this service (non-NATA results are shown with an asterisk). *NOTE: NATA News March 2014, p.7, states in relation to AS 4964-2004: "This is a qualitative method with a nominal reporting limit of 0.01 % " and that currently in Australia "there is no validated method available for the quantification of asbestos". This report is consistent with the analytical procedures and reporting recommendations in the NEPM and the WA DoH.*

Client Sample ID			BH01/0.0	BH02/0.0	BH03/0.0	BH04/0.0
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins Sample No.			**25-Jn0020556**	**25-Jn0020557**	**25-Jn0020558**	**25-Jn0020559**
Date Sampled			**Jun 06, 2025**	**Jun 06, 2025**	**Jun 06, 2025**	**Jun 06, 2025**
	LOR	Unit				
Asbestos in Soils (AS 4964-2004)						
Sample Description	-	Comment	Brown coarse grain soil and rocks	Brown coarse grain soil and rocks	Brown coarse grain soil and rocks	Brown coarse grain soil and rocks
Total Dry Mass	0.1	g	183	137	227	278
Total Analytical Fraction	0.1	g	183	137	227	278
Asbestos Detected	-	Yes/No	No	No	No	No
Materials Identified	-	Comment	N/A	N/A	N/A	N/A
Fibres Identified	-	Comment	Organic	Organic	Organic	Organic
Asbestos Content (as asbestos)	0.01	% w/w	< 0.01	< 0.01	< 0.01	< 0.01
Trace Analysis	0.1	g/kg	No trace asbestos detected	No trace asbestos detected	No trace asbestos detected	No trace asbestos detected
Asbestos in Soils (ASC NEPM 2013)						
Asbestos Containing Materials (ACM) >7 mm						
Total ACM (>7 mm)	0.1	g	< 0.1	< 0.1	< 0.1	< 0.1
ACM in Soil (as asbestos)*	0.01	% w/w	< 0.01	< 0.01	< 0.01	< 0.01
Fibrous Asbestos (FA) >7 mm						
Total FA	0.0005	g	< 0.0005	< 0.0005	< 0.0005	< 0.0005
FA in Soil (as asbestos)*	0.001	% w/w	< 0.001	< 0.001	< 0.001	< 0.001
Asbestos Fines (AF) <7 mm						
Total AF	0.0005	g	< 0.0005	< 0.0005	< 0.0005	< 0.0005
AF in Soil (as asbestos)*	0.001	% w/w	< 0.001	< 0.001	< 0.001	< 0.001

Client Sample ID			GS01	GS02
Sample Matrix			Soil	Soil
Eurofins Sample No.			25-Jn0020560	25-Jn0020561
Date Sampled			Jun 06, 2025	Jun 06, 2025
	LOR	Unit		
Asbestos in Soils (AS 4964-2004)				
Sample Description	-	Comment	Brown coarse grain soil and rocks	Brown coarse grain soil and rocks
Total Dry Mass	0.1	g	169	248
Total Analytical Fraction	0.1	g	169	248
Asbestos Detected	-	Yes/No	No	No
Materials Identified	-	Comment	N/A	N/A
Fibres Identified	-	Comment	Organic	Organic
Asbestos Content (as asbestos)	0.01	% w/w	< 0.01	< 0.01
Trace Analysis	0.1	g/kg	No trace asbestos detected	No trace asbestos detected
Asbestos in Soils (ASC NEPM 2013)				
Asbestos Containing Materials (ACM) >7 mm				
Total ACM (>7 mm)	0.1	g	< 0.1	< 0.1
ACM in Soil (as asbestos)*	0.01	% w/w	< 0.01	< 0.01
Fibrous Asbestos (FA) >7 mm				
Total FA	0.0005	g	< 0.0005	< 0.0005
FA in Soil (as asbestos)*	0.001	% w/w	< 0.001	< 0.001
Asbestos Fines (AF) <7 mm				
Total AF	0.0005	g	< 0.0005	< 0.0005
AF in Soil (as asbestos)*	0.001	% w/w	< 0.001	< 0.001

Sample History

Where samples are submitted/analysed over several days, the last date of extraction is reported.

If the date and time of sampling are not provided, the Laboratory will not be responsible for compromised results should testing be performed outside the recommended holding time.

Description	Testing Site	Extracted	Holding Time
LTM-ASB-8020 Method for the Qualitative Identification of Asbestos in Bulk Samples	Welshpool	Jun 10, 2025	Indefinite

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Project Name: BERKSHIRE RD FORESTFIELD
Project ID: WAE250028

Order No.: WAE250028
Report #: 1229833
Phone: 08 6272 0200
Fax: 08 9285 8444

Received: Jun 6, 2025 4:00 PM
Due: Jun 13, 2025
Priority: 5 Day
Contact Name: - ALL SRA/Results

Eurofins Analytical Services Manager : Natalie Hill

Sample Detail						Asbestos Absence /Presence	Metals M8	Moisture Set	Asbestos in Soils (ASC NEPM 2013)	OCOP in Soil	OCOP in Water
Perth Laboratory - NATA # 2377 Site # 2370 & 2554						X	X	X	X	X	X
External Laboratory											
No	**Sample ID**	**Sample Date**	**Sampling Time**	**Matrix**	**LAB ID**						
1	BH01/0.0	Jun 06, 2025		Soil	L25-Jn0020556		X	X	X	X	
2	BH02/0.0	Jun 06, 2025		Soil	L25-Jn0020557		X	X	X	X	
3	BH03/0.0	Jun 06, 2025		Soil	L25-Jn0020558		X	X	X	X	
4	BH04/0.0	Jun 06, 2025		Soil	L25-Jn0020559		X	X	X	X	
5	GS01	Jun 06, 2025		Soil	L25-Jn0020560		X	X	X	X	
6	GS02	Jun 06, 2025		Soil	L25-Jn0020561		X	X	X	X	
7	GS03	Jun 06, 2025		Building Materials	L25-Jn0020562	X					
8	QC101	Jun 06, 2025		Soil	L25-Jn0020563		X	X		X	
9	QC301	Jun 06, 2025		Water	L25-Jn0020564		X				X
Test Counts						1	8	7	6	7	1

Internal Quality Control Review and Glossary General

1. QC data may be available on request.
2. All soil results are reported on a dry basis, unless otherwise stated.
3. Samples were analysed on an 'as received' basis.
4. Information identified on this report in blue indicates data provided by the customer that may impact the results.
5. This report replaces any interim results previously issued.

Holding Times

Please refer to the most recent version of the 'Sample Preservation and Container Guide' for holding times (QS3001).

Units

% w/w:	Percentage weight-for-weight basis, e.g. of asbestos in asbestos-containing finds in soil samples (**% w/w**)
F/fld	Airborne fibre filter loading as Fibres (**N**) per Fields counted (**n**)
F/mL	Airborne fibre reported concentration as Fibres per millilitre of air drawn over the sampler membrane (**C**)
g, kg	Mass, e.g. of whole sample (**M**) or asbestos-containing find within the sample (**m**)
g/kg	Concentration in grams per kilogram
L, mL	Volume, e.g. of air as measured in AFM (**V** = **r** x **t**)
L/min	Airborne fibre sampling Flowrate as litres per minute of air drawn over the sampler membrane (**r**)
min	Time (**t**), e.g. of air sample collection period

Calculations

Airborne Fibre Concentration: $C = \left(\frac{A}{a}\right) \times \left(\frac{N}{n}\right) \times \left(\frac{1}{r}\right) \times \left(\frac{1}{t}\right) = K \times \left(\frac{N}{n}\right) \times \left(\frac{1}{V}\right)$

Asbestos Content (as asbestos): $\%\, w/w = \frac{(m \times P_A)}{M}$

Weighted Average (of asbestos): $\%_{WA} = \sum \frac{(m \times P_A)_x}{x}$

Terms

%Asbestos	Estimated percentage of asbestos in a given matrix may be derived from knowledge or experience of the material, informed by HSG264 *Appendix 2*, else assumed to be 15% in accordance with WA DOH *Appendix 2* (**P_A**). This estimate is not NATA-accredited.
ACM	Asbestos Containing Materials. Asbestos in a non-asbestos matrix is typically presented in bonded (non-friable) condition. For the NEPM and WA DOH, ACM corresponds to material larger than 7 mm x 7 mm.
AF	Asbestos Fines. Asbestos contamination within a soil sample, as defined by WA DOH. Includes loose fibre bundles and small pieces of friable and non-friable material, such as asbestos cement fragments mixed with soil. Considered under the NEPM as equivalent to “non-bonded / friable”.
AFM	Airborne Fibre Monitoring, e.g., by the MFM.
Amosite	Amosite Asbestos Detected. Amosite may also refer to Fibrous Grunerite or Brown Asbestos. Identified in accordance with AS 5370:2024* Sampling and qualitative identification of asbestos in bulk materials (ISO 22262-1:2012, MOD), formerly AS 4964-2004.
AS	Australian Standard.
Asbestos Content (as asbestos)	Total %w/w asbestos content in asbestos-containing finds in a soil sample (**% w/w**).
Chrysotile	Chrysotile Asbestos Detected. Chrysotile may also refer to Fibrous Serpentine or White Asbestos. Identified in accordance with AS 5370:2024* Sampling and qualitative identification of asbestos in bulk materials (ISO 22262-1:2012, MOD), formerly AS 4964-2004.
COC	Chain of Custody.
Crocidolite	Crocidolite Asbestos Detected. Crocidolite may also refer to Fibrous Riebeckite or Blue Asbestos. Identified in accordance with AS 5370:2024* Sampling and qualitative identification of asbestos in bulk materials (ISO 22262-1:2012, MOD), formerly AS 4964-2004.
Dry	Sample is dried by heating before analysis.
DS	Dispersion Staining. The technique required for unequivocal identification of asbestos fibres by PLM.
FA	Fibrous Asbestos. Asbestos-containing material that is wholly or in part friable, including materials with higher asbestos content with a propensity to become friable with handling, and any material previously non-friable and severely degraded. For the NEPM and WA DOH, FA generally corresponds to material larger than 7 mm x 7 mm, although FA may be more difficult to distinguish visibly and may be assessed as AF.
Fibre Count	Total of all fibres (whether asbestos or not) meeting the counting criteria set out in the NOHSC:3003
Fibre ID	Fibre Identification. Unequivocal identification of asbestos fibres according to AS 5370:2024* Sampling and qualitative identification of asbestos in bulk materials (ISO 22262-1:2012, MOD), formerly AS 4964-2004. Includes Chrysotile, Amosite (Grunerite) or Crocidolite asbestos.
Friable	Asbestos-containing materials of any size that may be broken or crumbled by hand pressure. For the NEPM, this includes both AF and FA. It is outside of the laboratory’s remit to assess the degree of friability.
HSG248	UK HSE HSG248, *Asbestos: The Analysts Guide*, 2nd Edition (2021), ISBN: 9780616667079.
HSG264	UK HSE HSG264, *Asbestos: The Survey Guide* (2012), ISBN: 9780717665020
ISO (also ISO/IEC)	International Organization for Standardization / International Electrotechnical Commission.
K Factor	Microscope constant (**K**) as derived from the effective filter area of the given AFM membrane used for collecting the sample (**A**) and the projected eyepiece graticule area of the specific microscope used for the analysis (**a**).
LOR	Limit of Reporting.
MFM (also NOHSC:3003)	Membrane Filter Method. As described by the Australian Government National Occupational Health and Safety Commission, *Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Fibres*, 2nd Edition [NOHSC:3003(2005)].
MMVF	Man-Made Vitreous Fibre - exhibiting isotropic characteristics, including glass fibres, glass wool, rock wool, slag wool, ceramic fibres and “bio-soluble fibres. NOTE: previously known as “synthetic mineral fibre” (SMF).
NEPM (also ASC NEPM)	National Environment Protection (Assessment of Site Contamination) Measure, (2013, as amended).
Organic	Organic Fibres Detected. Organic may refer to Natural or Man-Made Polymeric Fibres. Identified per AS 5370:2024* Sampling and qualitative identification of asbestos in bulk materials (ISO 22262-1:2012, MOD), formerly AS 4964-2004.
PCM	Phase Contrast Microscopy. This is used for fibre counting, according to the MFM.
PLM	Polarised Light Microscopy. It is used for fibre identification and residual analysis according to AS 5370:2024* Sampling and qualitative identification of asbestos in bulk materials (ISO 22262-1:2012, MOD), formerly AS 4964-2004.
Sampling	Unless otherwise stated, Eurofins are not responsible for sampling equipment or the sampling process.
SRA	Sample Receipt Advice.
Residual Analysis	An analytical procedure is used to detect the presence of respirable fibres (particularly asbestos) in a given sample matrix according to AS 5370:2024* Sampling and qualitative identification of asbestos in bulk materials (ISO 22262-1:2012, MOD), formerly Trace Analysis in AS 4964-2004.
UK HSE HSG	United Kingdom, Health and Safety Executive, Health and Safety Guidance, publication.
Inconclusive	Fibrous minerals that are detected but have not been unequivocally identified by PLM with DS according to AS 5370:2024* Sampling and qualitative identification of asbestos in bulk materials (ISO 22262-1:2012, MOD), formerly AS 4964-2004. It may include (but is not limited to) actinolite, anthophyllite, or tremolite asbestos. SEM/TEM is required for definitive identification.
WA DOH	Reference document for the NEPM. Government of Western Australia, *Guidelines for the Assessment, Remediation and Management of Asbestos-Contaminated Sites in Western Australia* (updated 2021), including Appendix Four: *Laboratory analysis*
Weighted Average	Combined average %w/w asbestos content of all asbestos-containing finds in the given aliquot or total soil sample (**$\%_{WA}$**).

Comments

Sample Integrity

Custody Seals Intact (if used)	N/A
Attempt to Chill was evident	Yes
Sample correctly preserved	Yes
Appropriate sample containers have been used	Yes
Sample containers for volatile analysis received with minimal headspace	N/A
Samples received within HoldingTime	Yes
Some samples have been subcontracted	No

Asbestos Counter/Identifier:

Emilie Nelson	Senior Analyst-Asbestos
Angela Tan	Senior Analyst-Asbestos

Authorised by:

Rhys Thomas	Senior Analyst-Asbestos

Kim Rodgers
General Manager

Final Report – this report replaces any previously issued Report

- Indicates Not Requested

* Indicates NATA accreditation does not cover the performance of this service

Measurement uncertainty of test data is available on request

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Appendix F: Environmental Test Results

Location Code									
Field ID				**BH01/0.0**	**BH02/0.0**	**BH03/0.0**	**BH04/0.0**	**GS01**	**GS02**
Date				**06/06/2025**	**06/06/2025**	**06/06/2025**	**06/06/2025**	**06/06/2025**	**06/06/2025**
Sample Type				**Normal**	**Normal**	**Normal**	**Normal**	**Normal**	**Normal**
Lab Report Number				**1229833**	**1229833**	**1229833**	**1229833**	**1229833**	**1229833**
	Unit	EQL	NEPM 2013 Table 1A(1) HILs Res A Soil						
Herbicides									
Trifluralin	**mg/kg**	0.2		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Metals									
Arsenic	**mg/kg**	2	100	3.3	2.9	<2	<2	<2	<2
Cadmium	**mg/kg**	0.1	20	<0.1	<0.1	0.1	0.1	<0.1	<0.1
Chromium (III+VI)	**mg/kg**	1		20	51	12	17	3.3	15
Copper	**mg/kg**	1	6,000	2.9	3.0	10	50	2.6	5.5
Lead	**mg/kg**	1	300	8.4	21	25	24	2.5	17
Mercury	**mg/kg**	0.02	40	0.03	0.02	0.06	0.03	<0.02	<0.02
Nickel	**mg/kg**	1	400	2.0	3.6	2.5	15	<1	1.4
Zinc	**mg/kg**	5	7,400	12	12	93	40	23	31
Organochlorine Pesticides									
2,4-DDT	**mg/kg**	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4,4-DDE	**mg/kg**	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
a-BHC	**mg/kg**	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aldrin	**mg/kg**	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
b-BHC	**mg/kg**	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chlordane	**mg/kg**	0.01	50	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
d-BHC	**mg/kg**	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
DDD	**mg/kg**	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
DDT	**mg/kg**	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dieldrin	**mg/kg**	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan I	**mg/kg**	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan II	**mg/kg**	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan sulphate	**mg/kg**	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin	**mg/kg**	0.01	10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
g-BHC (Lindane)	**mg/kg**	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Heptachlor	**mg/kg**	0.01	6	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Heptachlor epoxide	**mg/kg**	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Methoxychlor	**mg/kg**	0.2	300	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Oxychlordane	**mg/kg**	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Organophosphorous Pesticides									
Chlorpyrifos	**mg/kg**	0.02	160	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Diazinon	**mg/kg**	0.2		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ethion	**mg/kg**	0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fenitrothion	**mg/kg**	0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Malathion	**mg/kg**	0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Pesticides									
Bifenthrin	**mg/kg**	0.2	600	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Bromophos	**mg/kg**	0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Appendix G: CSIRO Pamphlet BTF 18

Standard Geotechnical Definitions, Recommendations, Requirements and Limitations

Foundation Maintenance and Footing Performance:
A Homeowner's Guide

PUBLISHING

BTF 18-2011 replaces Information Sheet 10/91

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

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

Soil Types

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

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870-2011, 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.

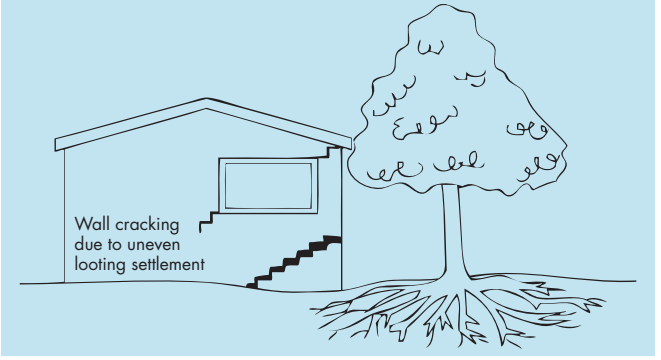
The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally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

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.

Trees can cause shrinkage and damage



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.

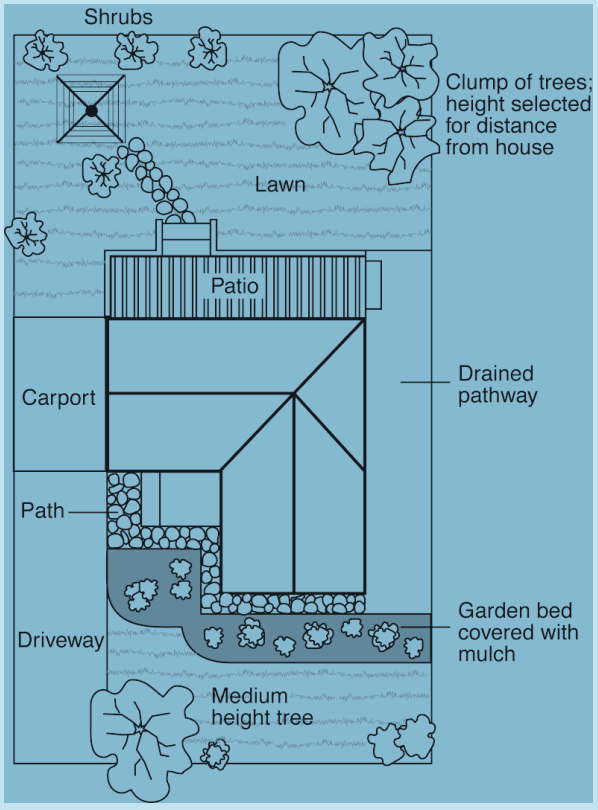
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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.

The information in this and other issues in the series was derived from various sources and was believed to be correct when published.

The information is advisory. It is provided in good faith and not claimed to be an exhaustive treatment of the relevant subject.

Further professional advice needs to be obtained before taking any action based on the information provided.

Distributed by

CSIRO PUBLISHING PO Box 1139, Collingwood 3066, Australia

Tel (03) 9662 7666 Fax (03) 9662 7555 www.publish.csiro.au

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GDR1 ABOUT THIS APPENDIX

These technical notes are to be read with the attached report. These notes contain important information regarding the study in the attached report, and the report cannot be considered in isolation without full reading of these notes.

Where there are conflicts between this appendix and the report text, the report text takes precedence.

Unless noted otherwise, geotechnical investigations are conducted in accordance with AS1726-2017, “Geotechnical site investigations”.

Unless noted otherwise, the report does not include any assessment (or implied assessment) of karst risk.

GDR2 DEFINITIONS

The following definitions apply:

- **Approved Fill** – fill that has been assessed and approved by the geotechnical engineer or civil designer for a particular purpose.
- **Bedding** – A controlled fill layer placed beneath buried elements such as pipes, cables or other infrastructure to provide uniform support and distribute loading.
- **Bulk Fill** – Controlled fill intended to support future infrastructure, but potentially lacking some engineering properties required for upper fill layers or adjacent to structures, where fill with specific properties may be required. Contrast with Select Fill.
- **Civil Design** – the engineering design of the earthworks including surface water and erosion control and subsurface drainage control (where required) to achieve an earthworked, drained site which is capable of supporting the proposed development (including target site classification to AS2870, where relevant). This design is separate to this geotechnical investigation and is a required element of a site development.
- **Clay** – A component of a soil with particles smaller than 0.002 mm in size.
- **Cohesionless (Non-cohesive) Soil** – A soil mass that has does not hold together at low applied stress levels. The strength of the soil depends solely on friction between particles.
- **Cohesive Soil** – A soil mass that has holds together and can adhere to itself.
- **Collapsible Soil** – a soil with high void ratio that is typically strong when dry but loses strength and consolidates under constant stress when wetted, usually due to loss of soil matric suction or dissolving of a chemical cementing agent.
- **Compaction –** The process of increasing the soil density, typically be mechanical means.
- **Competent Person** – A person who has, through a combination of training, education and experience, acquired knowledge and skills enabling that person to correctly perform a specified task.
- **Consistency** – The stiffness of a cohesive soil, at specific moisture contents, to resist mechanical stress or manipulation (remoulding).
- **Controlled (or engineered) Fill** – Any fill for which engineering properties are controlled during placement. Also referred to as structural fill.
- **Dense –** with respect to sandy soils, at a relatively high density index or dry density ratio, exhibiting better engineering parameters with respect to strength and stiffness than the same material at a lower density index.
- **Density** – A measure of the mass of material per unit volume.
- **Eccentric Load** – a load incorporating either a varying vertical load and/or a horizontal load such that the peak vertical stress exceeds the average vertical stress.
- **Embedment Fill** – A controlled fill material placed around and above buried infrastructure (such as pipes, cables or conduits) to provide protection and support.
- **Fill** – Any material that has been placed by anthropogenic processes.
- **Fines** – A component of a soil with particles smaller than 0.075 mm in size.
- **Groundwater** – Water located beneath the earth’s surface in pore spaces, fractures and voids in soil or rock.

- **Gravel** – A component of a soil with particles between 2.36 mm and 63 mm in size.
- **Heavily Loaded** – in reference to mobile plant, particularly intended for equipment where ground bearing pressures exceed 50 kPa and/or equipment has a high centre of gravity and could be prone to toppling. In reference to buildings/structures, where footing pressures exceed 100 kPa and/or footing dimensions exceed 1 m wide.
- **Hydraulic Conductivity** – ratio of volume flux to hydraulic gradient – a quantitative measure of soil's ability to transmit water when subjected to a hydraulic gradient. k_{sat} – saturated hydraulic conductivity, intended for dewatering assessment, subsoil drainage design and other engineering assessments where saturated soils are relevant. k_{unsat} – unsaturated hydraulic conductivity, intended for design of stormwater disposal elements such as soakwells and infiltration basins, where the base of disposal elements is above the groundwater level.
- **In situ** – In the place and condition in which it exists naturally. May also refer to fill that is present at any site prior to an investigation taking place.
- **Limestone** – A sedimentary carbonate rock. The use of the term does not infer a specific strength, carbonate content or grain size. Refer to GDR4.1 for further detail.
- **Loose** – with respect to sand soils, at a relatively low density index or dry density ratio, typically indicating poorer engineering parameters with respect to strength and stiffness than the same material at a higher density index.
- **Material** – Matter that meets the definitions of 'soil', 'rock', other engineered matter (i.e., concrete, bricks etc.) or non-engineered matter (organics, contaminated refuse, deleterious material).
- **May** – Indicates that the statement is an option.
- **Must** – Indicates that the statement is mandatory.
- **Natural** – In the context of soil or rock, material which is present as a result of natural geological processes and has not been subject to anthropogenic engineering processes (such as filling, excavation, replacement, etc).
- **Organic** – In the context of soil, material derived from living matter, primarily plants.
- **Overconsolidated** – a soil that has been subjected to a greater vertical stress than its current state.
- **Permeable Soil** – soil that meets the civil design permeability requirements to allow relatively rapid flow of water through the soil matrix.
- **Rock** – Any aggregate of minerals and/or materials that cannot be disaggregated by hand in air or water without prior soaking.
- **Sand** – a component of soil with particle size between 0.075 mm and 2.36 mm.
- **Select Fill** – a controlled fill which has been chosen for particular engineering characteristics (such as strength, CBR, grading, permeability, etc), commonly for use as a higher-grade capping layer or adjacent to structures. Contrast with Bulk Fill.
- **Shall** – Indicates that the statement is mandatory.
- **Should** – Indicates that the statement is a recommendation.
- **Silt** – A component of a soil with particles between 0.075 mm and 0.002 mm in size.
- **Soil** – Particulate materials that occur in the ground and can be disaggregated or remoulded by hand in air or water without prior soaking.
- **Sand** – A component of a soil with particle between 0.075 mm and 2.36 mm in size.
- **Uncontrolled Fill** – Any material that has been deposited by anthropogenic process, which does not meet the definition of 'controlled fill'.

GDR3 GEOTECHNICAL TEST METHODS AND INTERPRETATION

GDR3.1 Test Pit Excavation

Test pit excavations are formed using mechanical excavation equipment (typically an excavator) or hand dug, with the objective of inspecting (or profiling) the soil exposed in the excavation.

Typical limitations on test pit excavations are:

- Limited depth of excavation – typically governed by reach of the excavator arm.
- Cannot be excavated below groundwater in cohesionless soils, due to collapse and water ingress.
- Cannot be excavated through very stiff / very dense soils (i.e., desiccated clays or cemented soils) or most rock.
- Cannot typically obtain rock samples that are suitable for strength testing.

Test pits are usually mechanically excavated with a toothed bucket (intended for excavation in clay or weak rock) or a flat-edged bucket (typically for sands).

When hand-dug test pits are excavated, it is usually for recovery of near-surface soils or inspection of shallow in-ground elements.

We note that where test pits are excavated on a site, they are only ever loosely backfilled during our studies. They must always be located during site preparation works, over-excavated to their full depth and plan extents and re-filled with approved fill in compacted layers.

GDR3.2 Cone Penetration Tests (CPTs)

Cone penetration testing (CPT) is done by Galt or specialist contractors and typically to AS1289.6.5.1. The test involves pushing an instrumented cone into the soil with a hydraulically operated pushing frame. The test measures tip resistance and sleeve friction on the cone, which are then plotted with depth.

We interpret soil types and associated geotechnical soil parameters from CPT data using the following:

Technical Interpretations and International Guides

- Robertson P.K., Campanella R.G., Gillespie D. and Grieg J. (1986). “Use of piezometer cone data”. Proceedings of the ASCE Speciality Conference In Situ ’86: Use of In Situ Tests in Geotechnical Engineering, Blacksburg, pp 1263-80, American Society of Civil Engineers (ASCE).
- Robertson, P.K., Cabal K.L. (2016) “Guide to Cone Penetration Testing for Geotechnical Engineering 6th Edition 2015”. Gregg Drilling & Testing, Inc., California.
- Baldi G., Bellotti R., Ghionna V.H., Jamiolkowski M., Lo Presti D. C. (1989) “Modulus of sands from CPTs and DMTs”. Proc. 12th Int. Conf. on SMFE, Rio de Janeiro, Vol 1, p165-170, Balkema, Rotterdam.

Local (Perth and Western Australia) Research, Interpretation and Guides

- Fahey, M., Lehane, B., Stewart, D. (2003) “Soil stiffness for shallow foundation design in the Perth CBD”. Australian Geomechanics Vol. 8 No. 3.
- Main Roads Western Australia (MRWA) (2009) “Structures Engineering Design Manual”. Document 3912/03, Perth.
- Lehane B. (2017). “CPT-Based Design of Foundations”, E.H. Davis Memorial Lecture, Australian Geomechanics, Vol 54. No. 4’ and
- Galt’s in-house correlations between CPT data and other geotechnical testing.

GDR3.3 Borehole Drilling

Boreholes are drilled for sampling of the soil and rock, with a small disturbance footprint. Typical techniques are:

- Auger drilling (hand auger or machine auger) – for recovery of soil at relatively shallow depths only. Cannot penetrate cemented soils or rock.
- Push probe drilling – for recovery of soil at relatively shallow depths and below groundwater. Cannot penetrate cemented soils or rock.

- Air core drilling – for recovery of soil, cemented soil and rock (typically up to high strength rock). Not suited to drilling of very high strength rock.
- Diamond coring (or rotary coring) – for recovery of cemented soil, rock and some soil types (typically not sand). Suited to all strengths of rock.

If used, standard penetration tests (SPTs) are done in accordance with AS1289.6.3.1. Correlations for consistency and density are based on:

- Standards Australia (2016), "HB160-2006, Soils Testing".

GDR3.4 Dynamic Cone Penetrometer (DCP)

The DCP is a hand-held tool for assessing penetration resistance of a soil. This comprises a 16 mm rod equipped with a 20 mm cone, hammered into the ground using a falling 9 kg weight on a 510 mm slide hammer on the top of the rod. This is done in accordance with AS1289.6.3.2 and the blow counts to hammer in the rod are measured in 100 mm penetration increments. Where provided, correlations for consistency and density are based on:

- Standards Australia (2016), "HB160-2006, Soils Testing".

GDR3.5 Perth Sand Penetrometer (PSP)

The PSP is a variation on a DCP and uses a 9 kg weight on a 600 mm slide hammer to hammer in a 16 mm rod with a blunt (square-faced) end. Testing is done in accordance with AS1289.6.3.3, with the following typical variations:

- Testing is often done to a greater depth than the 450 mm covered in the standard.
- Blow counts are sometimes recorded in 150 mm intervals (compared to 300 mm intervals used in the standard) to provide better resolution on the tests.

Where provided, correlations for density are based on:

- Standards Australia (2016), "HB160-2006, Soils Testing".

GDR3.6 Dynamic Probing Super Heavy (DPSH)

The DPSH test involves driving a solid cone (20 cm^2) into the ground using a 63.5 kg hammer falling 760 mm. Testing is done in accordance with EN ISO 22476-2 – Geotechnical engineering – Field testing – Part 2: Dynamic probing – DPSH-B.

Results may be presented as either:

- N10 (No. of blows required for every 100 mm penetration);
- N30 (No. of blows required for every 300 mm penetration); or
- q_d (dynamic tip resistance, analogous to CPT q_c).

GDR3.7 Inverse Auger Hole Infiltration Test (Falling Head, Unsaturated Soil)

Infiltration tests are carried out using the 'inverse auger hole' method described by:

- Cocks, G (2007), "Disposal of Stormwater Runoff by Soakage in Perth Western Australia", Journal and News of the Australian Geomechanics Society, Volume 42 No. 3, pp 101-114

This test is an unsaturated falling head test, in that it is carried out above the groundwater table and is intended to mimic the behaviour of soak wells and similar drainage elements (i.e. soakage basins), which discharge stormwater into an unsaturated medium.

The hole is wetted only for a short period prior to the testing.

The test is usually repeated three times, with the intention that the second and third tests provide similar results (within about 10%-20%). Tests are done over a short duration, typically 2 minutes to 10 minutes. The focus of the testing is generally when the head is low (200 mm or lower), such that the relevant lateral zone is as saturated as the zone directly below the borehole.

The hydraulic conductivity derived from this test is not to be used for applications where saturated hydraulic conductivity is relevant, e.g.:

- Subsoil drainage design; and

- Dewatering estimations.

Based on Galt's in-house research, this method does not completely saturate the soil in any reasonable test length, and thus may not be suitable for assessment of soils at sites where the critical drainage condition is a fully saturated soil (i.e., in areas with high groundwater tables). Our research on sand sites indicates that the test does correlate well with actual soak well performance, in unsaturated sand zones without impermeable zones.

GDR3.8 Guelph Permeameter Test (Constant Head, Quasi-Saturated Soil)

The Guelph permeameter test, conducted in accordance with the constant head test method outlined in Appendix G of AS1547, is a constant-head test in nominally "saturated" soil (in that the test is conducted until a "steady state" is reached). However, we note that this test can only be done above the groundwater table and as such, is in an unsaturated zone. Therefore, the hydraulic conductivity derived from this test should be used with caution and evaluated against other test methods (such as saturated, constant-head permeability testing from laboratory samples, or in situ saturated hydraulic conductivity testing below the groundwater table).

GDR4 GEOLOGICAL UNITS

GDR4.1 Limestone

The term 'Limestone' is used to describe a carbonate rock. Tamala Limestone is the common limestone in Western Australia, and typically comprises cemented quartz and shell fragments cemented together by calcium carbonate.

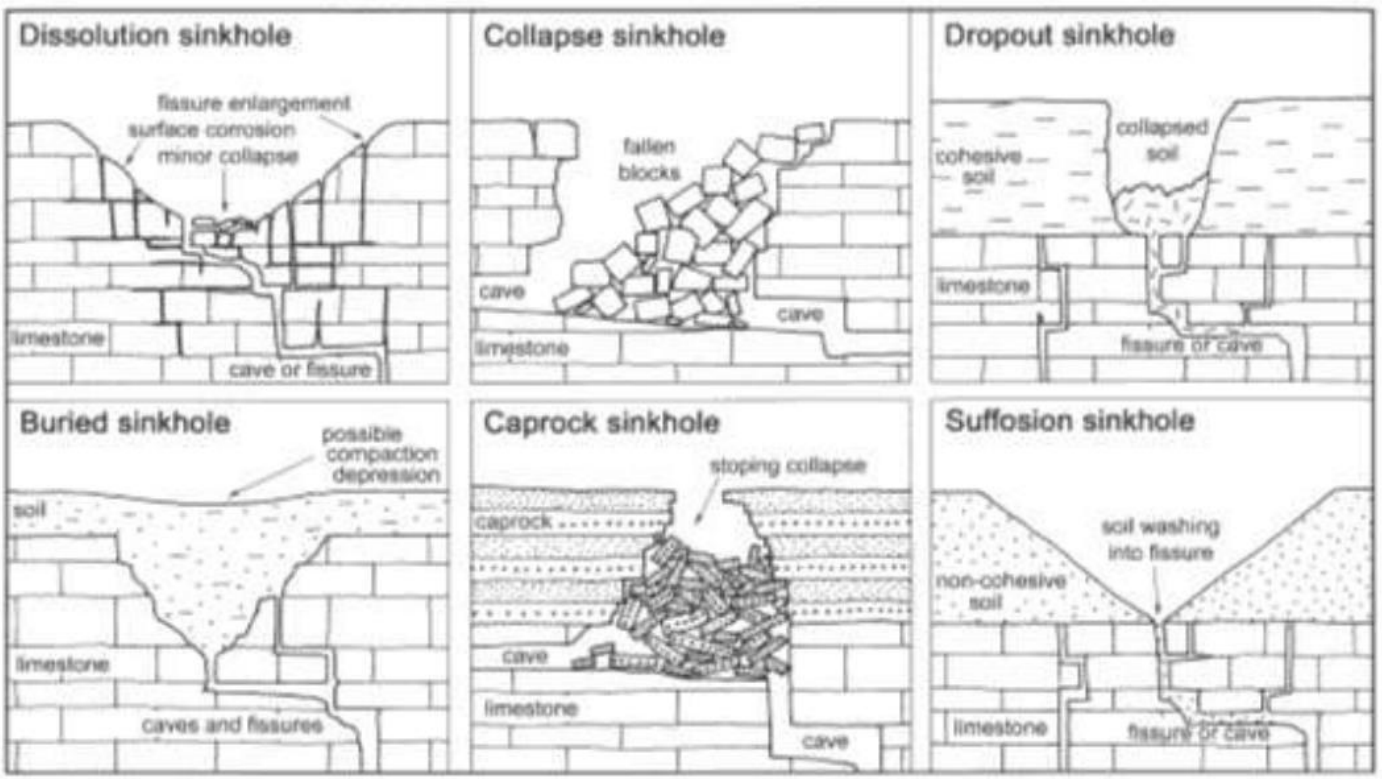
Limestone can vary significantly across short distances in composition, strength and cementation. Tamala limestones in Western Australia also have known possible geological features including:

- Caprock/calcrete – The formation of a very hard duricrust, usually due to sun exposure. Caprock may be up to 3 m thick, but typically around 1.5 m thick. Caprock is very difficult to excavate and may require the use of hydraulic rock breakers or rock saws to excavate.
- Solution features/tubes – Often initially formed due to the presence of Eucalypt and Jarrah roots during limestone formation, and often increasing in depth and size due to ongoing weathering. May be up to 500 mm in diameter. These are typically filled with very loose, unconsolidated sand.
- Pinnacles – Pinnacles are usually the limestone that is left around surrounding solution features. Often can comprise very hard limestone/caprock that can be substantially higher than surrounding areas. Pinnacles may have also been formed by surrounding erosion (i.e., wind/water).
- Karst/caves – Karst is caused by the dissolution of limestone, typically where there is interaction in low-lying areas with water and limestone. Karst manifests itself as loose near-surface sand with cavities (caves) in the underlying limestone. This can lead to sinkholes and collapse of overlying structures.

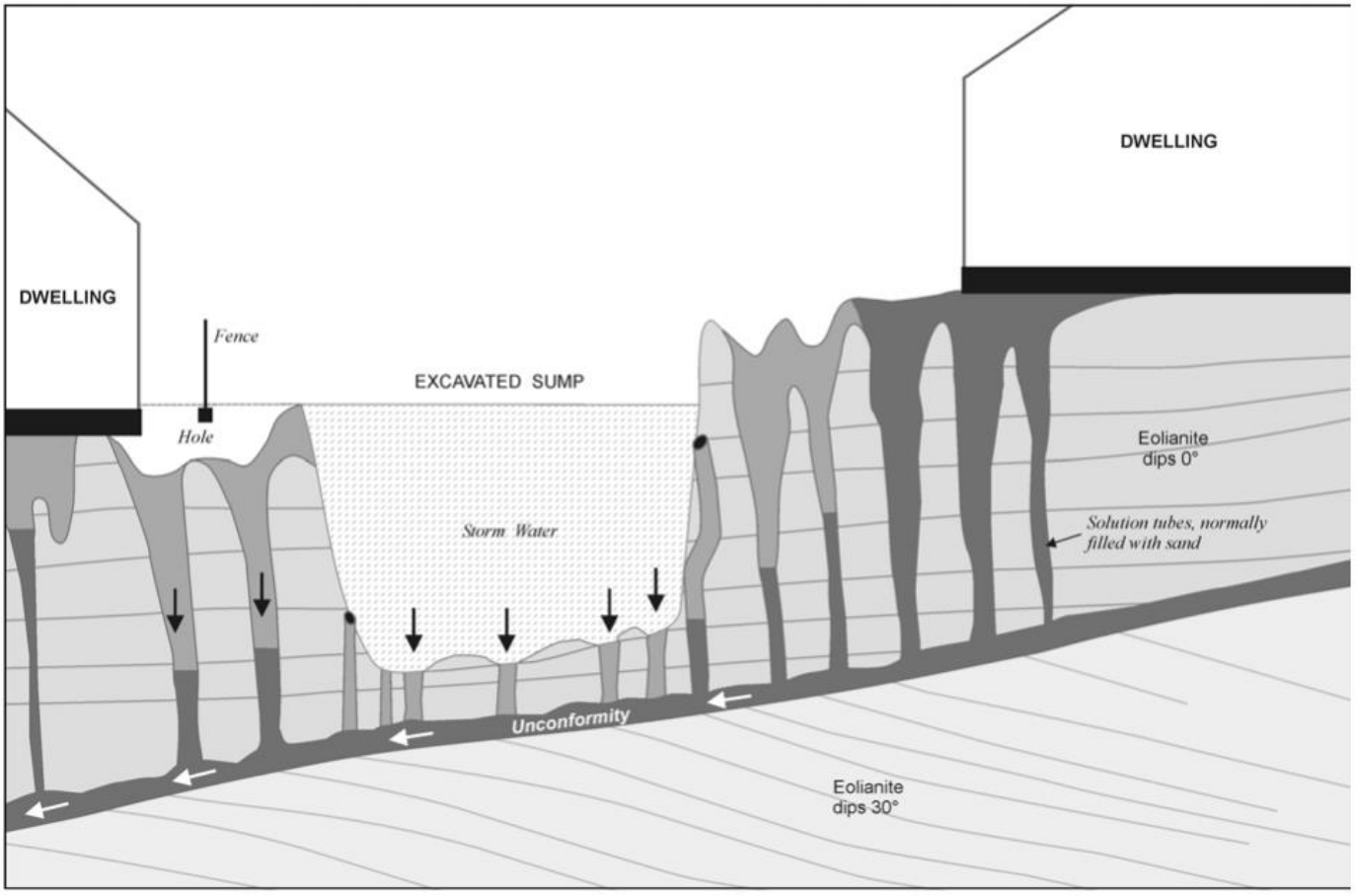
Inline images showing typical pinnacle/solution features and Karstic features follow. These are taken from:

- Gordon, R. (2003). "Coastal Limestones". Australian Geomechanics Vol.38 No. 4, The Engineering Geology of Perth.
- Waltham, A. & Fookes, P. (2003). "Engineering Classification of Karst Ground Conditions: Quarterly Journal of Engineering Geology and Hydrogeology, Vol 36.

Inline Image GDR 1 - Karstic Sinkhole Features from Waltham and Fookes (2003)



Inline Image GDR 2: Pinnacle/Solution Features from Gordon (2003)



GDR4.2 Pindan Sands and Collapsible Soils

In the Western Australian context, Pindan sands are sandy soils present predominantly across the Pilbara and Kimberley regions. Pindan sands are typically:

- Red brown in colour.
- Between 10% and 40% fines.
- Of aeolian origin, usually resulting in unconsolidated in situ conditions (nuclear density gauge testing often indicates these soils have in situ density ratios of 80%-85% of modified maximum dry density).
- Very strong when dry due to high soil suctions in the fine fraction, which create strong bonds between the sand particles.

As the grains are usually held in place by the dry fine fraction, this can lead to:

- very high settlements (i.e., “collapse”) as the grain-to-grain bonds are weakened as matric suction decreases on soaking; and
- loss of vertical and horizontal strength/stiffness as the grain-to-grain bonds weaken.

The risks associate with Pindan sands are usually quantified in terms of the collapse potential/magnitude of possible collapse events.

Other similar soils are present in Western Australia that may exhibit similar collapse potential and may not strictly be Pindan sands (i.e., have other grain-to-grain bonding mechanisms).

GDR5 SITE CLASSIFICATION

Site classification refers to the assessment of a site in reference to AS2870-2011, “Residential slabs and footings”. The method for assessing the site class is outlined in Section 2 of AS2870-2011, which indicates that this may be done by:

- assessing the characteristic surface movement, due to seasonal moisture changes in the soil profile;
- assessing the performance of existing foundations; or
- assessment of the soil profile (where there are deleterious inclusions, landfill, putrescible waste etc.).

The site classifications based on the expected characteristic surface movement are summarised in Table GDR 1.

Table GDR 1: Summary of Site Classifications (AS2870-2011)

Class	Description	Characteristic Surface Movement (y_s)
A	Most sand and rock site with little or no ground movement from moisture change	Not Defined (typically <5 mm)
S	Slightly reactive clay sites with only slight ground movement from moisture changes	0 – 20 mm
M	Moderately reactive clay sites, which may experience moderate ground movements from moisture change	20 – 40 mm
H1	Highly reactive sites, which may experience high ground movements from moisture change	40 – 60 mm
H2	Highly reactive sites, which may experience very high ground movements from moisture change	60 – 75 mm
E	Extremely reactive sites, which may experience extreme ground movements from moisture change	>75 mm
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise	Not Defined

The calculated characteristic surface movement is predominantly based on:

- the reactivity (i.e., the shrink-swell potential) of the soil (and any proposed fill);
- the design depth of soil suction change, which is the maximum expected depth of soil suction change due to seasonal soil moisture changes; and
- the depth to any bedrock and groundwater table.

The design depth of soil suction change for Western Australia has been refined using the Thornthwaite Moisture Index (TMI). We have carried out assessment using the depths as detailed in:

- Hu Y, Saraceni P, Cocks G, Zhou M (2016). "TMI assessment and climate zones in Western Australia". Australian Geomechanics Journal, Vol.51 No.3.
- Hu Y, Raj A, Cocks G, Verheyde F (2019). "Re-assessment of TMI based climate zones in metropolitan Perth, WA". ANZ Geomechanics Conference 2019, Perth Australia.

The design depth of soil suction change for Northern Territory is based on the research presented in:

- Jackson, S (2022), "Thornthwaite moisture index and climate zones in the Northern Territory", Australian Geomechanics Journal, Vol. 57 No. 3.

We highlight that AS2870-2011 does not make any reference to the fines content of a soil when assessing the site classification.

Where a site classification is provided in our reports, it is always predicated on the requirement that the recommended site preparation procedures are carried out.

We also highlight that the footing performance and shrink-swell movements of a site can be impacted by the planting or removal of trees. This should be considered where appropriate, and we refer to the CSIRO BTF 18-2011 "Foundation Maintenance and Footing Performance: A Homeowner's Guide" for further information.

AS 2870 is limited to single and double storey residential buildings with normal shallow footings with a maximum bearing pressure of 100 kPa and is not applicable where development types other than this are proposed.

GDR6 SITE PREPARATION

GDR6.1 General

The intent of the site preparation guidelines provided in the above report are to ensure that the earthworks can be constructed to meet specific requirements, i.e., minimum compaction, fill requirements, removal of unsuitable material etc. The site preparation guidelines are not exhaustive, and on-site conditions may dictate that other preparation measures may be required to meet geotechnical requirements.

GDR6.2 Site Preparation

Site preparation measures outlined in this section relate to bulk earthworks at the site in preparation for the construction of buildings, pavements and other structures.

The preparation of a site in accordance with outlined measures below or those presented in the report text does not imply that the site is suitable for heavily loaded plant or eccentric loads. This is especially applicable for working platforms for mobile plant including cranes, crawlers or the like. The site surface may still not be trafficable for mobile plant. Individual working platform assessments must be done if heavily loaded mobile plant are proposed.

GDR6.2.1 Common Measures

The common measures outlined below are to prepare standard sites in advance of proof compaction, bulk excavation and filling. These measures are applicable to most sites, however the applicability of these measures is stated in the main report.

Table GDR 2: Common Measures

Measure	Commentary
Demolish and remove structures and pavements	Demolish existing structures and pavements, including removal of all buried services and footings and dispose off-site.
Remove demolition debris and other deleterious material	Remove any demolition debris and other deleterious material from site including old footings, slabs, soak wells, buried services, paving and building rubble.
Strip uncontrolled fill (where present)	Strip any uncontrolled fill from the site (where encountered) and, if suitable, stockpile it for potential re-use as non-structural fill. If contaminated, dispose off-site. Refer to the report text for discussions on the presence of detected uncontrolled fill and its composition. It is important to realise that undetected uncontrolled fill may be present between test locations and the absence of its identification in our report does not preclude its presence. If uncontrolled fill is detected during site works, please contact us for inspection and to provide recommendations.
Remove trees	All tree roots must be removed, this may result in significant excavation in places. Where tree roots and stumps are removed, the disturbed soil must be over-excavated and replaced with controlled, compacted fill. Backfilling of over-excavations is discussed in the following sections .
Strip and stockpile topsoil.	Strip and stockpile topsoil from unpaved areas of the site for potential re-use in non-structural applications. The topsoil strip is only necessary to remove roots and we recommend a topsoil strip as necessary to remove all roots from the soil.
Carry out bulk excavation	Excavate to the required level. Stockpile suitable excavated material for potential re-use as fill (the re-use of spoil as fill , if appropriate, is discussed in the report text) and remove unsuitable or excess material off-site.
Batter edges of excavation	Excavations should be battered to a temporary slope as given in the report text where applicable and not in close proximity to adjacent structures etc. If required, construct temporary/permanent retaining walls where batters cannot be accommodated.

By following these measures, the site should have been prepared to a point where topsoil and vegetation has been removed to expose either natural soil or controlled fill. Over-excavation to the required levels may then be required for some projects. Once complete, the site is now ready for proof compaction and filling.

GDR6.2.2 Sand Sites

The preparation measures outlined below are provided for sand sites meeting the following criteria:

- Site underlain by sand.
- No collapsible soils present.
- No deep loose sand.
- Compaction of a loose upper horizon to maximum 1 m depth.
- No shallow groundwater (<1 m deep).
- No limestone or other rock present at shallow depth.
- “Common Measures” outlined in Section GDR6.2.1 have been completed (as required).

The applicability of these measures is stated in the main report. These measures must be carried out for all areas where structures, footings, pavements and any other settlement-sensitive infrastructure is proposed.

Unless specified otherwise in the report, the **Approved Fill** to be used is outlined in Section GDR8 (**Permeable Sand** where permeable fill is required, else **General Sand**). The specific selection is subject to the requirements of the civil designer.

Table GDR 3: Sand Site Measures

Measure	Commentary
Moisture condition and proof compact.	Moisture condition and compact the exposed sandy ground to achieve the density specified in Section GDR7.1 ("sand") to a depth of at least 900 mm.
Test proof compaction	Check that the density specified in Section GDR7.1 ("sand") has been achieved to a depth of at least 900 mm. We note that the applicability of the use of the PSP for compaction control is discussed in the report. Unless specifically approved for use on the subject site, the contractor must **not** assume that the use of the PSP is appropriate.
Treat areas of loose or unsuitable material	Any areas of loose sand or unsuitable material (including over-excavated areas of former trees and root balls) must be removed and replaced with **Approved Fill** as outlined in the report or as noted above. The report will explain the suitability of site-derived materials for re-use as approved fill.
Carry out bulk filling	Where fill is required to build up levels, use **Approved Fill**, placed and compacted in layers of no greater than 300 mm loose thickness. Test compaction to achieve the density specified in Section GDR7.1.

In following this method, shallow/surficial loose sand will be compacted, and the site will be filled (where required) in preparation for supporting footings, ground slabs, pavements and the like.

GDR6.2.3 Deep Loose Sand Sites

The preparation measures outlined below are provided for sand sites meeting the following criteria:

- Site underlain by sand.
- Collapsible soils or deep loose sand present (if applicable, this is discussed in the report).
- Over-excavation, compaction and replacement of loose sand required.
- No shallow groundwater (<1 m deep).
- No limestone or other rock present at shallow depth.
- "Common Measures" outlined in Section GDR6.2.1 have been completed.

The greatest depth of compaction that can be achieved with standard compaction equipment (vibrating roller, etc) is around 1 m (for sands). As such, it is necessary to cut down the site level to a point where this compaction can be done to the lowest level needed to be improved.

The applicability of these measures is stated in the main report. These measures must be carried out for all areas where structures, footings and any other settlement-sensitive infrastructure are proposed. Not typically required for pavement subgrades, however, this is discussed in the report if required.

Unless specified otherwise in the report, the **Approved Fill** to be used is outlined in Section GDR8 (**Permeable Sand** where permeable fill is required, else **General Sand**). The specific selection is subject to the requirements of the civil designer.

Table GDR 4: Deep Loose Sand Site Measures

Measure	Commentary
Over-excavate to the required depth.	Over-excavate sand soil to the depth stated in the report and, if appropriate (discussed in report) retain it for re-use as fill. Over-excavation is likely to be done in stages depending on the site area available for earthworks. Excavations must be battered to a temporary slope as given in the report text where applicable and not in close proximity to adjacent structures etc. If required, construct temporary/permanent retaining walls where batters cannot be accommodated.
Moisture condition and proof compact.	Moisture condition and compact the exposed sandy ground to achieve the density specified in Section GDR7.1 ("sand") to a depth of at least 900 mm.
Test proof compaction	Check that the density specified in Section GDR7.1 ("sand") has been achieved to a depth of at least 900 mm. We note that the applicability of the use of the PSP for compaction control is discussed in the report. Unless specifically approved for use on the subject site, the contractor must **not** assume that the use of the PSP is appropriate.
Treat areas of loose or unsuitable material	Any areas of loose sand or unsuitable material (including over-excavated areas of former trees and root balls) must be removed and replaced with compacted **Approved Fill** as outlined in the report or as noted above. The report will explain the suitability of site-derived materials for re-use as approved fill.

Measure	Commentary
Carry out bulk filling	Where fill is required to build up levels (including restoration of the site surface level to the original level), use **Approved Fill**, placed and compacted in layers of no greater than 300 mm loose thickness. Test compaction as specified in Section GDR7.1.

In following this method, deep, loose sand will be compacted to a sufficient depth to reduce settlement impacts and the site will be filled (where required) in preparation for supporting footings, ground slabs, pavements and the like.

GDR6.2.4 Clayey Sites

The preparation measures outlined below are provided for sand sites meeting the following criteria:

- Site underlain by cohesive soils (typically >12% fines, i.e., clayey enough for the fines proportion of the soil to dominate behaviour).
- No collapsible soils present.
- No deep soft soils or organic soils.
- Over consolidated clayey soils present which will not be subject to significant primary or secondary consolidation (settlements expected to be within the limit of typical seasonal movements occasioned by moisture content changes, which would be captured in assignment of an AS2870 site classification).
- No shallow groundwater (<1 m deep)
- No rock present at shallow depth.
- "Common Measures" outlined in Section GDR6.2.1 have been completed.

The applicability of these measures is stated in the main report. These measures must be carried out for all areas where structures, footings, pavement subgrades and any other settlement-sensitive infrastructure is proposed.

Unless specified otherwise in the report, the **Approved Fill** to be used is **Clay** as outlined in Section GDR8.

Table GDR 5: Clay Site Measures

Measure	Commentary
Moisture condition and proof compact.	Moisture condition and compact the exposed clayey ground to achieve the density specified in Section GDR7.1 ("fine grained soils") to a depth of at least 300 mm.
Test proof compaction	Check that the density specified in Section GDR7.1 ("fine grained soils") has been achieved to a depth of at least 300 mm. The use of a penetrometer for compaction control of cohesive soils is not an appropriate substitute for in situ NDG testing.
Treat areas of loose or unsuitable material	Any areas of soft clayey soils or unsuitable material (including over-excavated areas of former trees and root balls) must be removed and replaced with compacted **Approved Fill**. The report will explain the suitability of site-derived materials for re-use as approved fill.
Carry out bulk filling	Where excavations are done into clayey soils (e.g. to treat soft zones, remove root balls and the like), they must not be backfilled filled with sand fill (even where a sand topping layer is proposed). Where fill is required (including backfilling of excavations to remove trees), only use **Approved Fill**, moisture conditioned, placed and compacted in layers of no greater than 300 mm loose thickness. Test moisture and compaction as specified in Section GDR7.1.
Grade completed clayey surface	Surface water control is essential for clayey sites. This also applies to control of infiltrated water into sand topping layers or the like. The surface of clayey ground must be graded at a minimum of 1% crossfall to drain. This is a general recommendation, and an appropriate civil design must be done to account for surface and subsoil drainage.
Install sand topping layer	Where a sand topping layer is proposed, this should be done as outlined in Section GDR6.2.5.

These measures do not take into account the objectives of the civil design for the site, particularly with regard to surface water drainage and groundwater control (including clay grading, subsoil drainage, thickness and composition of a sand topping layer and the like). This must be taken into account by the civil designer. General commentary on drainage control measures is presented in Section GDR14.

GDR6.2.5 Sand Topping Layer

Where a sand topping layer is required:

Unless specified otherwise in the report, the **Approved Fill** to be used is outlined in Section GDR8 (**Permeable Sand** where permeable fill is required, else **General Sand**). The specific selection is subject to the requirements of the civil designer.

Table GDR 6: Sand Topping Layer Measures

Measure	Commentary
Prepare Substrate	Prepare the clayey or other substrate as separately outlined prior to installing the topping layer.
Build up sand topping layer	Build up level to the required level with **Approved Fill**, placed and compacted in layers of no greater than 300 mm loose thickness to achieve the density specified in Section GDR7.1.

For the purposes of achieving the allowable bearing pressures and site classification discussed in the report, it is not necessary to have the bases of slabs and footings in the sand topping layer, i.e. if required, they may extend through the sand topping layer into clayey soil below.

GDR6.2.6 Limestone Sites

The preparation measures outlined below are provided for sites underlain by limestone (refer to Section GDR4.1), meeting the following criteria:

- Site underlain by sand overlying limestone.
- Compaction of a loose upper horizon to maximum 1 m depth, with localised deeper treatments between pinnacles if required.
- No shallow groundwater (<1 m deep)
- “Common Measures” outlined in Section GDR6.2.1 have been completed.

The site preparation measures outlined below are aimed at improvement of the site in preparation for construction of the structures including on-ground slabs, shallow footings, retaining walls and pavements.

Unless specified otherwise in the report, the **Approved Fill** may comprise one of the following as specified in Section GDR8 (the specific selection is subject to the requirements of the civil designer):

- **Permeable Sand** where permeable fill is required
- **General Sand** where permeable fill is not required
- **Mixed Sand/Limestone Fill** where permeable fill is not required

The re-use of any limestone for fill is subject to the requirements of the civil design and discussions in the report text. The use of **Mixed Sand/Limestone Fill** is discussed in Section GDR6.2.7. The preparation measures outlined in Table GDR 7 assume sand fill.

Table GDR 7: Standard Limestone Site Measures (Bulk Earthworks)

Measure	Commentary
Treat zones of loose sand	Where deep loose sand is present (particularly, but not exclusively, between limestone pinnacles), over-excavate to the depth as noted in the report . Sand should be retained for re-use as fill if recommended in the report. Limestone debris and pinnacles should be separated and only re-used if recommended in the report.
Moisture condition and proof compact.	Moisture condition and compact the exposed sandy ground to achieve the density specified in Section GDR7.1 ("sand") to a depth of at least 900 mm. Proof compaction of intact limestone is not required.
Test proof compaction	Check that the density specified in Section GDR7.1 ("sand") has been achieved to a depth of at least 900 mm. We note that the applicability of the use of the PSP for compaction control is discussed in the report. Unless specifically approved for use on the subject site, the contractor must not assume that the use of the PSP is appropriate. If refusal to the test method is encountered within the target test depth on limestone and the results to the refusal depth are acceptable, it is not necessary to repeat compaction testing at that location. Compaction control of intact limestone is not required.
Treat areas of loose or unsuitable material	Any areas of loose sand or unsuitable material (including over-excavated areas of former trees and root balls) must be removed and replaced with compacted **Approved Fill** as outlined in the report or as noted above. The report will explain the suitability of site-derived materials for re-use as approved fill.
Carry out bulk filling	Where fill is required to build up levels, use **Approved Fill**, placed and compacted in layers of no greater than 300 mm loose thickness. Test compaction to achieve the density specified in Section GDR7.1.

These measures do not take into account the specifics of the civil design, including the requirement (if any) for excavatable and/or free draining layers to achieve construction and drainage objectives. The civil design must take precedence and is not specifically considered in this advice.

Soakwells can perform poorly in limestone and specific advice may apply to the installation of soakwells in limestone areas. If not discussed in our report, please contact us for further advice.

Without further consultation with the structural designer, footings for any one structure must not be founded on a mixture of sand and intact limestone. This is due to potential differential settlements between limestone zones (relatively stiff) and soil zones (relatively soft). Where this is the case, the measures outlined in Table GDR 8 must be followed, only with guidance from the structural designer and Galt.

Table GDR 8: Standard Limestone Site Measures (Footing and Slab Preparation)

Measure	Commentary
Excavate and compact for slabs, subgrades, pad or strip footings	Excavate for pad and strip footings. Where a mix of soil and limestone is present below any one structure, one of the following must be done (to be agreed with structural designer and us): ▪ **Over-excavate limestone and replace with compacted soil:** Typically where the foundation largely comprises soil and a relatively small amount of limestone is present. Where footings and slabs are founded partly on soil and partly on limestone, over-excavate the limestone by at least 300 mm below the base of footing or slab and replace the excavated material with compacted **Approved Fill**. ▪ **Remove soil from over limestone and replace with concrete**: Typically where the foundation largely comprises limestone and a relatively small amount of soil is present. Localised zones of sand and mixed sand/limestone rubble must be removed and replaced with lean-mix concrete, e.g. 10 MPa blinding concrete. ▪ **Design the structure to accommodate differential foundation movements:** For example, include construction joints or use a more heavily reinforced footing (subject to the structural designer's requirements).
Test compaction of footing bases, slabs or subgrades.	Compact the exposed bases to achieve the density specified in Section GDR7.1 ("sand"), to a depth of at least 900 mm, or to the depth where limestone is intersected. If refusal to the test method is encountered within the target test depth on limestone and the results to the refusal depth are acceptable, it is not necessary to repeat compaction testing at that location. Compaction control of intact limestone is not required. Remove, replace and compact as required with approved fill any zone not achieving the density specified in Section GDR7.1 ("sand")

GDR6.2.7 Mixed Sand/Limestone Filling

On sites where deemed appropriate by the Civil Design, **Approved Fill** may comprise limestone rubble fill (**Mixed Sand/Limestone**, as specified in Section GDR8).

The preparation measures outlined below are provided for sites meeting the following criteria:

- No shallow groundwater (<1 m deep)
- "Common Measures" outlined in Section GDR6.2.1 have been completed.
- Substrate preparation for the relevant site type has been done in preparation for further filling (as relevant for sand, limestone or clayey sites discussed in the preceding sections).

The site preparation measures outlined below are required prior to construction of structures including on-ground slabs, shallow footings, retaining walls and pavements.

Table GDR 9: Mixed Sand/Limestone Fill Measures

Measure	Commentary
Develop a method specification for the filling	A performance specification is not appropriate for compaction control in **Mixed Sand/Limestone** fill, due to oversize limestone particles and the limitations of test methods. Therefore, a method specification is required. Development of a method specification is discussed in Section GDR7.5. A tentative method specification for **Mixed Sand/Limestone** Fill preparation is also provided.
Carry out bulk filling	Where fill is required to build up levels, use **Approved Fill**, placed and compacted in accordance with the developed method specification.
Maintain Construction Records	As performance testing cannot be done, quality assurance records are limited. Therefore, the parameters mentioned in Section GDR7.5.1 must be kept in a comprehensive record of the earthworks done to the developed method specification. The use of the PSP is possible only to check for loose sand zones between limestone particles. High PSP blow counts, where limestone particles are intersected, are meaningless in terms of assessing density of the prepared fill. The primary means of validation of the earthworks is conformance with the developed method specification.
Install sand topping layer	Where a sand topping layer is proposed, this should be done as outlined in Section GDR6.2.5.

These measures do not take into account the specifics of the civil design, including the requirement (if any) for excavatable and/or free draining layers to achieve construction and drainage objectives. The civil design must take precedence and is not specifically considered in this advice.

Soakwells can perform poorly in limestone fill and specific advice may apply to the installation of soakwells in limestone fill areas. If not discussed in our report, please contact us for further advice.

GDR6.2.8 Rock Sites

The preparation measures outlined below are provided for sites underlain by rock, meeting the following criteria:

- Site underlain by shallow soil overlying rock, or outcropping rock.
- No shallow groundwater or surface water (>1 m deep).
- Common site preparation measures outlined in GDR6.2.1 have been completed. In addition to these measures, any surface cobbles/boulders will need to be removed from the site.

The site preparation measures outlined below are aimed at improvement of the site for construction of structures including on-ground slabs, shallow footings, retaining walls and pavements.

Approved Fill will be as specified in this report. The re-use of any rock for fill is subject to the civil design requirements and any other requirements noted in the report text. The preparation measures outlined below assume **Approved Fill**.

Table GDR 10: Standard Rock Site Measures (Bulk Earthworks)

Measure	Commentary
Moisture condition and proof compact.	Moisture condition and compact the exposed ground (soil above rock) to achieve the density specified in Section GDR7.1 to a depth of at least 300 mm. Proof compaction of rock is not required.
Test proof compaction	Check that the density specified in Section GDR7.1 has been achieved to a depth of at least 300 mm. in situ NDG testing is suitable to assess compaction. Compaction control of intact rock is not required.
Treat areas of loose or unsuitable material	Any areas of loose / soft or unsuitable material (including over-excavated areas of former trees and root balls) must be removed and replaced with compacted **Approved Fill** as outlined in the report or as noted above. The report will explain the suitability of site-derived materials for re-use as **Approved Fill.**
Carry out bulk filling	Where fill is required to build up levels, use **Approved Fill**, placed and compacted in layers of no greater than 300 mm loose thickness. Test compaction to achieve the density specified in Section GDR7.1.
Grade surface	Surface water control may be required for lower permeability soils/rock, or at an interface where high permeability fill is placed over relatively impermeable soils/ rock. The surface of any impermeable ground / rock must be graded at a minimum of 1% crossfall to drain. This is a general recommendation, and an appropriate civil design must be done to account for surface and subsoil drainage.

These measures do not take into account the specifics of the civil design, including the requirement (if any) for excavatable and/or free draining layers to achieve construction and drainage objectives. The civil design must take precedence and is not specifically considered in this advice.

Soakwells can perform poorly in rock and specific advice may apply to the installation of soakwells in these areas. If not discussed in our report, please contact us for further advice.

Without further consultation with the structural designer, footings for any one structure must not be founded on a mixture of sand and rock. This is due to potential differential settlements between rock zones (relatively hard) and soil zones (relatively soft). Where this is the case, the measures outlined below must be followed, only with guidance from the structural designer and Galt.

Table GDR 11: Standard Rock Site Measures (Footing and Slab Preparation)

Measure	Commentary
Excavate and compact for slabs, subgrades, pad or strip footings	Excavate for pad and strip footings. Where a mix of soil and rock is present below any one structure, one of the following must be done (to be agreed with structural designer and us): ▪ **Over-excavate rock and replace with compacted soil:** Typically where the foundation largely comprises soil and a relatively small amount of rock is present. Where footings and slabs are founded partly on soil and partly on rock, over-excavate the rock by at least 300 mm below the base of footing or slab and replace the excavated material with compacted **Approved Fill**. ▪ **Remove soil from over rock and replace with concrete**: Typically where the foundation largely comprises rock and a relatively small amount of soil is present. Localised zones of sand and mixed sand/rock rubble must be removed and replaced with lean-mix concrete (e.g. 10 MPa blinding concrete) or cement stabilised sand (minimum UCS=2 MPa at 7 days). ▪ **Design the structure to accommodate differential foundation movements:** For example, include construction joints or use a more heavily reinforced footing (subject to the structural designer's requirements).

Measure	Commentary
Test compaction of footing bases, slabs or subgrades.	Compact the exposed bases to achieve the density specified in Section GDR7.1, to a depth of at least 300 mm, or to the depth where rock is intersected. If refusal to the test method is encountered within the target test depth on rock and the results to the refusal depth are acceptable, it is not necessary to repeat compaction testing at that location. Compaction control of intact rock is not required. Remove, replace and compact as required with **Approved Fill** any zone not achieving the density specified in Section GDR7.1.

GDR6.3 Guidance on Sites with Cohesive Soils

Cohesive soils (most commonly, "clayey" soils) require careful moisture conditioning to facilitate compaction. We recommend that the moisture content of the material is between optimum moisture content (OMC) and 2% wet of OMC at the time of placement and compaction. We note that compaction to the densities specified in Section GDR7.1 can be difficult to achieve for clayey material when not appropriately moisture conditioned.

Vibratory padfoot rollers are preferred for compacting cohesive fill to promote proper kneading and interlocking of subsequent layers.

Clayey soils will drain poorly when inundated following rain events and result in saturated conditions that may inhibit compaction of the soil. In general, it is preferable to avoid trying to re-work clayey sites within several days of any substantial rainfall.

We recommend that the surfaces of clayey sites are sealed by compaction (i.e., final compaction should be with a smooth drum roller) and graded to drain (to avoid low spots where water can pond and cause softening) prior to any rain events. Stripping back of softened materials to expose competent natural or compacted clayey soil is required before continuing earthworks.

If difficulties are experienced during compaction due to water, further advice should be sought from a geotechnical engineer.

GDR6.4 Preparation and Testing of Shallow Footings

GDR6.4.1 General

It is preferable to dig all footing excavations carefully with a flat-edged bucket to minimise the disturbance of underlying foundation soil.

Where the footing base is disturbed, or compaction is required, this must be done using appropriate compaction equipment particular to the task (as evaluated by the contractor) – typically a 'jumping jack', self-propelled plate compactor or an excavator-mounted plate compactor.

All footing bases must be tested to achieve the density requirements of Section GDR7.1 unless otherwise specified. PSP testing of sand foundations is only applicable where the use of the PSP is specifically approved in the report, otherwise all testing is to be done using the NDG.

Sand Topping Layer – Where a sand topping layer is present over a different soil (i.e., clay, limestone etc.), testing of the density of the sand topping layer is only necessary within the thickness of the sand topping layer. Testing does not need to extend into the underlying compacted substrate, which is separately subjected to compaction control.

Mixed Sand/Limestone Fill – Where mixed sand/limestone fill has been installed to a method specification, no compaction control testing is required, however re-compaction of the base must be done as noted above.

In situ limestone – where in situ limestone (weakly or more cemented limestone, with no sand zones or voids) is present at a footing base and no over-excavation has been done (refer to Section GDR6.2.6 regarding over-excavation of footing bases in limestone), then no compaction control testing is required.

Where loose or soft material is encountered, one of the following actions must be taken:

- Over-excavate the loose / soft layer to expose a suitable layer that does meet the required density (Section GDR7.1) and either:
- Place and compact Approved Fill (relevant to the appropriate preparation measures outlined in Section GDR6.2) to achieve the required density (Section GDR7.1); or

- Pouring blinding concrete (f'_c>15 MPa at 28 days) from the competent layer up to the underside of the footing.

All foundations must be assessed by a competent person prior to blinding.

GDR6.4.2 Footings in Clay

Where footings are excavated into natural clay and not subject to filling, density testing (e.g., NDG testing) is not required at the base of the footings. This will be highlighted in the report text if this is relevant to the site conditions. Footing bases must be dug with a flat-edged excavator bucket and the underlying soil not disturbed by trafficking or over-excavation.

In these instances, only testing with a DCP is required in accordance with AS1289.6.3.2 at the footing base to achieve the required blow counts indicated in the report text, to a minimum depth of 0.6 m below the base of the footing, or other depth as indicated in the report text. Where the minimum blow count specified cannot be met, the following options are possible to prepare the footing base:

- Scarify, moisture condition and re-compact all zones not achieving the minimum blow counts. Re-test with a DCP to confirm that any soft zones are remediated; or
- Over-excavate and replace all zones not achieving the minimum blow counts with a suitable compacted low permeability fill (e.g., crushed limestone, clayey fill or other approved fill). This fill must be compacted to the appropriate level as specified in GDR7; or
- Over-excavate and replace all zones not achieving the minimum blow counts with blinding concrete (min. 10 MPa at 28 days) or cement-stabilised sand (min. 2 MPa at 7 days). This is typically appropriate where only the upper zones below the footing base are soft.

Measures must be taken to minimise moisture changes in clayey foundation soils at the base of footing excavations. Concrete footings are to be poured soon after excavation to minimise the potential for excessive moisture change. The use of a concrete blinding layer following foundation preparation should be considered.

GDR7 COMPACTION AND MOISTURE CONDITIONING

GDR7.1 Requirements

Any soil within the significant founding zone of structures (buildings, slabs, pavements, etc.) must be suitably moisture conditioned and compacted. These soils must be compacted to the requirements as outlined below.

Table GDR 12: Compaction and Moisture Requirements

Soil Description	Soil Particle Limits	Moisture Requirement	Density Requirement (DDR)	Possible QA/QC Test Methods
Sand	<5% fines <5% gravel *Maximum particle size 9.5 mm*	MOMC ±2%	95% MMDD	PSP NDG
Gravel	<5% fines >50% gravel *Maximum particle size 19.0 mm*	MOMC ±2%	95% MMDD	NDG
Clayey/Silty Gravel	5-35% fines >50% gravel *Maximum particle size 19.0 mm*	MOMC ±2%	95% MMDD	NDG
Sand with fines or gravel	5-35% fines; and/or 5-50% gravel *Maximum particle size 19.0 mm*	MOMC ±2%	95% MMDD	NDG Method Specification
Fine grained soils (Clayey or Silty)	>35% fines *Maximum particle size 19.0 mm*	MOMC ±2%; or SOMC ±2%[2]	92% MMDD; or 95% SMDD	NDG Method Specification
Oversize/rubbly soil	Any soils with particles >19.0 mm	MOMC ±2%	95% MMDD (Or equivalent to)	Method Specification Detailed Assessment Based on Specific Material

NOTES: ***1.*** *DDR – Dry Density Ratio*

MMDD – Modified maximum dry density (AS1289.5.2.1)
MOMC – Modified optimum moisture content (AS1289.5.2.1)
SMDD – Standard maximum dry density (AS1289.5.1.1)
SOMC – Standard optimum moisture content (AS1289.5.1.1)
PSP – Perth Sand Penetrometer
NDG – Nuclear Density Gauge

2. *Preferably OMC to OMC +2%, for ease of compaction and producing a homogenous fill*
3. *Test frequencies are specified in Section GDR7.6.*

The soil groups and definitions outlined above are generally based on AS1726-2017. Test methods are discussed in subsequent sections.

GDR7.2 Construction Recommendations

Over-excavation and replacement of loose material must be done where the minimum DDR cannot be achieved.

Fill must be placed in horizontal layers of not greater than 300 mm loose thickness. Each layer must be compacted by suitable compaction equipment, and carefully controlled to ensure even compaction over the full area and depth of each layer.

Care will need to be taken if compacting in the vicinity of existing structures, such as the adjacent properties. This is particularly important if vibratory compaction is being carried out.

- Tynan (1973), "Ground Vibration and Damage Effects on Buildings", Australia Road Research Board, Special Report No. 11.

Tynan (1973) provides guidance on the selection of compaction equipment for use adjacent to structures. The distance of influence (i.e., the definition of "vicinity") will vary depending on the size of compaction plant proposed for use. Where there is concern regarding the impact on nearby structures, a dilapidation study should be done.

Care must be taken when compaction is undertaken when the site surface is within 1 m of the groundwater level, as compaction (particularly with vibration) can draw the water up to the surface. In this instance, consideration should be given to:

- Static rolling only;
- Using a pioneering layer (if possible); or
- Dewatering to keep the water at least 1 m below the surface being compacted.

GDR7.3 Nuclear Density Gauge

Where applicable, a nuclear density gauge (NDG) must be used in accordance with AS1289.5.8.1. NDG tests must be done to a depth of 300 mm or as otherwise indicated in the text of the attached report.

GDR7.4 Perth Sand Penetrometer

Where clean sand is used (<5% fines and <5% gravel), a Perth sand penetrometer (PSP) may be used for compaction control in accordance with AS1289.6.3.3. Refer to the report for recommended blow counts correlating to the specified density.

Where the fines or gravel contents of a sand soil exceed the maximum contents noted above, a PSP must not be used exclusively for compaction control. As a minimum, ongoing confirmation testing with an NDG is required. If not specified in our report, please contact us for further advice regarding test frequencies.

If difficulties are experienced recording the required blow counts, a site-specific PSP correlation should be carried out to determine the PSP blow count correlating to a DDR of 95% MMDD. In addition, a particle size distribution (PSD) test should be carried out to verify that the use of a PSP is suitable for the sands being tested. A site-specific PSP correlation must:

- be done on site;
- use the nuclear density gauge (NDG) to determine density at a minimum of 5 points with varying density to a depth of 300 mm below surface;
- include at least 1 point where the dry density ratio is in excess of 95% MMDD;
- use a calibrated PSP to determine the PSP blow count from 150 mm to 450 mm at each NDG test point; and
- be plotted on a chart of PSP blow count vs DDR.

Only where specifically stated as applicable in the report and where the use of the PSP is relevant as noted above, the following values may be taken as deemed to conform to a dry density ratio of 95% MMDD for the relevant sand type.

Table GDR 13: Deemed-to-comply Values for PSP Results in Perth Sands

Depth Interval (mm)	Bassendean	Tamala	Calcareous
0-150	SET	SET	SET
150-450	7	8	12
450-750	9	10	14
750-1050	11	12	16

NOTES:
1. *Blows per 300 mm interval*
2. *Bassendean Sand is typically a white - grey, low-fines quartz sand found on the eastern part of the Perth coastal plain*
3. *Tamala / Spearwood sand is typically yellow or orange, low-fines quartz sand found on the western part of the Perth coastal plain*
4. *Calcareous sands are typically white or yellow, calcareous sand found in low-lying areas on the western fringe of the Perth coastal plain*
5. *Values derived from Galt experience on PSP correlations done on sites across Perth for the 150-450 mm interval.*

GDR7.5 Method Specifications

GDR7.5.1 General

Where proposed, a method specification should be developed by a geotechnical engineer or similarly qualified person and ratified by us (including a site visit by us). The method specification should be confirmed by the construction of a trial pad or trial area and the compaction methodology should be checked against either:

- density, as assessed using a nuclear density gauge; or
- settlement, as assessed using a dGPS.

Specific advice should be requested for the development of a method specification, taking into consideration the material being compacted.

Method specification compliance should be maintained for all areas on a minimum 20 m grid, with the compliance to include:

- Roller used (weight, style, vibration);
- Water application rate (per lift);
- Layer thickness placed; and
- Number of passes with roller.

GDR7.5.2 Indicative Method Specification – Sand/Limestone Rubble Mix

Where mixed sand/limestone is used as structural fill, a performance specification is not appropriate due to the inaccuracies of standard test methods (NDG/PSP etc.) in this type of material. A method specification can be used instead. The following indicative method specification is provided for evaluation and trial but must be trialled and ratified by us prior to widespread employment on site. The following would be typically adopted:

- Maximum particle size: 250 mm
- Maximum loose layer thickness: 350 mm
- Minimum watering rate: 10 L/m^2/100 mm thickness of loose material (e.g. 35 L/m^2 for a 350 mm thick layer)
- Minimum 8 passes with a vibrating padfoot roller, minimum static weight 10 tonnes.
- The compacted fill must comprise closely packed particles without any significant voids between the larger particles.

GDR7.6 Testing Frequency

After compaction, verify that the required density has been achieved by testing at the base of excavation and through the full depth of any fill, and to a minimum depth of:

- 900 mm where a PSP is used; or
- 300 mm where a NDG is used.

The frequency of testing (when a method specification is not used) should be as follows:

Table GDR 14: Compaction Testing Frequency Requirements

Area	Minimum Testing Frequency	Minimum Tests Per Lot
Proof Compacted Area	1 test per 1,000 m^2 (30 m grid)	2
Structural Fill Outside of Building and Pavement Footprints	1 test per 500 m^3 2 tests per layer *Whichever is greater*	2
Structural Fill Within Building and Pavement Footprints	1 test per 500 m^3 4 tests per layer *Whichever is greater*	4
Spread/Pad Footings	1 test per 9 m^2 per footing	1
Strip Footings/Retaining Wall Foundations	Minimum 2 tests At 5 m centres *Whichever is greater*	2
On-ground slabs, pavements and rafts	Minimum 2 tests At 10 m centres 1 test per 100 m^2 *Whichever is greater*	2

NOTES: ***1.*** *A 'lot' is defined in the context of this section as a section of earthworks that is undertaken in one operation where the equipment, personnel, materials and methodology are consistent throughout the entire process. This would typically be limited to operations done in one day, but this is not mandatory.*

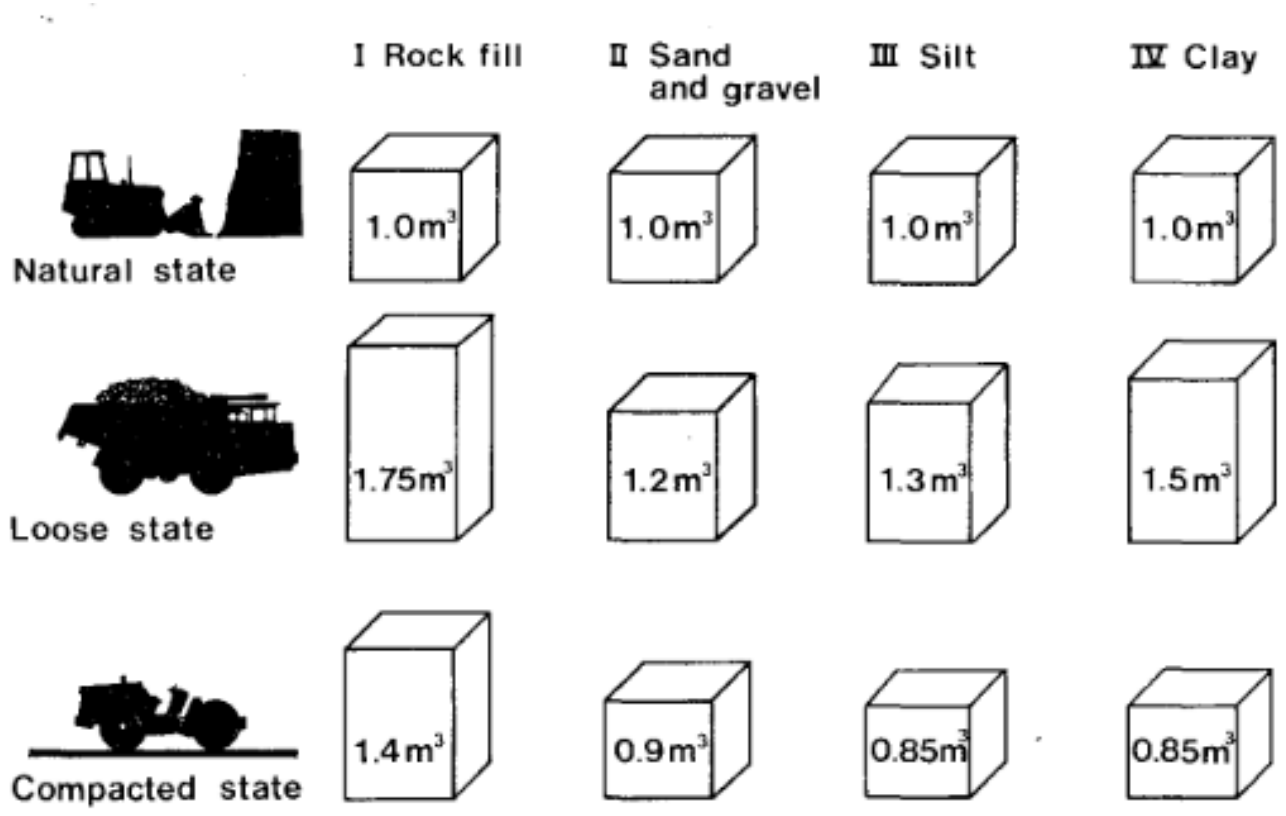
2. *There will frequently be multiple 'lots' in an earthworks process, therefore the number of tests must be adjusted according to the minimum number per lot in this table (where this is more than the frequency specified in 'testing requirements').*

GDR7.7 Bulking and Compaction Factors

All soils will "bulk" when excavated to stockpile, and "compact" when placed from stockpile to earthworks layers. Published bulk and compaction factors are presented below for conventional materials, taken from:

- Forssblad, L (1981), "Vibratory Soil and Rock Fill Compaction", Dynapac Maskin AB

Inline Image GDR 3: Volumes of Different Types of Fill Materials in Natural, Loose and Compacted State



These values are indicative only and will vary according to site specific conditions. The values provided here must not be used for commercial volume estimates or settling disputes regarding volumes.

GDR8 APPROVED FILL AND CONFORMANCE TESTING

Imported fill must comply with the material requirements as stated in AS 3798-2007, “Guidelines on Earthworks for Commercial and Residential Developments”.

Where doubt exists, a geotechnical engineer must be engaged to inspect and approve the use of potential fill materials.

The following table presents recommended material parameters for standard fill types. This does not take account of availability of materials either on site or in the local area. Refer to the report text for specific advice on fill at the subject site.

Table GDR 15: Standard Fill Recommendations

Soil Description	Application	Soil Particle Limits (%)[3]				k_{min}[1] (m/d)	OC[2] (%)	Atterberg Limits		CBR[6] (%)	Test Method[4]
		Fines	Sand	Gravel	Max.			LL (%)	PI (%)		
Permeable Sand	Permeable bulk fill Retaining wall backfill Permeable select fill	≤5	≥90	≤5	9.5	5	≤2	NP	NP	≥12	PSP NDG
General Sand	Bulk fill Select fill (permeability not required)	≤5	≥90	≤5	9.5	N/A	≤2	NP	NP	≥12	PSP NDG
Silty Sand	Bulk fill Select fill	≤35	≥55	≤10	9.5	N/A	≤2	<35	<11	≥12	NDG
Clayey Sand	Bulk fill Select fill	≤35	≥55	≤10	9.5	N/A	≤2	<40	N/A	≥12	NDG
Granular Fill	Bulk Fill	≤30[10]	Varies[10]	Varies[10]	37.5	N/A	≤2	<40	N/A	N/A	NDG
Mixed Sand/Limestone	Bulk fill (permeability not required)	≤5	≥20	≤80	250	N/A	≤2	NP	NP	N/A	NDG Method
Blue Metal Gravel[8]	Retaining wall backfill Drainage trench backfill	≤3	≤5	≥90	37.5	5	≤1	NP	NP	N/A	NDG
Clay[7]	Reinstatement of localised excavations in clay Bulk fill	≥12	Varies	≤30	19	N/A	≤2	Varies			NDG

NOTES:

1. *k_{min} – minimum saturated hydraulic conductivity (AS1289.6.7.1, remoulded to minimum DDR 100% MMDD).*
2. *OC – organic content (Walkley-Black method recommended, AS1289.4.1.1 – not loss on ignition methods)*
3. *% by mass.*
4. *Test method indicates possible compaction control methods for this material.*
   PSP – Perth sand penetrometer (AS1289.6.3.3). Where a PSP is used, a site-specific correlation must be done unless otherwise noted in the report.
   NDG – Nuclear density gauge (AS1289.5.8.1)
   Method – method specification
5. *Atterberg Limits: LL – liquid limit PI – plasticity index NP – non-plastic*
6. *CBR: California bearing ratio (for sand - remoulded to DDR 95% MMDD @ OMC, 4.5 kg surcharge). CBR values may be changed depending on the design pavement requirements.*
7. *"Clay" fill type is included for broad reference only and to illustrate preferred applications, particle size limits and recommended test method. Specific discussion on the use of clayey fills is included in the report text if applicable. Atterberg limit and CBR testing of clayey fills may be required and advice must be sought from us if not stated in the report.*
8. *"Blue metal" gravel refers to single sized, crushed, washed igneous rock gravel used for drainage purposes.*
9. *In the absence of specific test frequencies by the civil designer, the testing shown in Table GDR 16 must be done (highlights in Table GDR 15 show where the test is required).*
10. *Sand and gravel must be reasonably graded to control the risk of soil ingress from surrounding layers. Where the fines content is high (e.g. above ~15%), the gravel content should proportionally increase to meet the requirements for "granular fill". We recommend a minimum gravel content of 30% where the fines content is above 15%.*

Table GDR 16: Conformance Testing Frequency Requirements

Parameter	Frequency (m^3)	Minimum Tests per Source	AS1289 Reference
Particle size distribution	5,000	1	3.6.1
Hydraulic conductivity (permeability)	10,000	2	6.7.1
Organic content	5,000	1	4.1.1
Atterberg limits	5,000	1	3.1.1, 3.2.1, 3.3.1
CBR	10,000	2	6.1.1

NOTES: ***1.*** *Frequency is for the nominal number of cubic metres of compacted fill.*

2. *Unless stated otherwise in the report text, the conformance testing must also be carried out on site-derived materials to confirm suitability.*

GDR9 SHALLOW FOUNDATIONS

GDR9.1 Design

Footings and slabs may be designed in accordance with the assigned site classification in accordance with AS2870-2011. We note that AS2870-2011 is limited to single and double storey residential and commercial developments and may not be strictly applicable.

Where the report provides tables for shallow footing design, custom footings may be designed by the structural engineer using the data provided therein.

GDR9.2 Interpretation of Provided Values

BEARING PRESSURES

All settlement and bearing pressures estimates are provided on the assumption that the site preparation requirements outlined in the report are completed below all structures plus a minimum distance of 1 m beyond the outside edge of any footing or slab. It is essential that the soil below all foundations is appropriately prepared as outlined and meets the relevant compaction requirements.

Allowable bearing pressures for footings of intermediate plan dimensions (to any tabulated) can be interpolated. Footings that have a plan dimension either smaller or larger than those presented in the report will need to be considered individually along with other embedment depths.

Allowable bearing pressures, where provided, are considered to be the upper limit for shallow footings to limit total and differential settlements. Footings carrying eccentric loading, such as below retaining walls, must be assessed separately.

SETTLEMENTS

The reporting of settlements to any precision level is not intended to imply a high accuracy of settlement prediction. Settlements as reported should be considered ‘order of magnitude’.

Estimated settlements represent vertical downwards movement due to loading and do not take into account potential additional movement associated with the characteristic surface movement of the soil (which must be taken in addition to these settlements from loading, refer Section GDR5). The site classification is discussed in the report.

The actual settlement of any proposed structure will depend upon a number of factors including the applied pressures, footing size and base preparation. The estimated settlement(s) provided in this report are for the working bearing pressures as indicated. Differential settlements are likely between footings of similar sizes, loads and elevations (as stated in the report text). A proportion of the settlement is expected to occur during construction (i.e., during initial loading.

The provided settlement estimates (unless otherwise stated) do not include interaction effects from footings founded near other footings (i.e., groups of footings). Interaction effects will need to be considered if the spacing between adjacent footings is smaller than the dimension of the footings (i.e., the centre-to-centre spacing between footings is less than twice the width of the footing). This could act to double provided settlements, dependent on the footing configuration. Where an assessment of footing groups is required, a more detailed numerical or finite-element modelling analysis would need to be undertaken.

CREEP AND CONSOLIDATION

Creep settlement is an irreversible component of long-term soil settlement caused by sustained vertical stress. Consolidation is a time-dependent irreversible compression in a soil layer caused by a reduction in pore pressure between soil particles. Both creep and consolidation can occur in natural materials as a result of earthworks or the placement of loads on to soil layers. The settlements as presented for short-term loading do not include consideration for creep and consolidation settlements unless specifically stated.

GDR9.3 Raft Foundations

Where moduli of subgrade reactions are provided for the design of raft foundations, we highlight that these are an estimate of the elastic reaction of the soil. The values are provided based on an expected load and loaded area size. Soils are typically non-linear in their response and will have different stiffnesses at different levels of strain and load repetitions. This is due to the physical interaction of soil particles under different levels of stress.

The possibility of a non-linear response must be considered by the designer of any raft foundation.

GDR10 PILED FOUNDATIONS

Piles must be designed and tested in accordance with AS2159-2009, “Piling – Design and Installation”. We use the following interpretation/design methods to provide pile design parameters:

- Franki Africa Pty Ltd (2008) “A Guide to Practical Geotechnical Engineering in South Africa”. 4th ed.
- AFNOR (2012) “NF P 94-262 – Justification des ouvrages géo-techniques, Normes d’application nationale de l’Eurocode 7”, Afnor, Paris, July 2012.
- Lehane, B. (2017) “CPT-Based Design of Foundations”. E.H Davis Memorial Lecture, Australian Geomechanics Vol 54. No. 4.
- Lehane, B. et al. (2020) “A New ‘Unified’ CPT-Based Axial Pile Capacity Design for Drivel Piles in Sand”. Proceedings of the Fourth International Symposium on Frontiers of Offshore Geotechnics.
- Doan., Lehane, B. (2021) “CPT-Based Design Method for Axial Capacities of Drilled Shafts and Cast-in-place Piles.” American Society of Civil Engineers (ASCE), Journal of Geotechnical and Geoenvironmental Engineering.

The pile designer must:

- consider the possible variation in subsurface conditions at each pile location;
- consider any pile group effects based on the final piling configuration;
- assume that the unit shaft resistance in tension is less than 80% of the unit shaft resistance in compression to account for Poisson’s effect in sand;
- ignore pile resistance in the surficial 0.5 m or 1 x pile diameter (whichever is greater), if relevant;
- consider the impact of weak layers underlying stiffer layers (or vice versa) on end bearing capacity; and
- reduce the pile capacity in tension to no greater than 0.8 of the pile capacity in compression.

The piling contractor must:

- make their own assessment on the suitability of their equipment to install any piles at the subject site; and
- carry out or appoint a suitably experienced contractor to test the piles in accordance with AS2159.

Where dynamic or static testing of the piles does not occur, we consider that a design geotechnical reduction factor (ϕg) of 0.4 is applicable for the pile design. If testing of the piles is proposed by the piling contractor, a higher ϕg could be adopted.

Unless otherwise stated, providing pile design parameters does not specifically indicate the driveability of any piles into soil units.

A separate driveability study may be required and must be considered by the pile designer and installer. The given pile design parameters must not be used for driveability assessments as these parameters are likely to be un-conservative.

GDR11 EARTH RETAINING STRUCTURES

GDR11.1 General

Retaining structures may be designed in accordance with AS4678 (2002) "Earth Retaining Structures". Unless otherwise specifically stated, we recommend that all retaining walls are backfilled with free-draining soil (Permeable Sand or Blue Metal Gravel as defined in Section GDR8).

Where the cohesive soil is used as retaining wall backfill, a suitable, permanent drainage system must be placed behind the wall such that a build-up of pore pressure is prevented. A separator geotextile (Bidim A24, or similar, or heavier) must be used between the interface of any granular backfill and the cohesive soil.

Where drainage is not provided, the retaining wall must be designed to accommodate water pressure behind the wall (10 kPa per metre height).

GDR11.2 Earth Pressure Coefficients and Strength Parameters

Where earth pressure coefficients are provided for retaining walls, the wall designer must make an independent assessment of the parameters appropriate to the construction method to be used, including alternative values of wall friction. Unless otherwise stated, we have assumed a horizontal ground surface behind and in front of the retaining wall for provided parameters.

GDR11.2.1 Cohesionless Soils

Where cross-referenced for suitability in the report, the following parameters may be adopted for design of earth retaining structures in cohesionless soils (sand and gravel).

Table GDR 17: Retaining Wall Geotechnical Parameters (Cohesionless Soils)

Density	γ (kN/m^3)	ϕ' (°)	k_0	Wall Friction=0		Wall Friction=0.5ϕ		Wall Friction=0.67ϕ	
				k_a	k_p	k_a	k_p	k_a	k_p
Very Loose	17	30	0.44	0.33	3.00	0.29	4.81	0.28	5.74
Loose	17	32	0.42	0.31	3.25	0.27	5.55	0.26	6.83
Medium Dense	18	34	0.39	0.28	3.54	0.25	6.47	0.23	8.26
Dense	19	36	0.36	0.26	3.85	0.22	7.63	0.21	10.18
Very Dense (1)	19	38	0.34	0.24	4.20	0.21	9.11	0.20	12.85
Very Dense (2)	19	40	0.31	0.22	4.60	0.19	11.06	0.18	16.73

NOTES:

1. *Earth pressure coefficients are provided in this table for conditions of zero friction between the wall and the soil and with wall friction of 0.5Φ' or 0.67Φ'.*
2. *A horizontal ground surface behind and in front of the wall has been assumed.*
3. *The retaining wall designer should make an independent assessment of the parameters appropriate to the construction method to be used, including alternative values of wall friction.*
4. *γ – bulk unit weight*
   ϕ' – effective friction angle
   k_a – coefficient of active earth pressure (Coulomb – AS4678-2002, Appendix E)
   k_p – coefficient of passive earth pressure (Coulomb – AS4678-2002, Appendix E)
   k_0 – coefficient of at-rest earth pressure (Jaky)
5. *Maximum fines content 12% for applicability of this table for design purposes.*
6. *Unit weights based on Table D1 of AS4678-2002, for moist bulk weight.*
7. *Friction angle based on Equation D1 and Table D2 of AS4678-2002, based on rounded, moderately graded siliceous sand.*

GDR11.2.2 Cohesive Soils

Where cohesive soils (i.e. clayey or silty soils) are proposed for backfill, geotechnical design parameters may be provided in the form of effective strength and undrained strength parameters. We note that:

- Undrained strength parameters should be used for analysis of short-term stability, or stability under sudden loading of cohesive soils.
- The effective strength parameters should be used for analysis of free-draining soils and the long-term stability of cohesive soils.

Table GDR 18: Retaining Wall Geotechnical Design Parameters (Cohesive Soils – Undrained)

Consistency	γ_b (kN/m^3)	c_u (kPa)
Soft	17	12
Firm	18	25
Stiff	19	50
Very Stiff	20	100
Hard	20	200

NOTES:
1. *γ_b – bulk unit weight*
   c_u – undrained cohesion
   $\phi_u = 0^o$ (undrained friction angle)
2. *Unit weights based on Table D1 of AS4678-2002*
3. *Undrained cohesion based on lower end of shear strengths as define in AS1726-2017, Table 11*

Table GDR 19: Retaining Wall Geotechnical Design Parameters (Cohesive Soils – Drained)

Fines Content	PI (%)	γ_b (kN/m^3)	ϕ' (°)	c' (kPa)[5]
12-35%	All	19	32	0
>35%	10	20	30	0 – 5
>35%	20	20	26	0 – 5
>35%	30	20	23	0 – 5
>35%	40	20	21	0 – 5

NOTES:
1. *γ_b – bulk unit weight*
   c' – drained cohesion
   ϕ' – effective friction angle
   PI – plasticity index
2. *Unit weights based on Table D1 of AS4678-2002, assuming generally stiff to hard overconsolidated soils.*
3. *For fines contents <35% (silty sand and clayey sand), strength parameters based on:*
   - *Lehane, B. et al (2007) "A Laboratory Investigation of the Upper Horizons of the Perth/Guildford Formation in Perth CBD", Australian Geomechanics Vol 42. No. 3.*
4. *For fines content >35% (sandy clay), strength parameters based on:*
   - *CIVL5503 course notes (2004), "Underground Construction", University of Western Australia*
5. *c' = 0 recommended for long-term design. Table D4 of AS4678 suggests c' up to 5 kPa for 'poor' fine grained soils and 10 kPa for 'average' fine-grained soils. The use of c' for design is subject to the designer's judgement but recommended by us only for temporary works.*

Per AS4678-2002 Appendix E, horizontal earth pressures for frictional-cohesive soils may be calculated in accordance with the Rankine-Bell design model (illustrated in Figure E2 of AS4678). The earth pressures are as follows (Z = depth, all other terms have the meanings given in the above tables):

- Active: $p_a = \gamma\ Z\ tan^2\left(45 - \frac{\emptyset}{2}\right) - 2\ c\ tan\left(45 - \frac{\emptyset}{2}\right)$
- Passive: $p_p = \gamma\ Z\ tan^2\left(45 + \frac{\emptyset}{2}\right) + 2\ c\ tan\left(45 + \frac{\emptyset}{2}\right)$

GDR11.3 Design and Construction Considerations

Compaction plant can augment the lateral earth pressure acting on retaining walls. Hand operated compaction equipment is recommended within 2 m of any retaining walls to minimise compaction pressures.

Retaining walls can move and rotate under imposed soil loading resulting in settlement behind the wall. This must be considered in the design and during construction of the retaining walls in order that adjacent infrastructure is not adversely affected.

It is important to note that some ground movement will occur behind any soil retaining system, including gravity retaining walls.

GDR12 EXCAVATIONS, BATTERS AND SLOPES

GDR12.1 Excavatability

Our assessment of the excavatability of rock is based on a combination of:

- Our experience on earthworks and construction projects across Australia; and
- Figure 10 of the revised graphical method of assessing excavatability of rock by:
- Pettifer, G.S. & Fookes, P.G., "A revision of the graphical method for assessing the excavatability of rock", Quarterly Journal of Engineering Geology, 27, pp145-164, 1994.

GDR12.2 Safety

All excavations must be carried out in accordance with:

- Commission for Occupational Safety and Health (2022). "Excavation: Code of Practice", Department of Mines, Industry Regulation and Safety, 89pp, Perth.

Excavations in cohesionless soils are particularly prone to instability unless support is provided. Care must be exercised in such excavations and appropriate safety measures adopted where necessary, particularly in the vicinity of existing buildings, structures and infrastructure.

The toe of any batter must be at least 500 mm above groundwater (including perched groundwater).

Unless a specific slope stability assessment or retention design has been done, the toe of any excavation should not encroach within a line of 1V:3H to any nearby footings, pavements or other settlement-sensitive structures.

Surcharges (such as structures, plant and soil stockpiles) must not be placed at or close to the crest of unsupported excavations, without a specific slope stability assessment.

A geotechnical engineer must be consulted where there is any doubt regarding the stability or safety of unsupported excavations.

GDR12.3 Batters

Temporary batter slopes provided in the report are subject to the following conditions, unless otherwise stated:

- The maximum slope height is 2 m without specific advice and slope stability analysis.
- The groundwater level for the duration of the excavation must be at least 500 mm below the toe of the slope.
- No surcharges are present in the vicinity of the slope (i.e. must be outside a line of 1V:3H from the toe of the slope).

Unless noted specifically in the report, the following batters may be adopted (maximum height: 2 m):

Table GDR 20: Default Batter Angles

Situation	Material	Batter
Temporary	Cohesionless Soils (Sand/Gravel)	1V:2H
Temporary	Cohesive Soils – Soft	1V:2H
Temporary	Cohesive Soils – Firm, Stiff, Very Stiff or Hard	1V:1H
Temporary	Limestone – Variably Cemented	1V:1H
Temporary	Limestone – Well Cemented	1V:0.5H
Permanent	All Soils	1V:3H
Permanent	Limestone – Variably Cemented	1V:2H
Permanent	Limestone – Well Cemented	1V:1H

Where specified batters cannot be accommodated in the vicinity of existing footings, roads and services, temporary or permanent lateral support will be required.

Specific advice is required for batters higher than 2 m.

Erosion control must be considered for permanent slopes.

Rock slopes must be inspected, and all loose cobbles / boulders removed. Permanent rock slopes may require dentition works or possibly rock catch drains.

GDR12.4 Grouting

Permeation or jet grouting involves injecting a microfine cement into soil to form a grouted soil block (soilcrete) to support excavation and structures. Grouting is typically only effective where the soil has the capacity to "take" the grout and form a uniformly cemented soil mass. Permeation grouting is generally limited to relatively permeable, coarse-grained cohesionless soils (sands and gravels with <5% fines).

If grouting is proposed, we recommend the following:

- Grouting must be carried out by a suitably experienced contractor.
- Only microfine cement grout should be used (not GP or coarse cement blends) to ensure adequate penetration into the soil matrix.
- Grouting should be done on a grid of not greater than 300 m.
- Application rates must be discussed with the contractor.
- The grouted soil mass must have intimate contact with any structures it is intended to support.
- The contractor must satisfy themselves that the proposed grouting can be installed with their equipment and into the subsurface conditions encountered at the site, considering possible obstructions, groundwater, cemented layers, loose sands etc.
- Testing of the grouted soil mass must be done to ensure that the grout has adequately permeated through the soil matrix. This can be done by drilling into the soil mass to ensure the cementation is continuous.

Grouting is most effective on permeable, relatively loose natural sand. Where historical filling or other ground disturbances have occurred, the grouting process can be less effective due to the tendency of grout (or other liquids) to follow more permeable paths / zones through the disturbed soil.

GDR13 STORMWATER DISPOSAL AND DRAINAGE DESIGN

GDR13.1 Groundwater Separation – Controlled Groundwater

These recommendations ONLY apply to where regional controls on groundwater (primarily: subsoil drainage, but also surficial 'main drains') exist, i.e. only to areas where groundwater is actively controlled.

The following reference:

- IPWEA (2016), "Specification: Separation Distances for Groundwater Controlled Urban Development", Institute of Public Works Engineering Australasia

recommends the following separation distances from drainage infrastructure to groundwater:

- Underground infiltration systems: 0 mm from the 50% AEP (annual exceedance probability) phreatic surface.
- Surface infiltration systems (vegetated): 300 mm from the 50% AEP phreatic surface.

The above IPWEA reference also states that performance measures for underground infiltration systems are to have a: demonstration of acceptable volumetric capacity when groundwater is elevated above base of system and that the groundwater recedes below the invert of the system during mosquito breeding seasons (grated or partially open systems).

GDR13.2 Groundwater Separation – Uncontrolled Groundwater

These recommendations apply where regional controls on groundwater levels are not present. For infiltration into soakwells and soakage basins to be the full theoretical value, an adequate separation to groundwater must be achieved, because otherwise performance is hindered by inadequate separation to groundwater or partial submergence of the infiltrative element.

We recommend a minimum separation of 500 mm from the underside of infiltrative elements to maximum groundwater level.

- To average annual maximum groundwater level (AAMGL), where this has been defined for the site; or
- To historical maximum groundwater level, where this has been defined to the site.

GDR13.3 Design Hydraulic Conductivity Values

Where provided, the values of hydraulic conductivity (k) should be considered the maximum/upper limit design values. As discussed in Section GDR3.7, the inverse auger hole test is an unsaturated field test carried out above the groundwater table and, as such, presents the best-case conditions for drainage.

For soak wells in sand, we provide the design value taking into consideration the variability in materials and reduced permeability as a result of:

- Densification of sand during site preparation works; and
- Natural variation in sands.

Design k_{unsat} values provided for soak wells are only appropriate for the design of unsaturated soils where the base of disposal area is at least 500 mm above groundwater and 500 mm above any impermeable layer.

Where design values of k_{unsat} have been provided, clogging of the base of the soakwell / drainage basin has not been considered. Clogging will need to be controlled with maintenance over the life of the soakwell / drainage basin.

For the design of subsoil drains or modelling of saturated soil performance, a k_{sat} value must be given (in the report text) or assessed by laboratory testing (or a combination of field and laboratory testing). Unless specifically stated, k_{unsat} values presented in our report are for unsaturated conditions and intended for design of stormwater disposal elements above groundwater. If no k_{sat} value has been provided, do not use the provided k_{unsat} value for saturated drainage design. Please contact us for further advice.

For saturated or semi-saturated sands, the hydraulic conductivity must be assessed by testing of representative soil samples at a NATA accredited laboratory to determine:

- The modified maximum dry density (MMDD); and
- The constant-head permeability (AS1289.6.7.1) on a sample remoulded to at least 5% greater than the proposed specification density (i.e., sample should be remoulded to 100% MMDD if the earthworks specification requires a density ratio of 95% MMDD).

For saturated or semi-saturated clayey or silty soils, the hydraulic conductivity must be assessed by testing of representative soil samples at a NATA accredited laboratory to determine:

- The standard maximum dry density (SMDD); and
- The falling-head permeability (AS1289.6.7.2) on a sample remoulded to at least 3% greater than the proposed specification density (i.e., sample should be remoulded to 101% SMDD if the earthworks specification requires a density ratio of 98% SMDD).

GDR13.4 Soakwells

In uncontrolled groundwater environments, the base of any soakwell must be the higher of:

- At least 500 mm above the average annual maximum groundwater level (AAMGL).
- At least 500 mm above any low permeability/impermeable layers (clay, rock or otherwise).

In controlled groundwater environments (refer to Section GDR13.1), the base of any soakwell may be 0 mm above the controlled groundwater level at the location of the soakwell (as determined by the civil engineer).

Soak wells must be placed outside a line of 1V:2H extending below the edge of the nearest footing, subject to local council regulations. Discharge from soak wells has been known to promote densification of loose sandy soils, leading to settlements of footings and slabs. Soak wells should be carefully wrapped with geotextile to prevent migration of sand and fines into the soak well.

Where soak wells are proposed to dispose of water within a line of 1V:2H from any basement walls or similar, the walls must be waterproofed to prevent seepage or damp within the basement wall.

In potentially karstic terrain or areas of potentially collapsible soils, soakwells should typically be located 10 m from the nearest footing, slab or pavement.

GDR13.5 Design Groundwater Elevation

Where applicable, a recommended design groundwater elevation will be provided in the report and will be identified as such.

In the absence of a specific statement on design groundwater elevation, do not assume that:

- Absence of comments about groundwater indicates an absence of groundwater (in particular, sites that are dry in the dry season to the investigated depth may well become waterlogged in the rainy season).
- Where groundwater depths/levels are noted, that these are fixed (groundwater fluctuations occur over the course of the year and between wetter and drier years).

Where groundwater elevations are likely to be critical for a development (particularly where large-scale subdivision or large developments are proposed with substantial channelling of stormwater into on-site disposal by infiltration), a site-specific hydrology study is likely to be required to confirm design groundwater elevations.

GDR14 DRAINAGE CONTROL

In addition to the site preparation measures outlined for cohesive soils (refer Section GDR6.2.4), careful control of surface water and stormwater is essential to minimise the likelihood of cohesive soils decreasing in strength and affecting the installed infrastructure. These measures include:

- The ground surface of clayey soils should be graded to drain any seepage away from structures and prevent standing water over the cohesive soils. A grade of at least 1% is recommended.
- Pavements should be sealed to minimise water ingress.
- Stormwater disposal swales should be located at least 10 m away from buildings, retaining walls and pavements.
- Runoff from hardstandings and pavements must either be collected and discharged via pipes into discrete locations (via swales or soakage basins) at least 10 m away from structures and pavements or, alternatively, discharged over a wide area, but not allowed to collect and discharge into concentrated areas, particularly near structures and pavements.
- Spoon drains should be used to collect water at the crest of slopes to capture surface runoff and direct it away from running directly down slopes or seeping into the ground behind slopes.

These measures are general in nature only and do not take into account the civil design objectives, which must be addressed separately by the civil designer.

GDR15 DEWATERING

Dewatering may be required for excavations and construction below groundwater or perched groundwater tables. Common dewatering methods are summarised below:

Table GDR 21: Dewatering Recommendations

Material	Recommended Methods
Sandy Soils	Spears Deep Well Point
Impermeable Clay	Sump Pumping

Dewatering spears are typically suitable for small scale excavations below groundwater, with a typical recommendation for spears to be installed at 1 m below the base of any excavation. Dewatering spears may not be suitable where there are impermeable/cemented/strong transition layers, i.e., it may not be possible to extract water near an impermeable layer (rock/clay), or the spear may not be readily driven through a hard clay/cemented layer (i.e., coffee rock).

Sump pumping can be done by grading a clayey excavation to drain (i.e., by using spoon drains), and excavating a sump in the excavation. A sump can typically be backfilled with a blue metal gravel, with a pump wrapped in a geofabric (i.e., Bidim A14 or similar), with disposal of water away from the excavation.

Deep well point dewatering is typically suitable for larger excavations, where there are transitional layers or where the aquifer is confined. It may not be suitable where there are impermeable layers within the profile. It involves the installation of a deep filtered well to a depth required to draw down the groundwater level at the entire site. A deep well dewatering system must be designed by a suitable designer to provide design flow rates, draw down depths etc.

GDR16 PAVEMENT SUBGRADES

Unless otherwise specified, the provided subgrade California bearing ratio (CBR) is not a pavement design, but an assessment of the subgrade as an input into any required pavement designs.

Provided design values are based on the assumption that the relevant site preparation measures are completed for all pavement subgrades, including the use of appropriate approved fill and adequate compaction. We highlight that specific requirements such as those outlined by Main Roads WA (MRWA) or the local council in their construction specifications may have different requirements.

The provided design value is based on laboratory testing (where done), local experience, and the advice as outlined in:

- Main Roads Western Australia (2013). “Engineering Road Note 9 – Procedure for the Design of Road Pavements”. Western Australia Supplement to the Austroads Guide to Pavement Technology Part 2: Pavement Structural Design, East Perth.

Where the subgrade differs from that described in the text, the subgrade CBR must be confirmed.

The performance of any pavement is highly dependent on the surface and subsurface drainage provided (also considering factors like capillary rise from seasonally high groundwater tables). Adequate drainage must be provided to any pavements, and capillary rise must be considered by the designer.

GDR17 SOIL CORROSIVITY AND AGGRESSIVITY

The relevant exposure classifications for concrete and steel piles in soils based on the exposure conditions are presented in Table GDR 22 and Table GDR 23 respectively.

The relevant exposure classifications for concrete in sulfate soils based on the exposure conditions are presented in Table GDR 24.

Table GDR 22: Exposure Classification for Concrete Piles in Soil

Exposure Conditions				Exposure Classification	
Sulfates (expressed as SO_4)[1]					
In Soil (ppm)	In Groundwater (ppm)	pH	Chlorides in Groundwater (ppm)	Soil Conditions A[2]	Soil Conditions B[3]
< 5,000	< 1,000	> 5.5	<6000	Mild	Non-aggressive
5,000 – 10,000	1,000 – 3,000	4.5 – 5.5	6,000-12,000	Moderate	Mild
10, 000 – 20,000	3,000 – 10,000	4 – 4.5	12,000-30,000	Severe	Moderate
> 20,000	> 10,000	< 4	>30,000	Very Severe	Severe

NOTES:
1. *Approximately 100 ppm SO_4 = 80 ppm SO_3*
2. *Soil Conditions A – high permeability soils (e.g. sands and gravels) which are in groundwater*
3. *Soil Conditions B – low permeability soils (e.g. silts and clays) or all soils above groundwater*
4. *Table reproduced from Table 6.4.2(C) of AS2159-2009*

Table GDR 23: Exposure Classification for Steel Piles in Soil

pH	Chlorides		Resistivity (ohm.cm)	Exposure Classification	
	In Soil (ppm)	In Water (ppm)		Soil Conditions A[2]	Soil Conditions B[3]
> 5	< 5,000	< 1,000	> 5,000	Non-aggressive	Non-aggressive
4–5	5,000-20,000	1,000–10,000	2,000 – 5,000	Mildly aggressive	Non-aggressive
3–4	20,000-50,000	10,000–20,000	1,000 – 2,000	Moderately aggressive	Mildly aggressive
< 3	> 50,000	> 20,000	< 1,000	Severely aggressive	Moderately aggressive

NOTES:
1. *1 ppm (parts per million) is equivalent to 1 mg/kg*
2. *Soil Conditions A – high permeability soils (e.g. sands and gravels) which are in groundwater*
3. *Soil Conditions B – low permeability soils (e.g. silts and clays) or all soils above groundwater*
4. *Table reproduced from Table 6.5.2(C) of AS2159-2009*

Table GDR 24: Exposure Classification for Concrete in Sulfate Soils

Exposure Conditions			Exposure Classification	
Sulfates (expressed as SO_4)[1]				
In Soil (ppm)	In Groundwater (ppm)	pH	Soil Conditions A[2]	Soil Conditions B[3]
< 5,000	< 1,000	> 5.5	Mild	Non-aggressive
5,000 – 10,000	1,000 – 3,000	4.5 – 5.5	Moderate	Mild
10, 000 – 20,000	3,000 – 10,000	4 – 4.5	Severe	Moderate
> 20,000	> 10,000	< 4	Very Severe	Severe

NOTES:
1. *Approximately 100 ppm SO_4 = 80 ppm SO_3*
2. *Soil Conditions A – high permeability soils (e.g. sands and gravels) which are in groundwater*
3. *Soil Conditions B – low permeability soils (e.g. silts and clays) or all soils above groundwater*
4. *For disturbed soils, the assumption of soil A conditions where accelerated corrosion is possible should be considered.*
5. *Table reproduced from Table 4.8.1 of AS3600-2018*

GDR18 LIQUEFACTION

Soil liquefaction can occur when loose, granular, Holocene age material below the groundwater table is subjected to a seismic event (typically within 15 m of the ground surface). This can cause a loss of strength and result in vertical and lateral movements of the site surface.

Where a liquefaction analysis is carried out and outlined in the report, this has been done in accordance with consideration to the design earthquake details as presented in AS1170.4-2007:

- The hazard factor is taken from Figure 3.2 (C) and Table 3.2. The Hazard Factor (Z) for Western Australia represents the 1 in 500-year annual probability of exceedance of ground motions measured in gravity (g).
- The probability factor (k_p) is taken from Table 3.1.

Unless otherwise stated, an earthquake magnitude of 7.5 for the south-west of WA is based on research by:

- Dhu T., Sinadinovski C., Edwards M., Robinson D., Jones T., Jones A. (2004) “Earthquake Risk Assessment for Perth, Western Australia”. 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada. Paper No. 2748.

GDR19 EXPECTATIONS OF THE REPORT

The following sections have been prepared to clarify what is and is not provided in your report. It is intended to inform you of what your realistic expectations of this report should be and how to manage your risks associated with the conditions on site.

Geotechnical engineering and environmental science are less exact than other engineering and scientific disciplines. We include this information to help you understand where our responsibilities begin and end. You should read and understand this information. Please contact us if you do not understand the report or this explanation. We have extensive experience in a wide variety of projects and we can help you to manage your risk.

GDR20 THIS REPORT RELATES TO PROJECT-SPECIFIC CONDITIONS

This report was developed for a unique set of project-specific conditions to meet the needs of the nominated client. It took into account the following:

- the project objectives as we understood them and as described in this report;
- the specific site mentioned in this report; and
- the current and proposed development at the site.

It should not be used for any purpose other than that indicated in the report. You should not rely on this report if any of the following conditions apply:

- the report was not written for you;
- the report was not written for the site specific to your development;
- the report was not written for your project (including a development at the correct site but other than that listed in the report); or
- the report was written before significant changes occurred at the site (such as a development or a change in ground conditions).

You should always inform us of changes in the proposed project (including minor changes) and request an assessment of their impact.

Where we are not informed of developments relevant to your report, we cannot be held responsible or liable for problems that may arise as a consequence.

Where design is to be carried out by others using information provided by us, we recommend that we be involved in the design process by being engaged for consultation with other members of the project team. Furthermore, we recommend that we be able to review work produced by other members of the project team that relies on information provided in our report.

GDR21 DATA PROVIDED BY THIRD PARTIES

Where data is provided by third parties, it will be identified as such in our reports. We necessarily rely on the completeness and accuracy of data provided by third parties in order to draw conclusions presented in our reports. We are not responsible for omissions, incomplete or inaccurate data associated with third party data, including where we have been requested to provide advice in relation to field investigation data provided by third parties.

GDR22 SOIL LOGS

Our reports often include logs of intrusive and non-intrusive investigation techniques prepared by Galt. These logs are based on our interpretation of field data and laboratory results. The logs should only be read in conjunction with the report they were issued with and should not be re-drawn for inclusion in other documents not prepared by us.

GDR23 THIRD PARTY RELIANCE

We have prepared this report for use by the client. This report must be regarded as confidential to the client and the client's professional advisors. We do not accept any responsibility for contents of this document from any party other than the nominated client. We take no responsibility for any damages suffered by a third party because of any decisions or actions they may make based on this report. Any reliance or decisions made by a third party based on this report are the responsibility of the third party and not of us.

GDR24 CHANGE IN SUBSURFACE CONDITIONS

The recommendations in this report are based on the ground conditions that existed at the time when the study was undertaken. Changes in ground conditions can occur in numerous ways including anthropogenic events (such as construction or contaminating activities on or adjacent to the site) or natural events (such as floods, groundwater fluctuations or earthquakes). We should be consulted prior to use of this report so that we can comment on its reliability. It is important to note that where ground conditions have changed, additional sampling, testing or analysis may be required to fully assess the changed conditions.

GDR25 SUBSURFACE CONDITIONS DURING CONSTRUCTION

Practical constraints mean that we cannot know every minute detail about the subsurface conditions at a particular site. We use professional judgement to form an opinion about the subsurface conditions at the site. Some variation to our evaluated conditions is likely and significant variation is possible. Accordingly, our report should not be considered as final as it is developed from professional judgement and opinion.

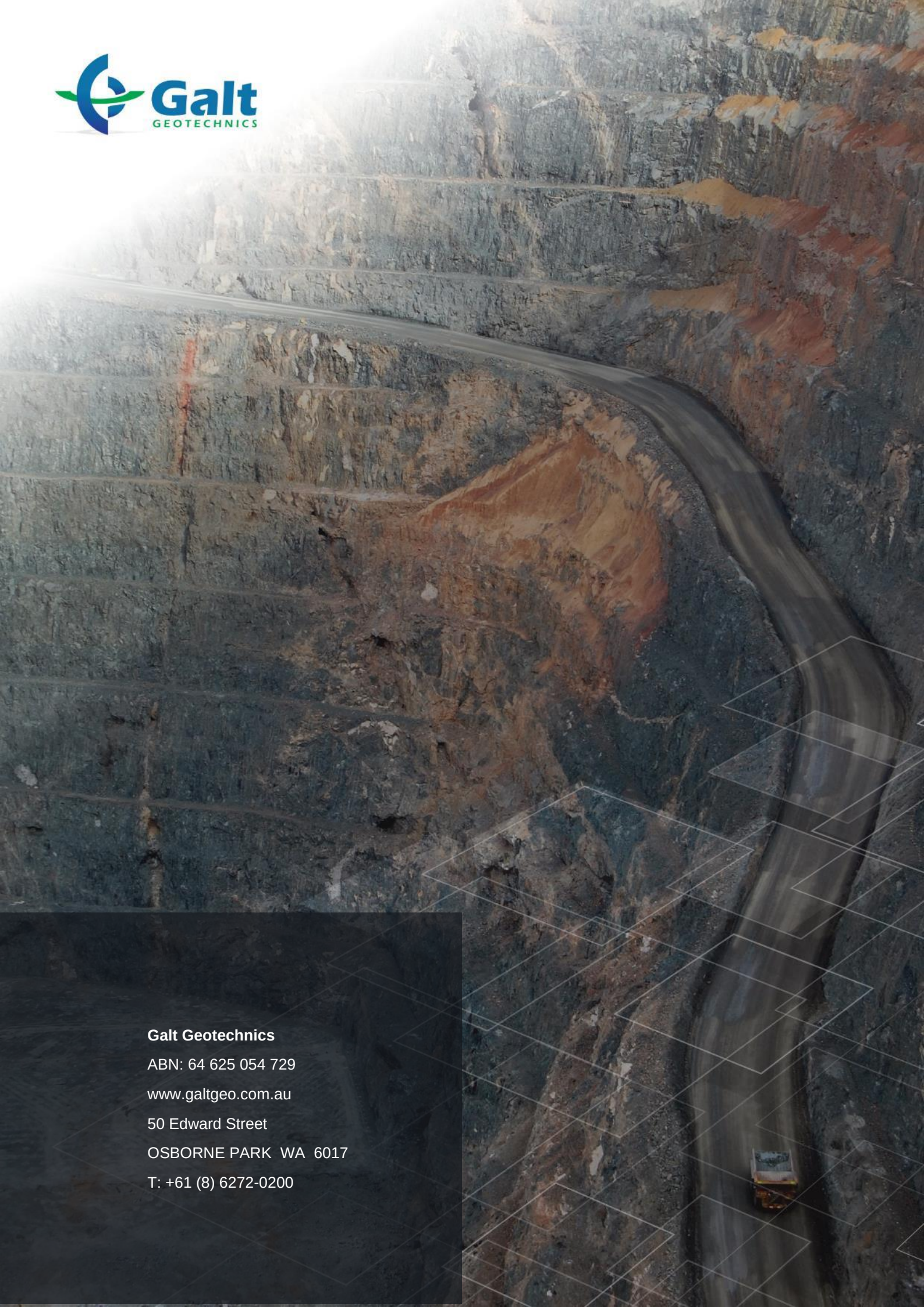
The most effective means of dealing with unanticipated ground conditions is to engage us for construction support. We can only finalise our recommendations by observing actual subsurface conditions encountered during construction. We cannot accept liability for a report's recommendations if we cannot observe construction.

GDR26 ENVIRONMENTAL AND GEOTECHNICAL ISSUES

Unless specifically mentioned otherwise in our report, environmental considerations are not addressed in geotechnical reports. Similarly, geotechnical issues are not addressed in environmental reports. The investigation techniques used for geotechnical investigations can differ from those used for environmental investigations. It is the client's responsibility to satisfy themselves that geotechnical and environmental considerations have been taken into account for the site.

Geotechnical advice presented in a Galt Environmental report has been provided by Galt Geotechnics under a sub-contract agreement. Similarly, environmental advice presented in a Galt Geotechnics report has been provided by Galt Environmental under a sub-contract agreement.

Unless specifically noted otherwise, no parties shall draw any inferences about the applicability of the Western Australian state government landfill levy from the contents of this document.



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