
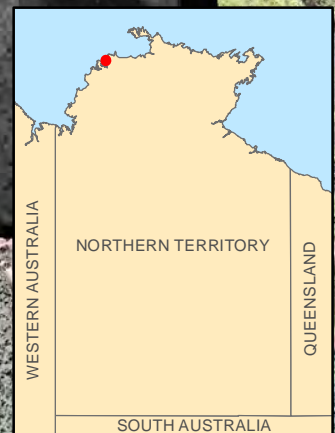
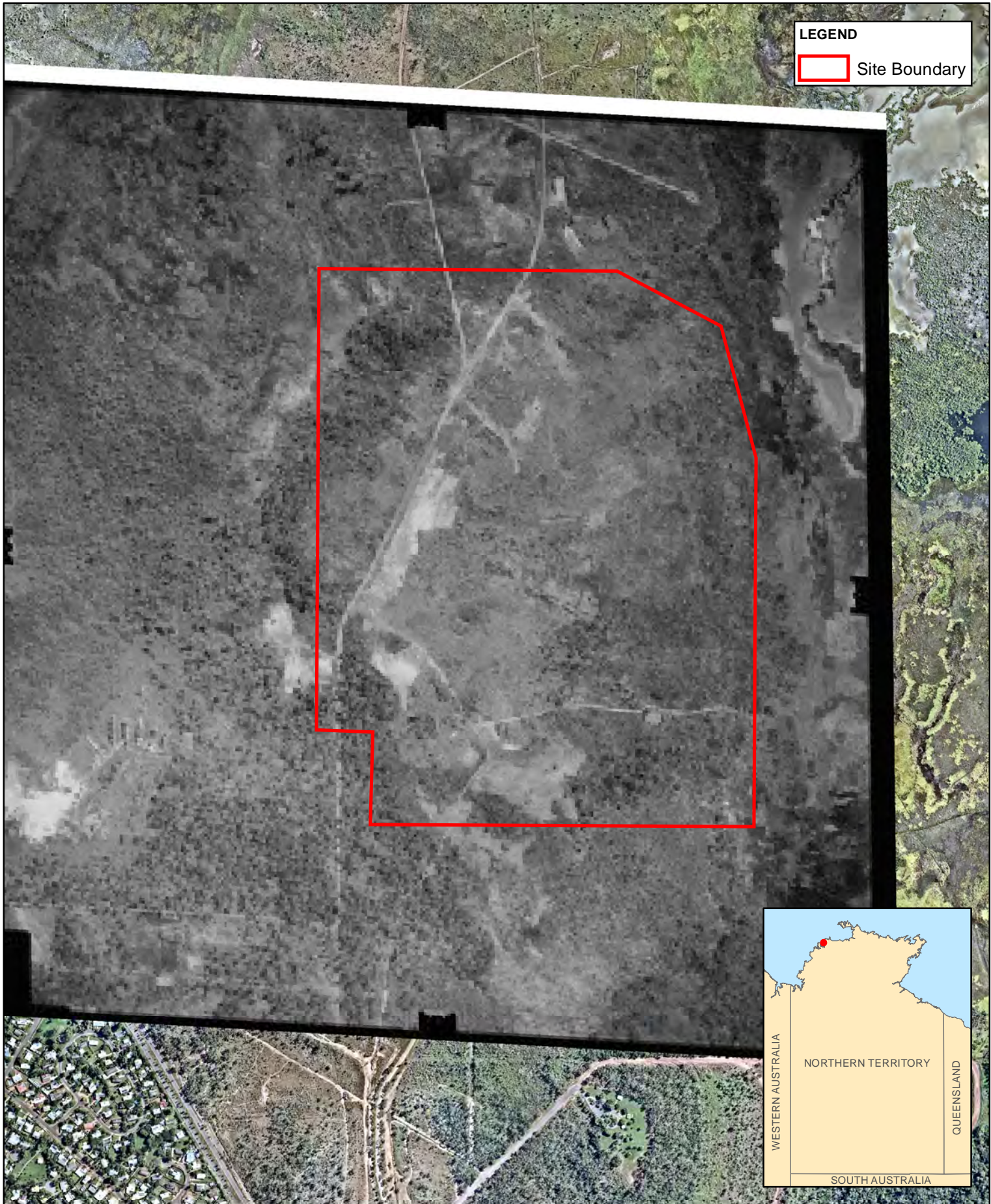




Appendix I Historical Aerial Photographs

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1974

**DARWIN
LANDFILL**



Figure 1

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AERIAL IMAGE SOURCE:	GOOGLE EARTH PRO © DIGITAL GLOBE 2018


N

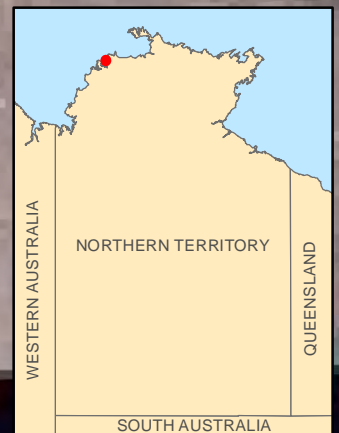


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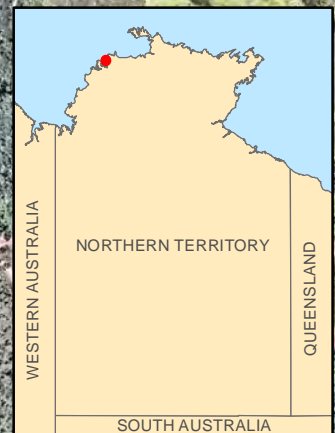
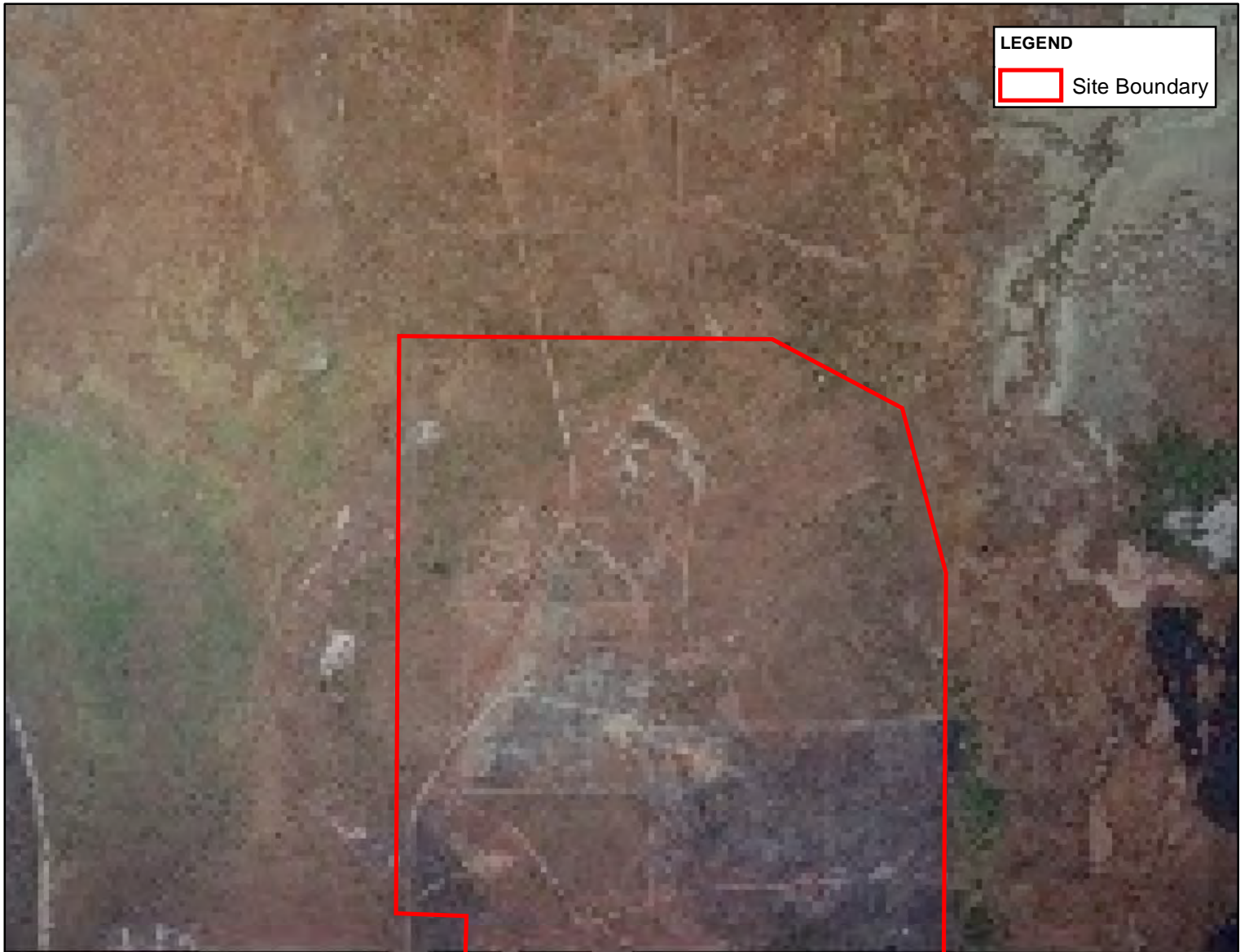
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<p>1983</p> 	<p>DARWIN LANDFILL</p> 	<p>Figure 2</p> <table border="1"> <tr> <td>CREATED BY:</td> <td>C. Smitt</td> </tr> <tr> <td>APPROVED BY:</td> <td>C. Smitt</td> </tr> <tr> <td>PROJECT REF. NO:</td> <td>AUS#XXXX-YYYY</td> </tr> <tr> <td>MAP PROJECTION:</td> <td>Transverse Mercator</td> </tr> <tr> <td>GRID/DATUM:</td> <td>GDA2020 MGA Zone 52</td> </tr> <tr> <td>SCALE:</td> <td>1:10,000</td> </tr> <tr> <td>AERIAL IMAGE SOURCE:</td> <td>GOOGLE EARTH PRO © DIGITAL GLOBE 2018</td> </tr> </table> 	CREATED BY:	C. Smitt	APPROVED BY:	C. Smitt	PROJECT REF. NO:	AUS#XXXX-YYYY	MAP PROJECTION:	Transverse Mercator	GRID/DATUM:	GDA2020 MGA Zone 52	SCALE:	1:10,000	AERIAL IMAGE SOURCE:	GOOGLE EARTH PRO © DIGITAL GLOBE 2018
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APPROVED BY:	C. Smitt															
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<p>1985</p> 	<p>DARWIN LANDFILL</p> 	<p>Figure 3</p> <table border="1"> <tr> <td>CREATED BY:</td> <td>C. Smitt</td> </tr> <tr> <td>APPROVED BY:</td> <td>C. Smitt</td> </tr> <tr> <td>PROJECT REF. NO:</td> <td>AUS##XXXX-YYYY</td> </tr> <tr> <td>MAP PROJECTION:</td> <td>Transverse Mercator</td> </tr> <tr> <td>GRID/DATUM:</td> <td>GDA2020 MGA Zone 52</td> </tr> <tr> <td>SCALE:</td> <td>1:10,000</td> </tr> <tr> <td>AERIAL IMAGE SOURCE:</td> <td>GOOGLE EARTH PRO © DIGITAL GLOBE 2018</td> </tr> </table> 	CREATED BY:	C. Smitt	APPROVED BY:	C. Smitt	PROJECT REF. NO:	AUS##XXXX-YYYY	MAP PROJECTION:	Transverse Mercator	GRID/DATUM:	GDA2020 MGA Zone 52	SCALE:	1:10,000	AERIAL IMAGE SOURCE:	GOOGLE EARTH PRO © DIGITAL GLOBE 2018
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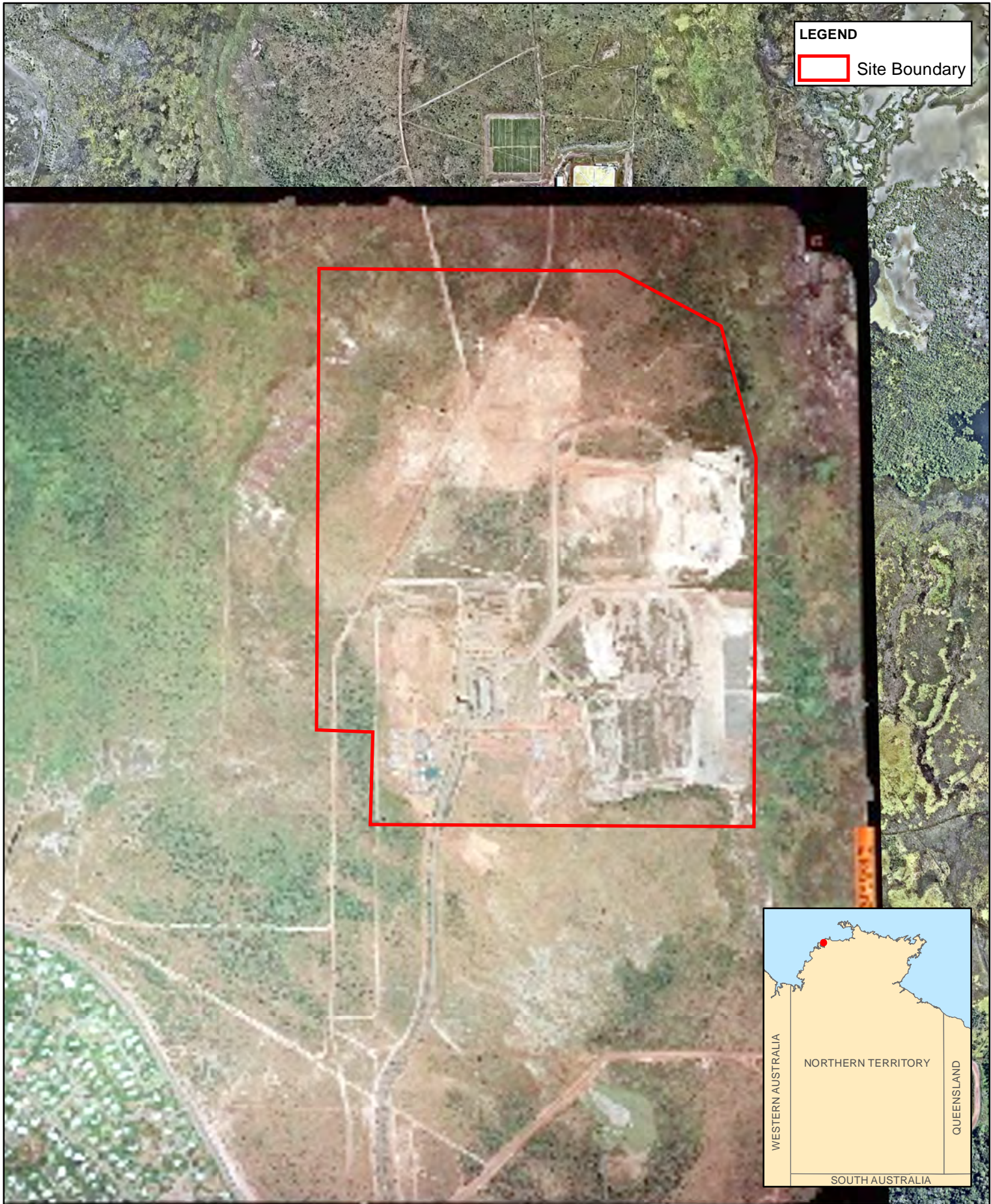
1990

**DARWIN
LANDFILL**

Figure 4

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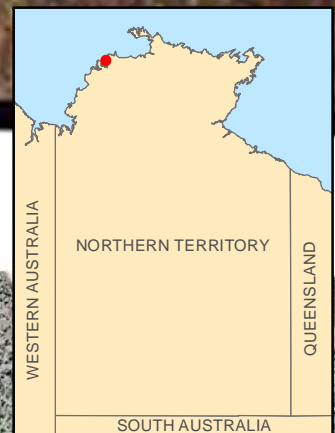
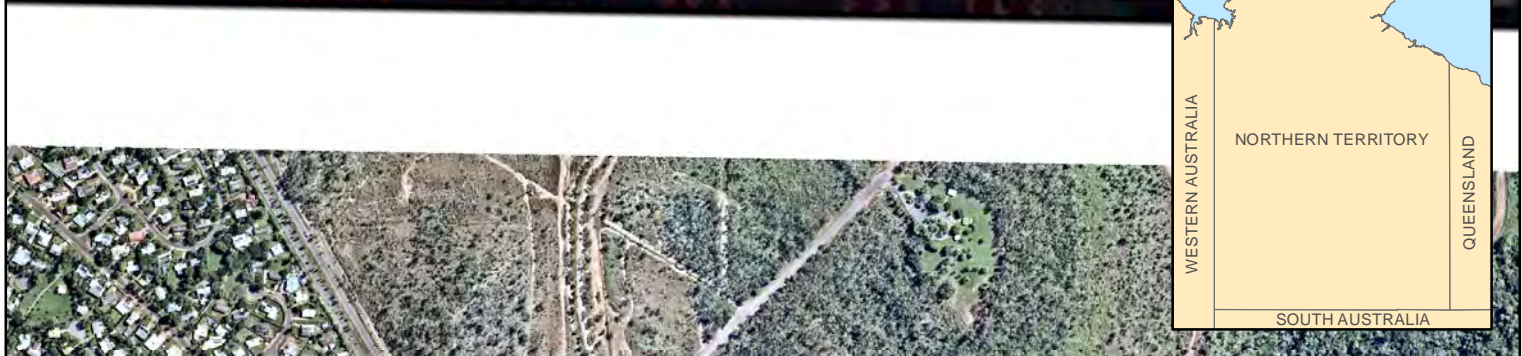
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<p>1994</p> <div style="text-align: center; margin-top: 20px;"> </div>	<p>DARWIN LANDFILL</p> <hr/>	<p>Figure 5</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="font-size: small;">CREATED BY:</td> <td>C. Smitt</td> </tr> <tr> <td style="font-size: small;">APPROVED BY:</td> <td>C. Smitt</td> </tr> <tr> <td style="font-size: small;">PROJECT REF. NO:</td> <td>AUS##XXXX-YYYY</td> </tr> <tr> <td style="font-size: small;">MAP PROJECTION:</td> <td>Transverse Mercator</td> </tr> <tr> <td style="font-size: small;">GRID/DATUM:</td> <td>GDA2020 MGA Zone 52</td> </tr> <tr> <td style="font-size: small;">SCALE:</td> <td>1:10,000</td> </tr> <tr> <td style="font-size: small;">AERIAL IMAGE SOURCE:</td> <td>GOOGLE EARTH PRO © DIGITAL GLOBE 2018</td> </tr> </table> <div style="text-align: right; margin-top: 10px;"> </div>	CREATED BY:	C. Smitt	APPROVED BY:	C. Smitt	PROJECT REF. NO:	AUS##XXXX-YYYY	MAP PROJECTION:	Transverse Mercator	GRID/DATUM:	GDA2020 MGA Zone 52	SCALE:	1:10,000	AERIAL IMAGE SOURCE:	GOOGLE EARTH PRO © DIGITAL GLOBE 2018
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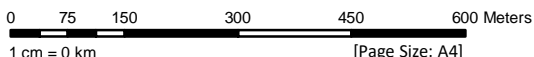
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2001




**DARWIN
LANDFILL**




Figure 6

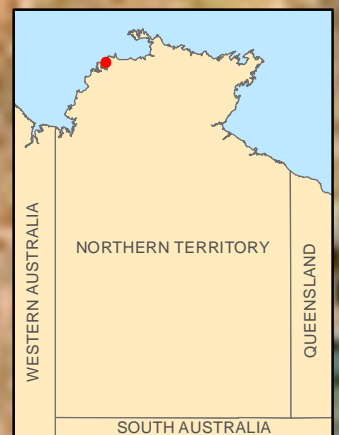
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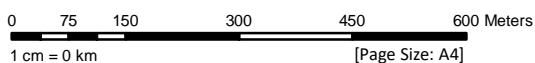
2002

**DARWIN
LANDFILL**




Figure 7

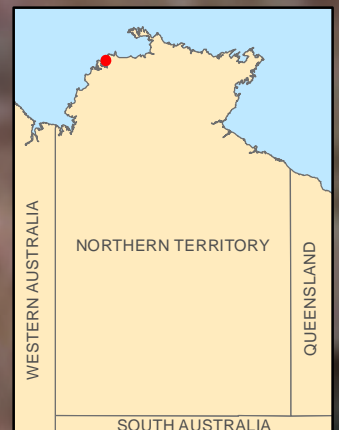
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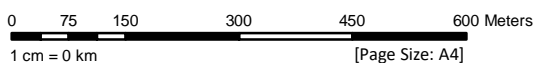
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2010

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Figure 8



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2012

**DARWIN
LANDFILL**

Figure 9

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2013

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Figure 10

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2014

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Figure 11

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2015

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Figure 12

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2016

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LANDFILL**

Figure 13

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2017

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LANDFILL**

Figure 14

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2018

**DARWIN
LANDFILL**

Figure 15

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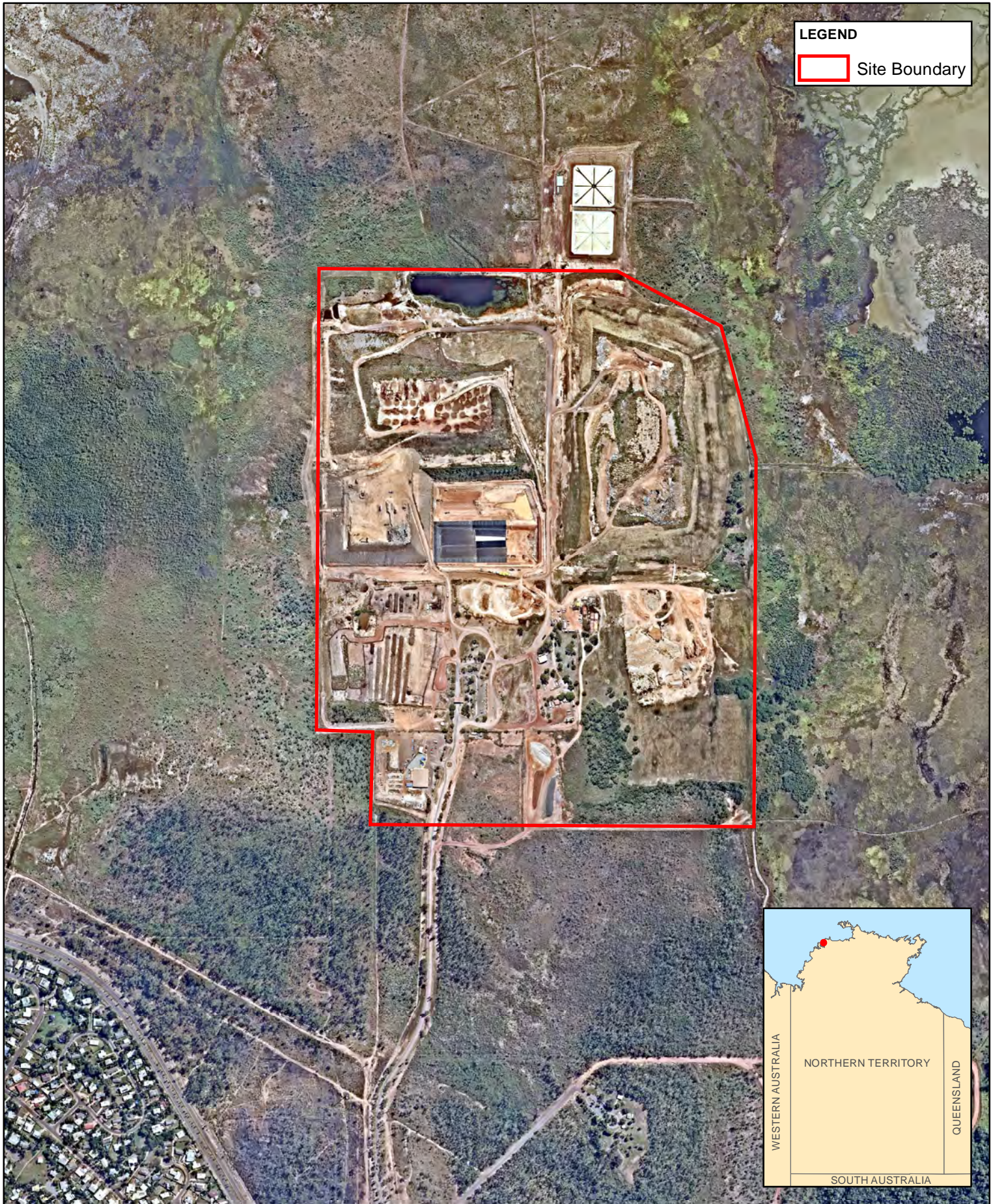
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<p>2019</p>	<p>DARWIN LANDFILL</p>	<p>Figure 16</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;">CREATED BY:</td> <td>C. Smitt</td> </tr> <tr> <td>APPROVED BY:</td> <td>C. Smitt</td> </tr> <tr> <td>PROJECT REF. NO:</td> <td>AUS##XXXX-YYYY</td> </tr> <tr> <td>MAP PROJECTION:</td> <td>Transverse Mercator</td> </tr> <tr> <td>GRID/DATUM:</td> <td>GDA2020 MGA Zone 52</td> </tr> <tr> <td>SCALE:</td> <td>1:10,000</td> </tr> <tr> <td>AERIAL IMAGE SOURCE:</td> <td>GOOGLE EARTH PRO © DIGITAL GLOBE 2018</td> </tr> </table>	CREATED BY:	C. Smitt	APPROVED BY:	C. Smitt	PROJECT REF. NO:	AUS##XXXX-YYYY	MAP PROJECTION:	Transverse Mercator	GRID/DATUM:	GDA2020 MGA Zone 52	SCALE:	1:10,000	AERIAL IMAGE SOURCE:	GOOGLE EARTH PRO © DIGITAL GLOBE 2018
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2020

**DARWIN
LANDFILL**

Figure 17

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2021

**DARWIN
LANDFILL**

Figure 18

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 Site Boundary



Internal Document Control Information:
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2022

0 75 150 300 450 600 Meters
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**DARWIN
 LANDFILL**

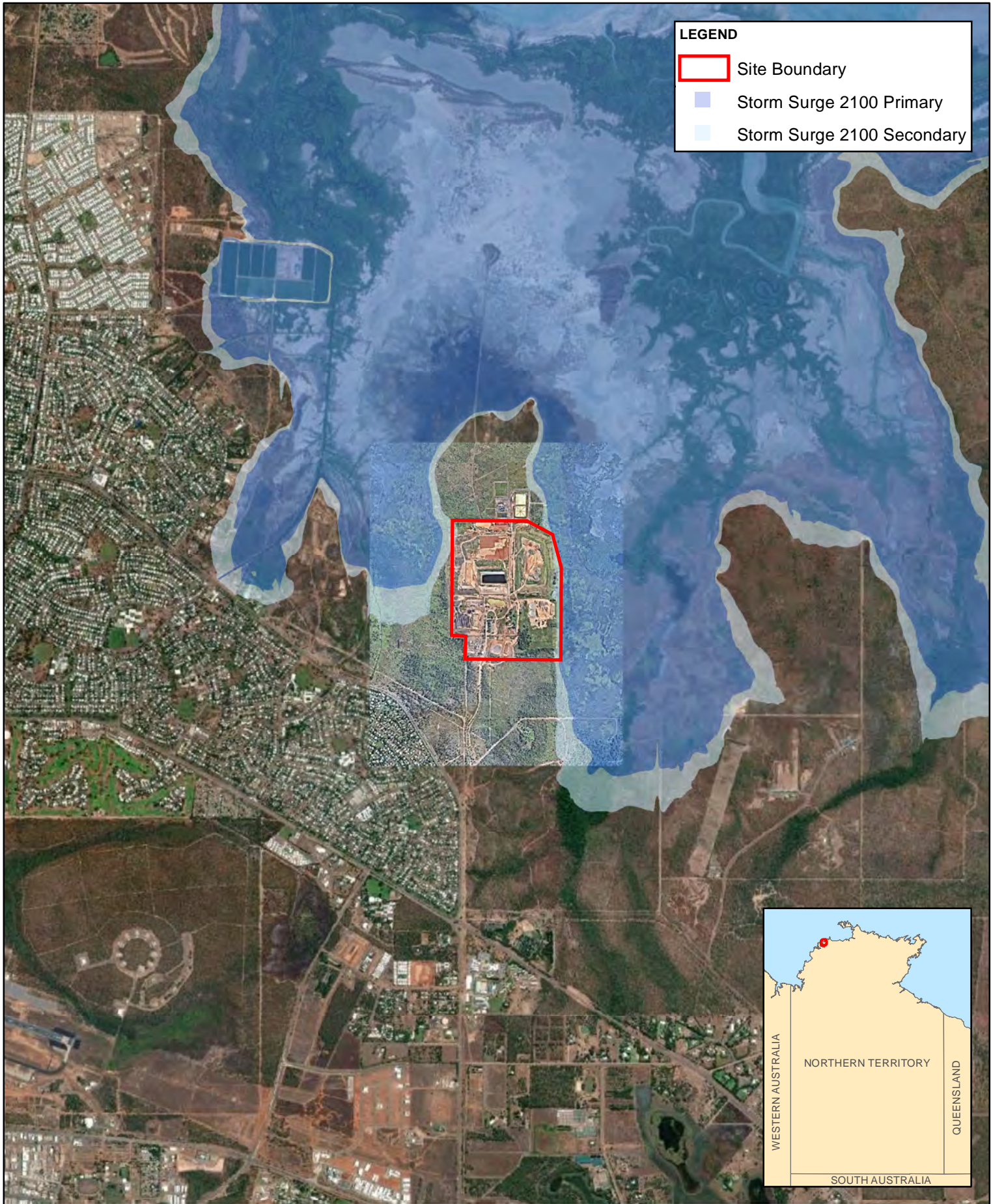
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Figure 19

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APPROVED BY:	C. Smitt
PROJECT REF. NO:	AUS##XXXX-YYYY
MAP PROJECTION:	Transverse Mercator
GRID/DATUM:	GDA2020 MGA Zone 52
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LEGEND

- Site Boundary
- Storm Surge 2100 Primary
- Storm Surge 2100 Secondary

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Appendix J LFG Collection

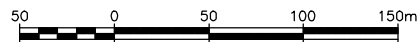


NEARMAP PTY LTD AERIAL DATED 06 JUN 2021

LEGEND			
⊗	LANDFILL GAS WELL	---	FENCE LINE
●	RISER GAS WELL	—	90mm WELL SOLID FLOWLINE
■	WELL MANIFOLD STATION	- - - -	125mm LATERAL
⊕	CKV / J-TRAP	- - - - -	160mm MAIN/LATERAL HEADER
CKV	CONDENSATE KNOCKOUT VESSEL	— — —	200mm MAIN HEADER
JT	J-TRAP	— — — —	225mm MAIN HEADER
⊥	FLARE	— — — — —	250mm MAIN HEADER
	RISER	— — — — — —	280mm MAIN HEADER

NOTES:

- HIGH VOLTAGE LINE FOR PUMP AND FLARE IN MAIN LINE.
- WELLS 17, 18, 38, 24 AND 25 COMBINED VERTICAL/LATERAL WELLS.
- MANUAL CONDENSATE PUMPOUT LEG. WATER PUMP STATION UNDERGROUND.
- TELSTRA 40mm CONDUIT IS APPROXIMATELY 300mm BELOW SURFACE WHERE IT CROSSES THIS POINT.



SCALE 1:2000 FOR A1 SIZE
SCALE 1:4000 FOR A3 SIZE
MGA94 ZONE 52

AS BUILT

No	DATE	DRN	DESN	CHKD	APP	DESCRIPTION
13	24/11/22	GC	SV	DD		INSTALLED 14 NEW WELLS, INSTALLED AND RELOCATED 160 mm MAINS RECONNECTED CELLS 3 & 4
12	19/11/20	JF	DD	SV	DD	WELLS 132-144 ADDED. REMOVED SN Q & M. NEW SECTIONS OF 160 mm MAIN ADDED
11	04/12/19	JF	DD	RB	DD	3 LATERAL LINES ADDED. NEW SECTIONS OF 160 mm MAIN ADDED. VARIOUS CHANGES MADE TO CELL 4 & 5
10	16/02/17	OS	-	DD	DD	MAIN & STATION P ADDED. RENUMBERED FROM 2029-CA-003
9	05/04/16	OS	GF	SV	OS	NEW 114-128, 130 & 131 REDILLS 103, 104, 112, 113 REMOVED 102, 107 & STN S
8	05/02/16	OS	-	-	-	MOVED TO MGA94 CO-ORDS

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SHOAL BAY RENEWABLE ENERGY FACILITY

GAS FIELD LAYOUT

SCALE	DRAWING NUMBER	PAGE	SIZE	REV
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CO-ORDINATES						CO-ORDINATES					
ASSET	LOCATION	EASTING	NORTHING	RL	DATE	ASSET	LOCATION	EASTING	NORTHING	RL	DATE
132	160mm MAIN	709262.13	8630320.10	38.4	Oct-20						
133	160mm MAIN	709357.45	8630312.66	38.83	Oct-20						
134	160mm MAIN	709076.63	8630165.86	26.51	Oct-20						
135	160mm MAIN	709074.63	8630131.29	26.79	Oct-20						
136	160mm MAIN	709086.32	8630091.86	29.26	Oct-20						
137	160mm MAIN	709085.00	8630052.37	29.51	Oct-20						
138	160mm MAIN	709120.95	8630048.31	29.68	Oct-20						
139	160mm MAIN	709154.19	8630048.68	29.99	Oct-20						
140	160mm MAIN	709191.60	8630049.84	30.26	Oct-20						
141	160mm MAIN	709294.09	8630333.26	37.45	Oct-20						
142	160mm MAIN	709395.15	8630328.25	31.18	Oct-20						
143	160mm MAIN	709101.62	8630348.08	27.59	Oct-20						
144	DISCONNECTED	709092.94	8630384.71	25.2	Oct-20						
109	redrill	160mm MAIN	709325.97	8630339.09	37.16	Oct-20					
110	redrill	160mm MAIN	709367.83	8630352.81	36.41	Oct-20					
111	redrill	160mm MAIN	709389.32	8630384.84	34	Oct-20					
115	redrill	160mm MAIN	709123.28	8630274.34	33.54	Oct-20					
117	redrill	160mm MAIN	709131.22	8630340.31	35.56	Oct-20					
119	redrill	160mm MAIN	709199.28	8630271.64	38.25	Oct-20					
123	redrill	160mm MAIN	709163.06	8630342.62	36.78	Oct-20					
127	redrill	160mm MAIN	709243.13	8630290.52	39.95	Oct-20					
128	redrill	160mm MAIN	709163.68	8630266.45	37.58	Oct-20					
131	redrill	160mm MAIN	709368.42	8630276.68	37.03	Oct-20					
145	160mm MAIN	709166.47	8630214.49	37.38	May-22						
146	DISCONNECTED	709128.69	8630203.07	36.77	May-22						
147	160mm MAIN	709164.92	8630191.68	37.14	May-22						
148	DISCONNECTED	709110.28	8630163.17	36.26	May-22						
149	160mm MAIN	709136.50	8630158.63	36.01	May-22						
150	160mm MAIN	709165.09	8630149.35	36.45	May-22						
151	DISCONNECTED	709114.86	8630119.88	36.01	May-22						
152	160mm MAIN	709154.75	8630117.16	36.09	May-22						
153	160mm MAIN	709129.57	8630082.19	36.78	May-22						
154	160mm MAIN	709165.76	8630081.27	37.19	May-22						
156	160mm MAIN	709199.55	8630117.04	27.24	May-22						
158	160mm MAIN	709117.21	8630413.40	23.52	May-22						
159	160mm MAIN	709162.76	8630407.75	25.12	May-22						
161	160mm MAIN	709238.89	8630422.42	23.45	May-22						

AS BUILT

No	DATE	DRN	DESN	CHKD	APP	DESCRIPTION
13	24/11/22	GC	GC	SV	DD	INSTALLED 14 NEW WELLS, INSTALLED AND RELOCATED 160 mm MAINS RECONNECTED CELLS 3 & 4
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DATE:	31/08/04

SHOAL BAY RENEWABLE ENERGY FACILITY			
GAS FIELD LAYOUT			
SCALE	DRAWING NUMBER	PAGE	SIZE
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REV	13		



MONTHLY LANDFILL GAS REPORT

Site: Shoal Bay

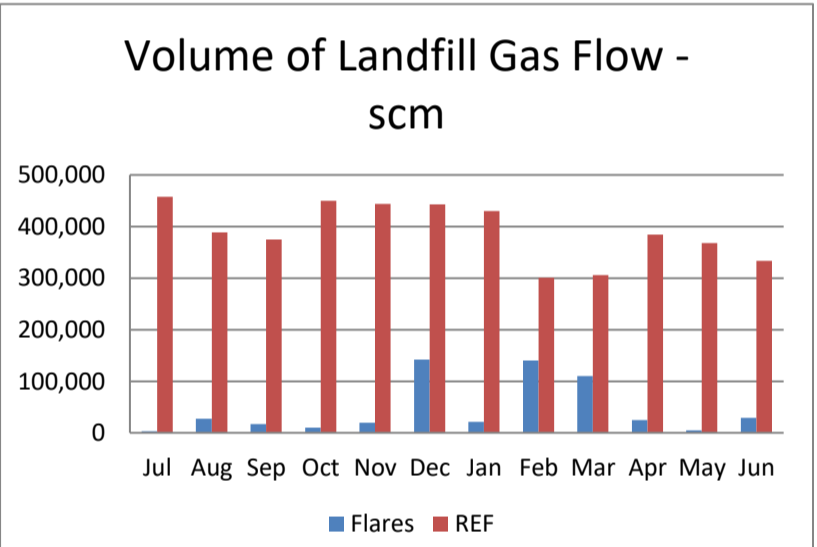
Client: Darwin City Council

Month: Jun-2021

Flare

Volume of landfill gas flared:	29,246	m ³	(current month)
Average flow rate:	41	m ³ /h	(current month)
Cumulative volume of landfill gas flared:	550,279	m ³	(financial year to date)
Report month hours:	720		(current month)
Combined hours all flares:	57		(current month)
Average methane composition of landfill gas:	N/A	%	(current month)
Average carbon dioxide composition of landfill gas:	N/A	%	(current month)
Average oxygen composition of landfill gas:	N/A	%	(current month)
Carbon dioxide equivalent methane combusted (CO ₂ e) (approx):	N/A	tonnes	(current month)

Cumulative Monthly Landfill Gas Report						
2020-21 FY	Volume of Landfill Gas Flow - scm			CO ₂ e - tonnes		Exported KWH
	Month	Flares	REF	Total	Flares	
Jul	3,239	457,544	460,783	N/A	3,953	733,644
Aug	27,119	388,472	415,591	N/A	3,450	604,240
Sep	16,942	375,022	391,964	N/A	3,247	571,792
Oct	10,154	449,665	459,819	N/A	4,020	718,516
Nov	19,843	443,487	463,330	N/A	4,399	737,160
Dec	141,845	443,008	584,853	1,464	4,557	740,463
Jan	21,568	430,193	451,761	239	4,726	750,825
Feb	140,650	300,900	441,550	1,461	3,133	520,272
Mar	110,018	305,413	415,431	1,125	3,071	534,555
Apr	24,435	384,366	408,801	N/A	4,010	648,160
May	5,220	368,067	373,287	N/A	3,778	602,529
Jun	29,246	333,825	363,071	N/A	3,199	540,541
TOTALS	550,279	4,679,962	5,230,241	4,289	45,542	7,702,697



Renewable Energy Facility

Volume of landfill gas utilised:	333,825	m ³	(current month)
Average flow rate less down time:	526	m ³ /h	(current month)
Average flow rate calendar month:	464	m ³ /h	(current month)
Exported KWH:	540541	KWH	(current month)
Average methane composition of landfill gas:	50.3	%	(current month)
Average carbon dioxide composition of landfill gas:	0	%	(current month)
Average oxygen composition of landfill gas:	0	%	(current month)
Power station operation:	634.10	Hours	(current month)
Cumulative Station Hours	634.20	Hours	(current month)
Carbon dioxide equivalent methane combusted (CO ₂ e) (approx):	3198.86	tonnes	(current month)

REF Comment:

Utility trips 34.9 hours downtime.

Gas Field Comment

Flare Summary 01/06/2022 to 30/06/2022

Volume of landfill gas flared	27,252 m ³	(current month)
Cumulative volume of landfill gas flared	585,478 m ³	(financial year to date)
Average flow rate	38 m ³ /h	(current month)
Hours in reporting period	710.3 hours	(current month)
Flare combined operation hours	72.9 hours	(current month)

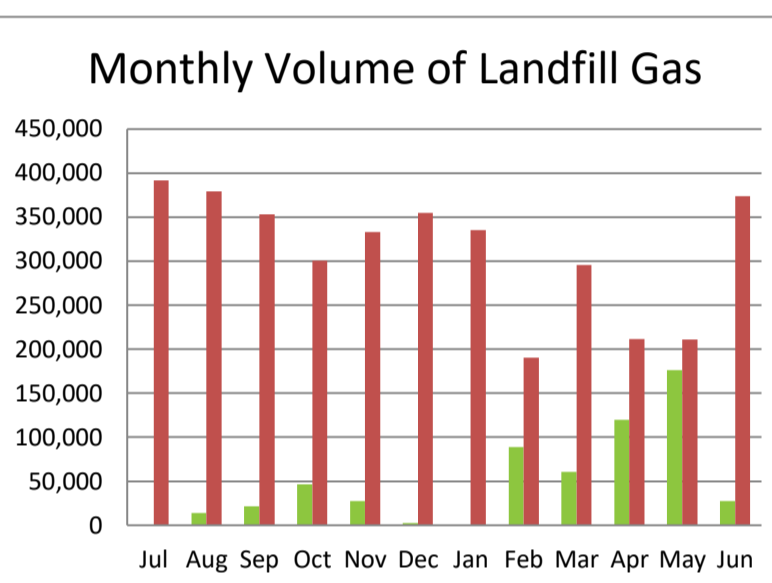
Average Gas Composition

Methane	48.0 %	(current month)
Carbon Dioxide	28.0 %	(current month)
Oxygen	0.8 %	(current month)

Carbon dioxide equivalent methane combusted (CO₂e) 249.06 tonnes (current month)

Gas Volume by Month FY 2021/22

Month	m ³			CO ₂ e		Generated kWh
	Flares	REF	Total	Flares	REF	
Jul	0	391,796	391,796	N/A	3,577.93	631,238
Aug	13,974	379,339	393,313	N/A	3,452.04	585,609
Sep	21,566	353,299	374,865	N/A	3,281.02	533,266
Oct	46,468	300,417	346,885	N/A	2,873.45	454,097
Nov	27,610	332,933	360,543	N/A	3,188.60	518,045
Dec	2,527	354,950	357,477	N/A	3,451.21	562,869
Jan	849	335,136	335,985	N/A	3,389.34	537,303
Feb	88,565	190,187	278,752	N/A	1,998.25	280,404
Mar	60,447	295,406	355,853	N/A	3,099.27	434,090
Apr	120,025	211,293	331,318	N/A	2,185.14	306,777
May	176,195	210,876	387,071	N/A	2,043.00	311,085
Jun	27,252	373,695	400,947	249.06	3,466.98	566,934
Totals	585,478	3,729,327	4,314,805	249.06	36,006.23	5,721,717



Renewable Energy Facility

Volume of landfill gas utilised	373,695 m ³	(current month)
Average flow rate less down time	584 m ³	(current month)
Average flow rate calendar month	519 m ³ /h	(current month)
Generated kWh	566,934 kWh	(current month)
Average methane composition of landfill gas	48.7 %	(current month)
Average carbon dioxide composition of landfill gas	N/A %	(current month)
Average oxygen composition of landfill gas	N/A %	(current month)
Power station operation	639.70 hours	(current month)
Cumulative station hours	639.70 hours	(current month)
Carbon dioxide equivalent methane combusted (CO ₂ e)	3,466.98 tonnes	(current month)

REF Comments

Gas Field Comments



Shoal Bay Monthly Landfill Gas Report

February 2023

Flare Summary

01/02/2023 to 01/03/2023

Volume of landfill gas flared	82,371 m ³	(current month)
Cumulative volume of landfill gas flared	414,069 m ³	(financial year to date)
Average flow rate	123 m ³ /h	(current month)
Hours in reporting period	672.0 hours	(current month)
Flare combined operation hours	379.9 hours	(current month)

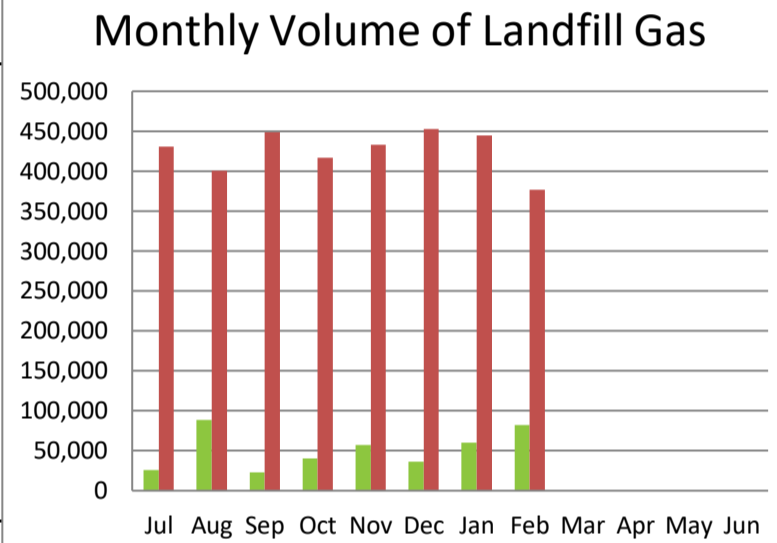
Average Gas Composition

Methane	53.2 %	(current month)
Carbon Dioxide	30.0 %	(current month)
Oxygen	0.2 %	(current month)
Carbon dioxide equivalent methane combusted (CO ₂ e)	834.36 tonnes	(current month)

Gas Volume by Month

FY 2022/23

Month	m ³			CO ₂ e		Generated kWh
	Flares	REF	Total	Flares	REF	
Jul	25,946	430,678	456,624	N/A	3,943.26	670,251
Aug	88,701	400,423	489,124	717.77	3,804.90	644,817
Sep	23,097	448,783	471,880	N/A	4,421.44	742,877
Oct	40,408	417,007	457,415	N/A	4,191.04	706,180
Nov	57,235	433,144	490,379	544.88	4,266.08	719,338
Dec	36,381	452,702	489,083	358.82	4,544.36	769,969
Jan	59,930	444,604	504,534	605.91	4,465.47	756,472
Feb	82,371	376,812	459,183	834.36	3,918.01	653,578
Mar						
Apr						
May						
Jun						
Totals	414,069	3,404,153	3,818,222	3,061.74	33,554.56	5,663,482



Renewable Energy Facility

Volume of landfill gas utilised	376,812 m ³	(current month)
Average flow rate less down time	598 m ³	(current month)
Average flow rate calendar month	560 m ³ /h	(current month)
Generated kWh	653,578 kWh	(current month)
Average methane composition of landfill gas	54.6 %	(current month)
Average carbon dioxide composition of landfill gas	N/A %	(current month)
Average oxygen composition of landfill gas	N/A %	(current month)
Power station operation	629.50 hours	(current month)
Cumulative station hours	629.50 hours	(current month)
Carbon dioxide equivalent methane combusted (CO ₂ e)	3,918.01 tonnes	(current month)

REF Comments

Utility trips 4.0 engine hours downtime.

Gas Field Comments



Appendix K Landfill Development Plan



31 August 2016

LANDFILL DEVELOPMENT PLAN

Stage 5 to Stage 10 General Waste Cells, Shoal Bay Waste Management Facility, Darwin

Submitted to:
City of Darwin

REPORT

Report Number. 1526230-020-R-Rev0

Distribution:

City of Darwin
Golder Associates Pty Ltd





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APPENDICES

APPENDIX A

Important Information



1.0 INTRODUCTION

The City of Darwin (Council) commissioned Golder Associates Pty Ltd (Golder) to prepare a Landfill Development Plan for future general waste landfill cells at the Shoal Bay Waste Management Facility (SBWMF) in Darwin. The SBWMF leased by Council from the Department of Defence and is subject to land use restrictions associated with uncleared unexploded ordinance (UXO).

Future development of landfill stages to support continued general waste disposal at SBWMF until at least the end of the current lease in 2034.

This Landfill Development Plan for Stages 5 to 10 general waste disposal cells presents the following:

- Proposed stage floor, leachate collection and final landform geometry.
- Nominal timing for stage construction and filling.
- Indicative stormwater drain alignments.
- Indicative sizing and locations of future sediment ponds.
- Key considerations for the detailed design of future general waste cells.

The Landfill Development Plan for inert waste disposal within Stage 2 is presented separately (Golder reference 1653988-008, August 2016).

2.0 BACKGROUND INFORMATION

2.1 General

This Landfill Development Plan should be read in conjunction with the following documents:

- Report 1: '*Environment Protection and Biodiversity Conservation Act 1999 Self-Assessment, Shoal Bay Landfill, Darwin*', Golder reference 1546097-002-R-Rev1, dated June 2016.
- Report 2: '*Design Report for Stage 5 Landfill Liner and Leachate Collection System, Shoal Bay Waste Management Facility, Darwin*', Golder reference 1526230-009-R-Rev2, dated May 2016.
- Report 3: '*Technical Specification, Shoal Bay Landfill Stage 5 Waste Containment Cells*', Golder reference 1526230-008-R-Rev6, dated June 2016.
- Report 4: '*Final Landform Geometry Options Review, Future Landfill Stages 5 to 10, Shoal Bay Waste Management Facility*' Golder reference 1526230-006-L-Rev1, dated May 2016.

2.2 Regulatory Requirements and Licence Conditions

The site is operated by Territoria Civil under Environment Protection Licence EPL 188, dated 1 July 2016, (the Licence) issued by the Northern Territory Environment Protection Authority (NT EPA).

Similar to recent practice, it is anticipated that the NT EPA will require that the detailed design and construction of future general waste cell stages will be subject to audit by a Qualified Person (Environmental Auditor) to assess compliance of the design with the NT EPA *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites in the Northern Territory* dated January 2013 (the NT EPA Guidelines). Detailed design documents prepared separately by Golder for Stage 5 (refer above) have been subject to this audit process.

The SBWMF is licensed for operating premises for the disposal of waste by burial that service, or are designed to service, the waste disposal requirements of more than 1000 persons and disposal of the following listed wastes:

- Animal effluent and residues.
- Asbestos (typically placed in Stage 2 Inert Waste Landfill).
- Clinical and related wastes.



- Sewerage sludge and residues including nightsoil and septic tank sludge.
- Soils contaminated with a listed waste.
- Tyres (typically placed in Stage 2 Inert Waste Landfill).

2.3 Waste Management Activities

Current waste management activities within the SBWMF are shown on Figure 1 and include a “buy-back” shop, public transfer station, green waste processing, inert waste landfilling (Stage 2), general waste landfilling (Stage 3 and Stage 4) and leachate storage.

Landfill activities have been carried out at the SBWMF since 1987. Stages 1 and 2, located in the eastern part of the operations area, are unlined cells that previously accepted general waste. Geomembrane-lined waste cells currently used for the disposal of general waste comprise Stage 3, constructed between 2001 and 2007, and Stage 4, constructed in 2013.

The site also includes an active landfill gas management system, with collection of landfill gas in Stages 3 and 4, and a leachate management system, with collection of leachate from Stages 3 and 4 and storage in the North and South Leachate Ponds. Development of a holistic leachate management strategy and supporting infrastructure for the site is currently underway, and will include a leachate treatment system.

2.4 General Waste Disposal Rates

For the full 2015 financial year, the SBWMF received approximately 140,000 tonnes of general waste that was placed within Stage 3/Stage 4 (averaging approximately 11,700 t/month). This represented a reduction from the previous year, during which approximately 160,000 tonnes of general waste was received (averaging approximately 13,400 t/month).

Council is currently preparing a waste management strategy to increase resource recovery and reduce the volume of waste disposed to landfill. In the absence of a final preferred waste diversion target, the following two scenarios were used as the basis for estimating future general waste landfill airspace capacity requirements:

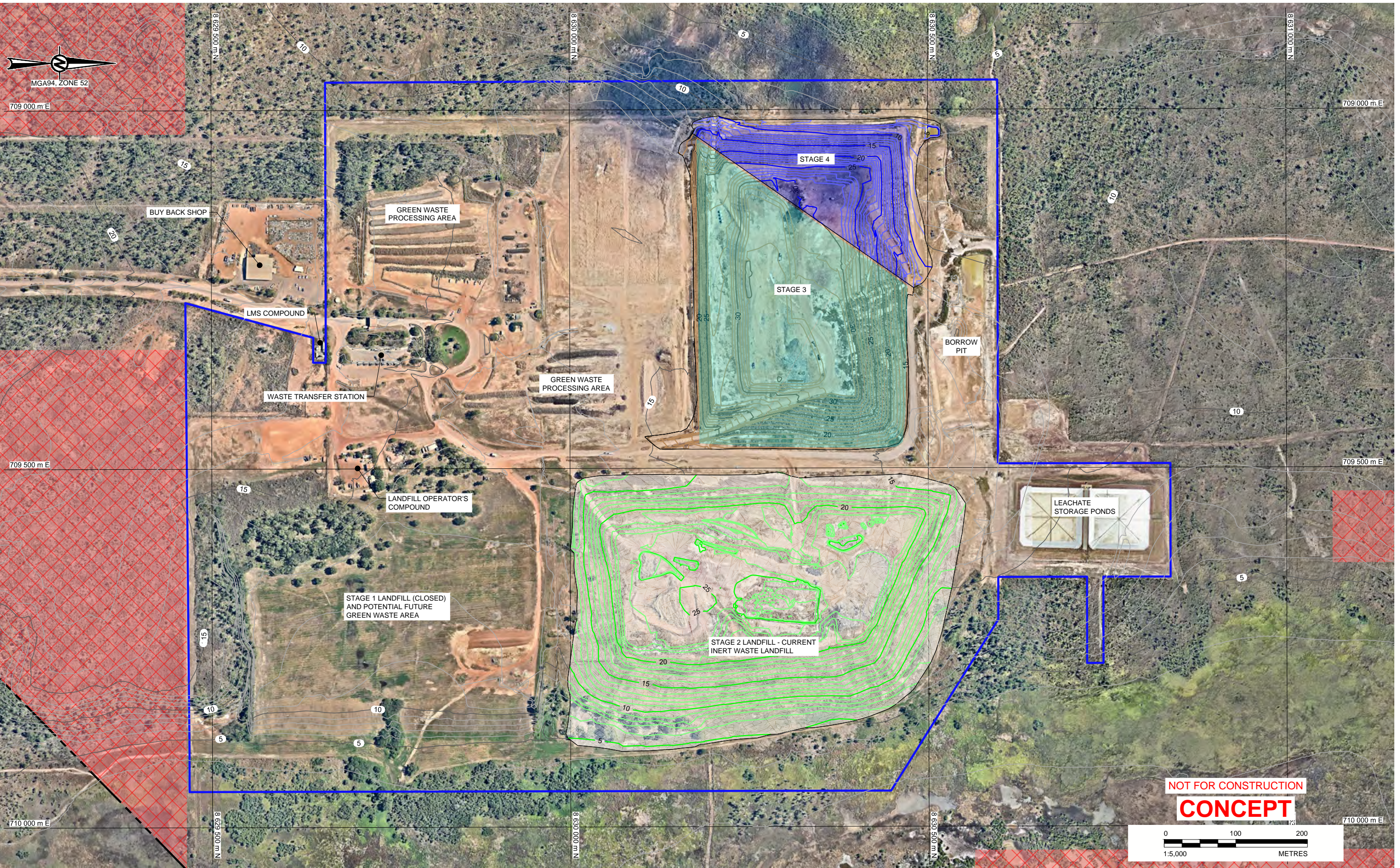
- **“Lower Range Filling Rate”**: Annual cell filling rate of 175,000 m³ (14,600 m³/month) based on waste disposal rate of 140,000 t/year (11,700 t/month, as in 2014) and airspace utilisation rate of 0.8 t/m³. For the 19 year period between 2016 and 2034, this would require a total landfill airspace of 3,325,000 m³.
- **“Upper Range Filling Rate”**: Annual cell filling rate of 230,000 m³ (19,000 m³/month) based on waste disposal rate of 160,000 t/year (13,400 t/month, as in 2015) and airspace utilisation rate of 0.7 t/m³. For the 19 year period between 2016 and 2034, this would require a total landfill airspace of 4,370,000 m³.

2.5 Stage 3/Stage 4 General Waste Landfill

The interim landform for placement of general waste within the Stage 3/Stage 4 lined cell footprint area is shown on Figure 2. The estimated remaining airspace capacity remaining to reach the interim landform shape (approximately 187,000 m³ at the end of July 2016) is expected to be filled during the early part of the 2017 dry season.

At completion the Stage 3/Stage 4 interim landform will comprise the following:

- Northern batter: Slope gradient between 5H:1V to 3H:1V
- Eastern batter: Slope gradient between 5H:1V to 4H:1V
- Southern Batter: Slope gradient of 2H:1V below RL 26 mAHD and 3H:1V above
- Western Batter: Slope gradient of 3H:1V.



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- LEASE AREA BOUNDARY IS BASED ON CADASTRAL BOUNDARIES IN CADD FILE "CADASTRE_SHOALBAYREGION.DXF".
- UNEXPLODED ORDINANCE CLEARANCE AREA IS BASED ON BOUNDARIES IN DRAWING TITLE "RAAF BOMBING RANGE LEASE AREA FOR DARWIN CITY COUNCIL LOT 3952", DRAWING DATED 25 AUGUST 1999, DRAWING NUMBER DA00350_1, FILE NAME "20100043_20140908_145851_01948_3536.PDF", MAPINFO FILES "EXCLUSION" AND COUNCIL LEASE.

LEGEND

- UNCLEARED UNEXPLODED ORDINANCE AREA
- ACTIVE LANDFILL STAGE 3
- ACTIVE LANDFILL STAGE 4
- LANDFILL OPERATIONS BOUNDARY
- LEASE BOUNDARY

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REVIEWED	JSB
APPROVED	JSB

PROJECT
 SHOAL BAY WASTE MANAGEMENT FACILITY
 GENERAL WASTE LANDFILL DEVELOPMENT PLAN

TITLE
 SITE LAYOUT PLAN

PROJECT NO.	DOC	REV.	FIGURE
1526230	020	0	F001

Path: \\golder\gis\pgr\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\BAY_LANDFILL\BAY_PROJECTS\1526230 - COD - Shoal Bay Landfill Design\DOC 020 CAPING ASSESSMENT staging\1 File Name: FIGURE F001.dwg

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3.0 FUTURE STAGE LAYOUT AND CONCEPT DESIGN

3.1 Preferred Location

The original design plans for Stage 3 continued a further 200 m southwards from the current footprint of Stage 3/Stage 4. The design of Stage 4 was based upon previous Landfill Development Plan for future stages to be located north of the current footprint of Stage 3/Stage 4.

Following a review of conditions within the SBWMF, Council decided to revert to the construction of future general waste cells south of the Stage 3/Stage 4 footprint based upon the following key constraints:

- The existing 2H:1V southern waste batter is potentially unstable due to the presence of an elevated leachate mound. New landfill stages along the southern batter will buttress this area, reducing the risk of slope failure.
- The elevated leachate mound in Stage 3/Stage 4 is causing leachate breakouts around the perimeter of Stage 3. Due to its steepness, it has not been possible to install a permanent leachate interception trench along the toe of the southern batter as has been completed for the northern and eastern batter slopes. New landfill stages along the southern batter will provide a permanent solution for the containment of leachate along the southern batter.
- Council is currently undertaking a procurement process for the installation of permanent leachate treatment/disposal infrastructure. The preferred location for this infrastructure is adjacent to the recently constructed leachate storage ponds located north of the Stage 3/Stage 4 footprint.
- Council has a strong preference contain future waste management infrastructure development infrastructure within the existing disturbed footprint area. Beyond a cleared borrow pit, the area located to the north of the Stage 3/Stage 4 footprint has generally been revegetated following historical defence use.

3.2 Leachate Management

Moisture content plays an important role in how rainfall infiltration migrates downwards through waste into the leachate collection system. At the time of placement, most waste material has a relatively low moisture content (“*moist waste*”, 10% to 20% by weight), particularly when placed during the dry season period. This waste material then has the capacity to adsorb or store additional moisture up to its field capacity (“*saturated waste*”, 30% to 40% by weight).

Based upon practical experience and results of water balance modelling for the SBWMF and other landfill sites located in Northern Australia, Golder has identified five key landfill operation phases that influence leachate volumes and waste moisture content through the landfills lifecycle as summarised in on Figure 3.

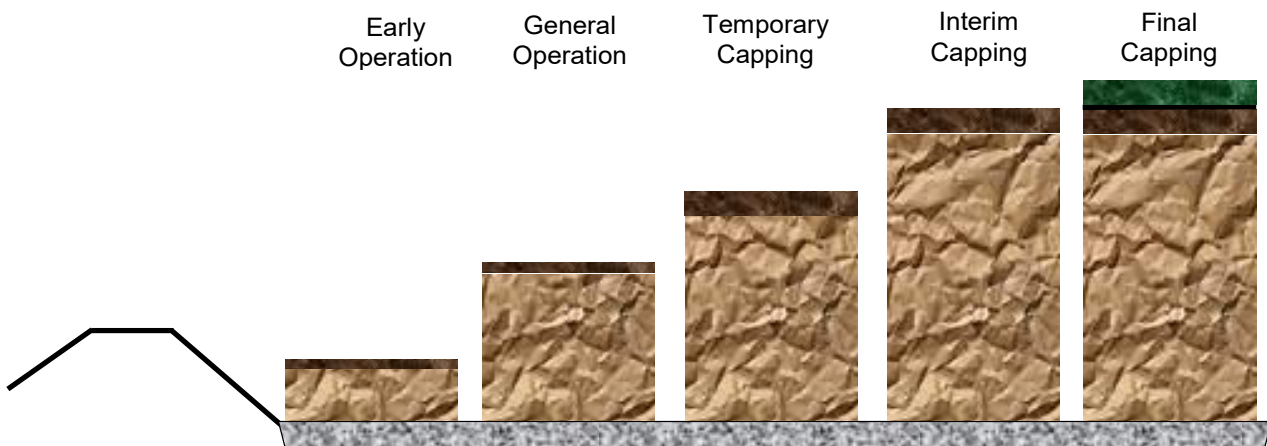


Figure 3: Key Landfill Operation Phases



The Early Operations phase is considered to have the most influential impact on leachate volumes due to issues that include:

- Poor stormwater drainage.
- Limited moisture adsorption capacity.

To reduce the volume of leachate generated during the Early Operations phase it is important to optimise the size of new cells and use sub-cells to ensure that the entire cell floor can be covered with a waste depth of at least 5 m during the dry season period as indicated on Figure 4.

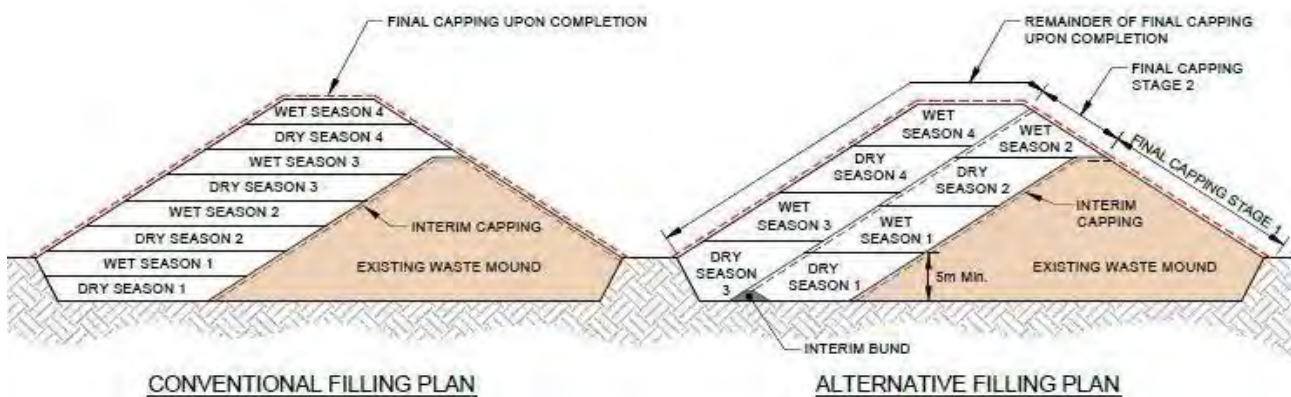


Figure 4: Leachate Minimising Landfill Filling Plan

The layout and sizing of Stage 5 to Stage 10 shown on Figure 2 were based upon the above approach and the adopted waste disposal volumes from Section 2.4, with each stage divided into two independent cells (A and B) to be filled in sequence as follows.

- Cell A: First dry season > 5 m depth and then first wet season to > 10 m depth,
- Cell B: Second dry season > 5 m depth and then second wet season to > 10 m depth.
- Cell A and Cell B: Subsequent dry seasons and wet seasons 10 m depth and above.

3.3 Groundwater Elevations and Subgrade Drainage

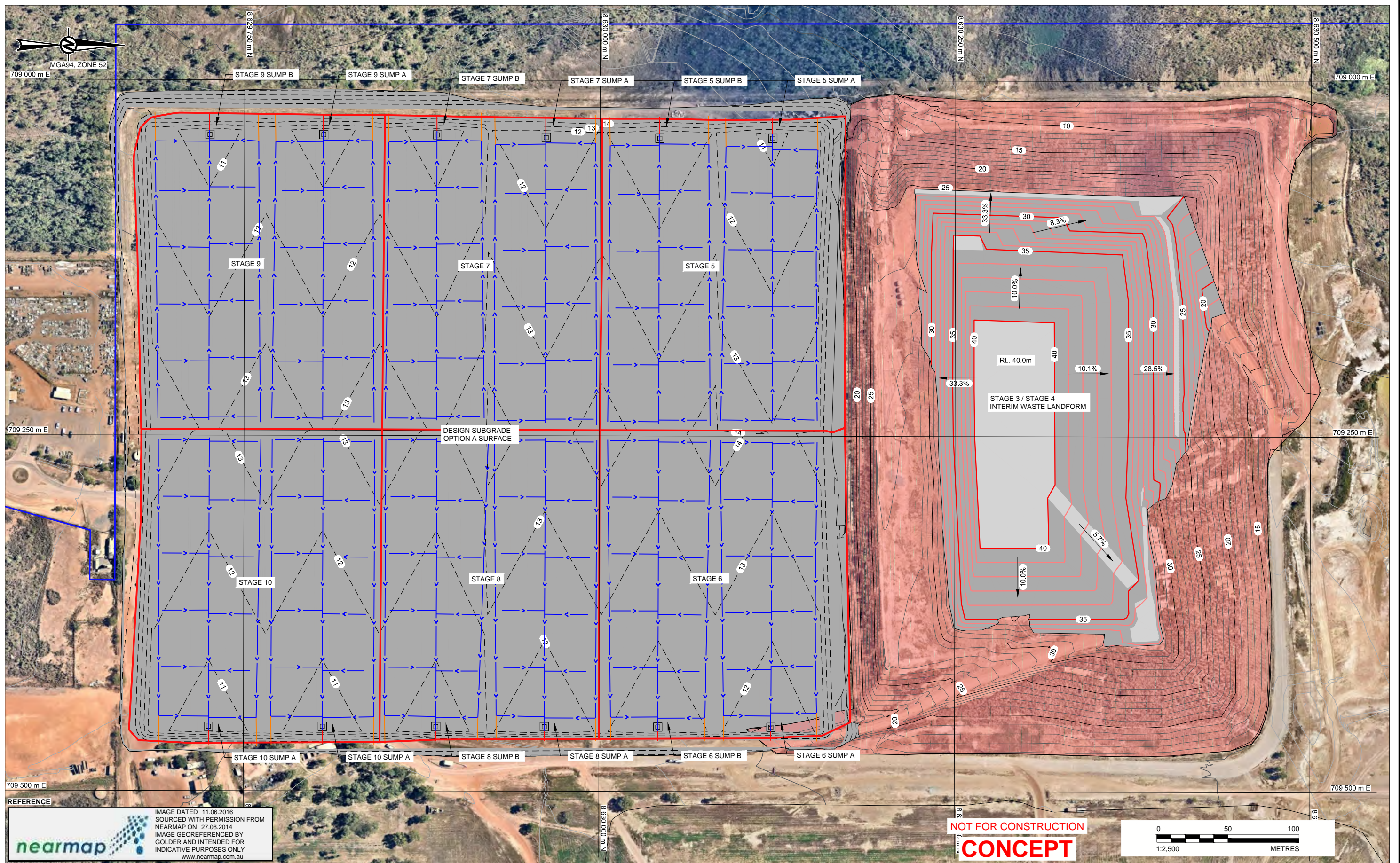
Assessments undertaken to support the detailed design of Stage 5 identified that groundwater elevations within the SBWMF can rise close to the natural ground surface during the wet season. This limits the depth of excavations that can be undertaken for the purposes of winning construction material on-site and optimising the subgrade surface and waste disposal airspace capacity for new waste stages.

To support some excavation below the original ground surface and maintain a buffer between groundwater and the landfill liner, it is necessary to install a network of subsurface drains to prevent short term groundwater rises during the wet season.

Preliminary assessments indicate that by limiting the depth of excavations to less than 3 m it should be possible to gravity drain elevated groundwater levels that form below the western footprint of the proposed future stages shown on Figure 2 (Stage 5, Stage 7, Stage 9) west towards the low-lying adjacent wetlands. For subgrade excavations below the eastern footprint of the proposed future stages shown on Figure 2 (Stage 6, Stage 8, Stage 10) it may be necessary to actively pump groundwater from subgrade drainage systems below each stage.

3.4 Subgrade and Leachate Collection Options

The subgrade surface represents the bottom of the landfill liner system, and the top of the subgrade drainage system. Two options were considered for the future stage subgrade surface and leachate collection drainage as shown on Figure 5 (Option A) and Figure 6 (Option B), comprising:



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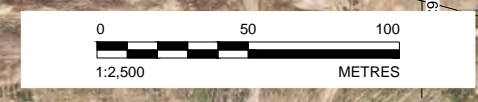
NOTES:

- EXISTING GROUND SURFACE COMPRISES THE FOLLOWING:
 - SEPTEMBER 2015 SURVEY WITHIN THE FOOTPRINT OF STAGE 3 / STAGE 4. SURVEY BY EARL JAMES & ASSOCIATES ON 29 SEPTEMBER 2015, DRAWING TITLE "VOLUMES - END OF MONTH - SEPTEMBER 29 2015", DRAWING NUMBER 15/5209/126, CAD FILE NAME "5209-126 (3D INFO)".
 - AUGUST 2015 SURVEY IN AREAS OUTSIDE THE FOOTPRINT OF STAGE 3/STAGE 4. SURVEY BY AUSURV SURVEYORS P/L COMPLETED ON 1 AUGUST 2015, DRAWING TITLE "DETAIL SURVEY SHOAL BAY WASTE MANAGEMENT FACILITY", DRAWING NUMBER 15-0099-1, CAD FILE NAME "15-0099 SHOAL BAY LANDFILL".
- EXISTING TOP OF STAGE 3 / STAGE 4 SURFACE IS BASED ON 28 JUNE 2016 SURVEY.
- DESIGN SUBGRADE SURFACES IS THE DESIGN SUBGRADE SURFACE OPTION A DRAINING DOWN TOWARDS EAST AND WEST PRESENTED IN GOLDER DOCUMENT 152630-006-L-REV1.

LEGEND

	28 JUNE 2016 SURVEY SURFACE IN FOOTPRINT OF STAGE 3 / STAGE 4 - 1m CONTOURS - REFER TO NOTE 1
	DESIGN SUBGRADE SURFACE - SUBGRADE OPTION A, 1m CONTOURS - REFER TO NOTE 3
	LEACHATE DRAINAGE PIPES
	INSPECTION RISER PIPES
	LEACHATE RISER PIPES
	FUTURE LANDFILL STAGES
	LANDFILL OPERATIONS BOUNDARY

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CONCEPT



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PREPARED	MMC
REVIEWED	JSB
APPROVED	JSB

PROJECT
 SHOAL BAY WASTE MANAGEMENT FACILITY
 GENERAL WASTE LANDFILL DEVELOPMENT PLAN

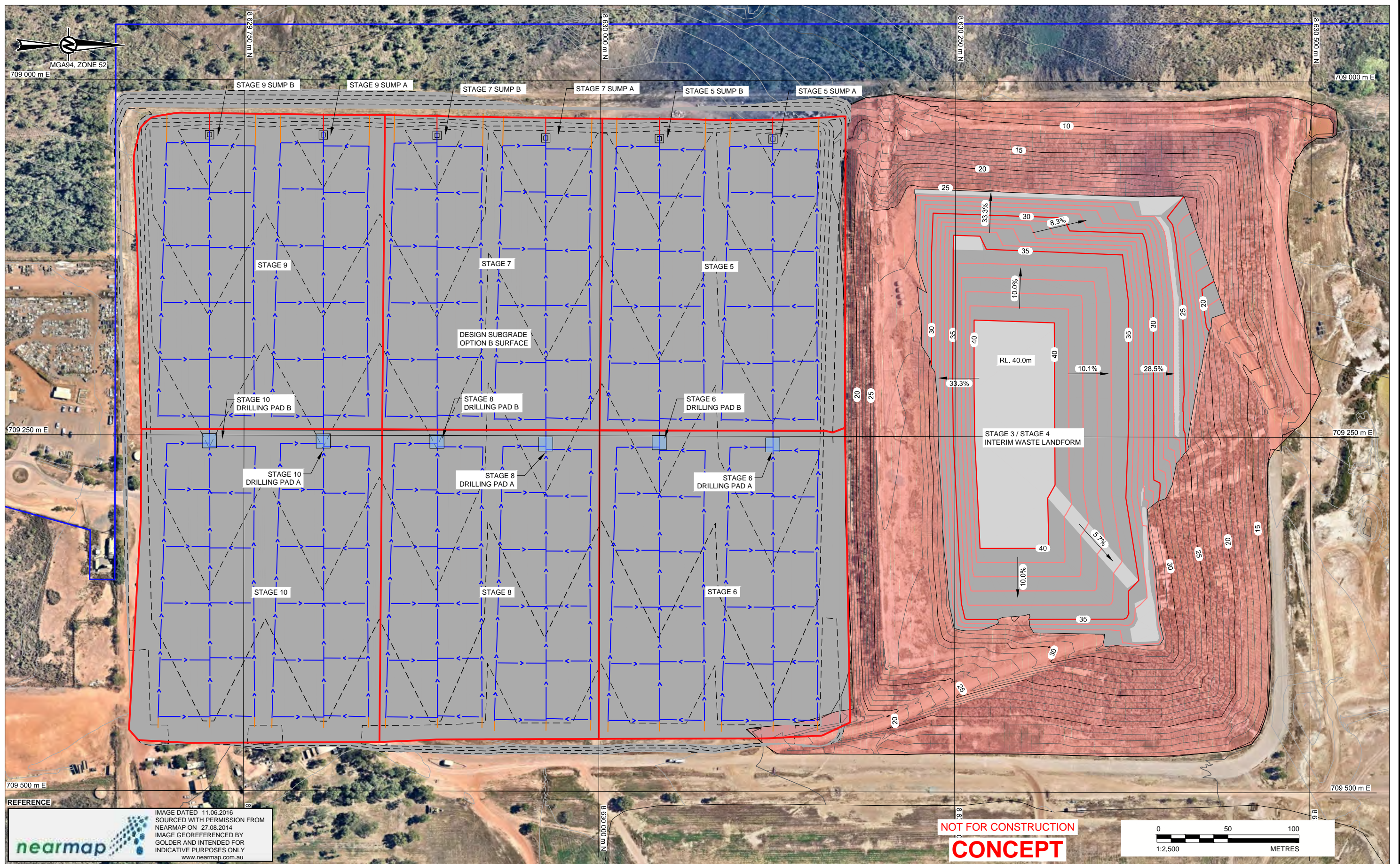
TITLE
**FUTURE STAGE SUBGRADE AND LEACHATE COLLECTION
 PLAN - OPTION A**

PROJECT NO.	DOC	REV.
1526230	020	0

FIGURE
F005

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- NOTES:**
- EXISTING GROUND SURFACE COMPRISES THE FOLLOWING:
 - SEPTEMBER 2015 SURVEY WITHIN THE FOOTPRINT OF STAGE 3 / STAGE 4. SURVEY BY EARL JAMES & ASSOCIATES ON 29 SEPTEMBER 2015, DRAWING TITLE "VOLUMES - END OF MONTH - SEPTEMBER 29 2015", DRAWING NUMBER 15/5209/126, CAD FILE NAME "5209-126 (3D INFO)".
 - AUGUST 2015 SURVEY IN AREAS OUTSIDE THE FOOTPRINT OF STAGE 3/STAGE 4. SURVEY BY AUSURV SURVEYORS P/L COMPLETED ON 1 AUGUST 2015, DRAWING TITLE "DETAIL SURVEY SHOAL BAY WASTE MANAGEMENT FACILITY", DRAWING NUMBER 15-0099-1, CAD FILE NAME "15-0099 SHOAL BAY LANDFILL".
 - EXISTING TOP OF STAGE 3 / STAGE 4 SURFACE IS BASED ON 28 JUNE 2016 SURVEY.
 - DESIGN SUBGRADE SURFACES IS THE DESIGN SUBGRADE SURFACE OPTION B DRAINING DOWN TOWARDS THE WEST PRESENTED IN GOLDBER DOCUMENT 152630-006-L-REV1.

LEGEND

- 28 JUNE 2016 SURVEY SURFACE IN FOOTPRINT OF STAGE 3 / STAGE 4 - 1m CONTOURS - REFER TO NOTE 1
- DESIGN SUBGRADE SURFACE - SUBGRADE OPTION A, 1m CONTOURS - REFER TO NOTE 3
- LEACHATE DRAINAGE PIPES
- INSPECTION RISER PIPES
- LEACHATE RISER PIPES
- FUTURE LANDFILL STAGES
- LANDFILL OPERATIONS BOUNDARY

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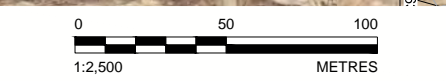
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DESIGNED	SRM
PREPARED	MMC
REVIEWED	JSB
APPROVED	JSB

PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
GENERAL WASTE LANDFILL DEVELOPMENT PLAN

TITLE
**FUTURE STAGE SUBGRADE AND LEACHATE COLLECTION
PLAN - OPTION B**

PROJECT NO.	DOC	REV.	FIGURE
1526230	020	0	F006

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CONCEPT**



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- Option A – Split Cell Floor Leachate Drainage
 - Subgrade of Stage 5, Stage 7, and Stage 9 shaped to drain to the west (1% gradient) into six collection sumps.
 - Subgrade of Stage 6, Stage 8, and Stage 10 shaped to drain to the east (1% gradient) into six collection sumps.
 - Advantages:
 - Increased waste disposal airspace capacity (approximately 230,000 m³).
 - Increased volume construction materials that can be won from cut earthworks.
 - Reduces leachate drainage distance (maximum of 200 m).
 - Disadvantages:
 - Pumping may be required below eastern stages (Stage 6, Stage 8 and Stage 10) to maintain buffer distance between cell liners and groundwater.
 - Increased risk of blasting to support cut earthworks.
- Option B – Combined Cell Floor Leachate Drainage
 - Subgrade of all stages (Stage 5 to Stage 10) shaped to drain to the west (1% gradient) into six collection sumps.
 - Advantages:
 - Pumping unlikely to be required below eastern stages (Stage 6, Stage 8, Stage 10) to maintain buffer distance between cell liners and groundwater.
 - Reduced risk of blasting to support cut earthworks.
 - Disadvantages:
 - Reduced waste disposal airspace capacity.
 - Reduced volume construction materials that can be won from cut earthworks. It may be necessary to borrow material from other on-site areas or import fill material to support construction of the eastern stages (Stage 6, Stage 8, Stage 10).
 - Increased leachate drainage distance (maximum of 400 m). This is likely to require additional design redundancy in the event of a failure of the leachate collection system that could include the construction of drilling pads in the floor of eastern stages to protect the liner in the event that leachate extraction wells are required in the future.

The subgrade surface to be adopted for each future stage would need be finalised during detailed design based upon a range of considerations that include:

- Findings from ongoing groundwater monitoring at the SBWMF.
- The availability of alternative sources of fill material for construction.
- Future changes to design standards and regulatory requirements.

To allow for the adoption of either option for during the design of Stage 6, the design for Stage 5 allows for the connection and drainage capacity of leachate from Stage 6.

For the purposes of this Landfill Development Plan, estimated airspace volumes were based upon Option A.

Within each general waste landfill stage the leachate collection system would comprise the following as shown on Figure 5 (Option A) and Figure 6 (option B):

- A cushion geotextile to protect the liner system from the leachate collection system.



- Two sub cells (A and B) with central valley graded (minimum 1%) to gravity drain towards a leachate collection sump.
- A network of internal pipes along the valley floor, along the change in grade between the cell floor and better slopes, and regularly spaced across the grade of the cell floor.
- A gravel drainage blanket across the entire cell floor and up the side batters to within 1 m vertical distance of the internal batter crest.
- A separation geotextile to reduce the migration of fines and other material from overlying waste into the leachate collection system.

For further information on the design of the leachate collection please refer to Report 2 and Report 3.

3.5 Liner System

For the construction of Stage 5, a three-layer composite liner was adopted, comprising 300 mm thick compacted fines-rich engineered fill, overlain with GCL, overlain with 2 mm thick HDPE geomembrane. This liner system was developed as an alternative to the suggested liner system in the NT EPA Guidelines¹ based on consideration of the project context and the need to manage practical issues associated with sourcing materials suitable for construction of a clay liner at the site.

For further information on the design of the leachate collection please refer to Report 2 and Report 3.

For the purposes of this Landfill Development Plan, estimated airspace volumes were based upon the adoption of a similar liner and leachate collection system to that used for Stage 5 for the other future stages (Stage 6 to Stage 10).

3.6 Final Waste Landform

Options for the final overall waste landform for current and future general waste stages (Stage 3 to Stage 10) were reviewed in Report 4 that considered external batter gradients of 5H:1V, 4H:1V and 3H:1V up to a maximum elevation of RL70 mAHD. It is understood that Council will review select its preferred external batter gradient and maximum landfill elevation following the finalisation of a separate resource recovery strategy that will strongly influence waste disposal airspace requirements during the remaining period (2034) of the current lease for the SBWMF.

For the purposes of this Landfill Development Plan, an external batter gradient of 4H:1V and maximum waste elevation of RL54.9 mAHD was adopted as shown on Figure 7. This option provides minimum working area width of 80 m across the upper plateau surface of each stage.

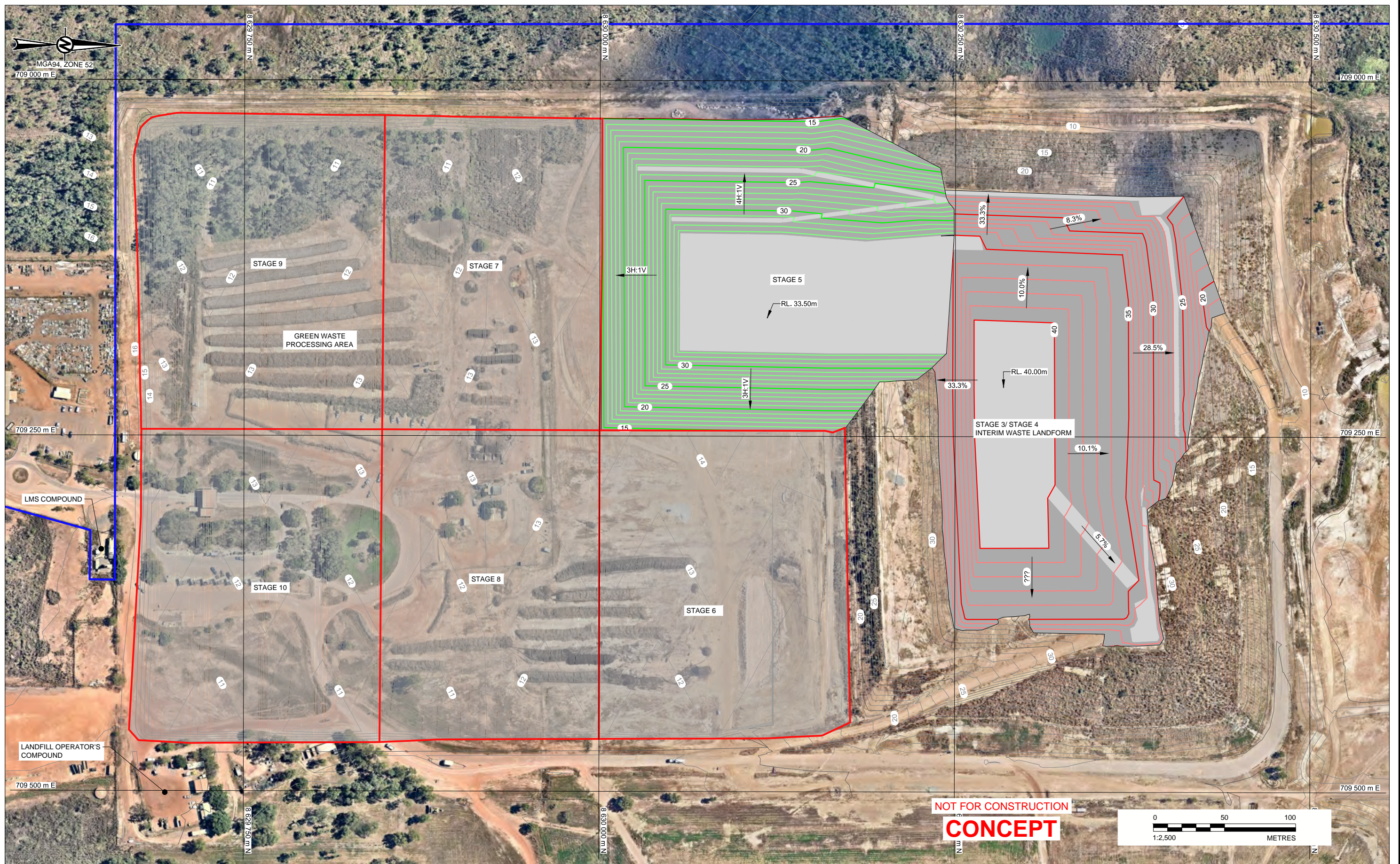
3.7 Interim Landforms

The proposed development sequence and interim landforms for each future general waste stage are shown as follows:

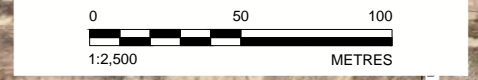
- Figure 8: Stage 5
- Figure 9: Stage 6
- Figure 10: Stage 7
- Figure 11: Stage 8
- Figure 12: Stage 9
- Figure 13: Stage 10
- Figure 14 Typical sections through the interim stage landforms and final landform

The interim landforms are based upon adoption of interim internal batter gradients of 3H:1V.

¹ The suggested liner system in the NT EPA Guidelines comprises a 600 mm thick clay liner overlain with 1.5 mm thick HDPE geomembrane.



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- LEGEND**
- STAGE 5 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
 - STAGE 3 AND 4 INTERIM AND FINAL WASTE LANFORM, 1m CONTOURS
 - FUTURE LANDFILL STAGES
 - LANDFILL OPERATIONS BOUNDARY

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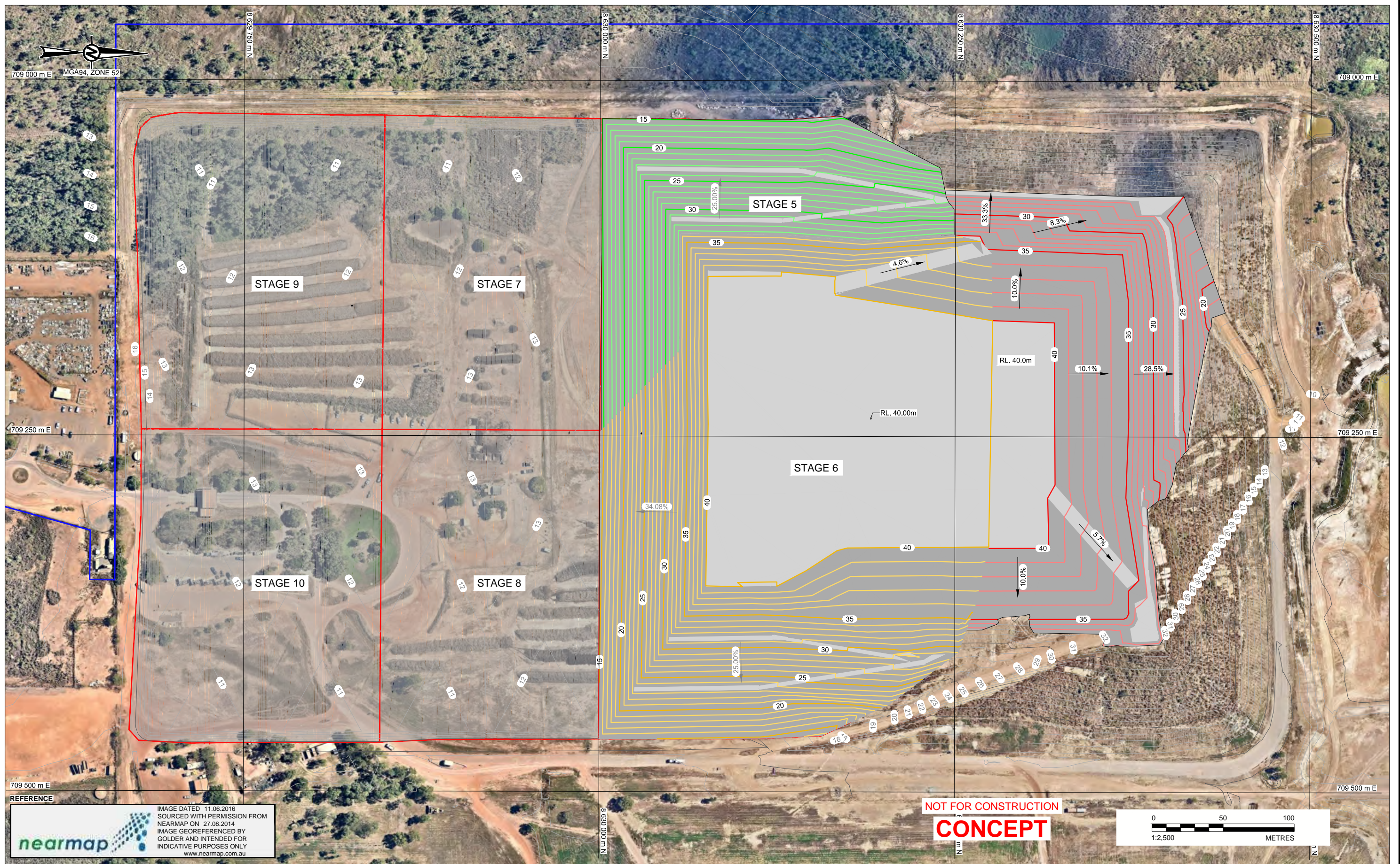
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STAGE 5 DEVELOPMENT AND INTERIM LANDFORM PLAN

PROJECT NO.	DOC	REV.
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FIGURE
F008

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- LEGEND**
- STAGE 3 AND 4 INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
 - STAGE 5 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
 - STAGE 6 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
 - FUTURE LANDFILL STAGES
 - LANDFILL OPERATIONS BOUNDARY

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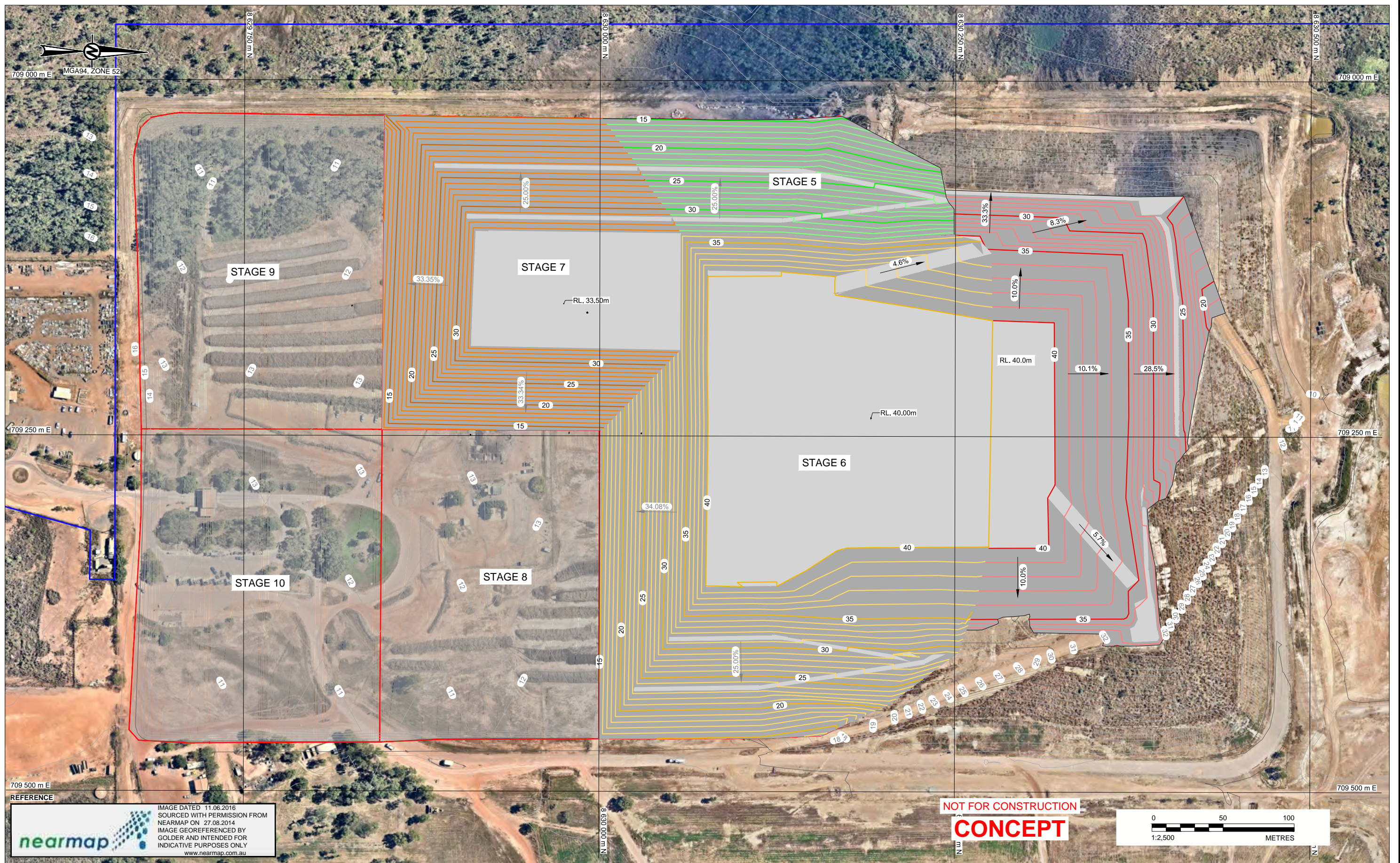
PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
GENERAL WASTE LANDFILL DEVELOPMENT PLAN

TITLE
STAGE 6 DEVELOPMENT AND INTERIM LANDFORM PLAN

PROJECT NO.	DOC	REV.
1526230	020	0

FIGURE
F009

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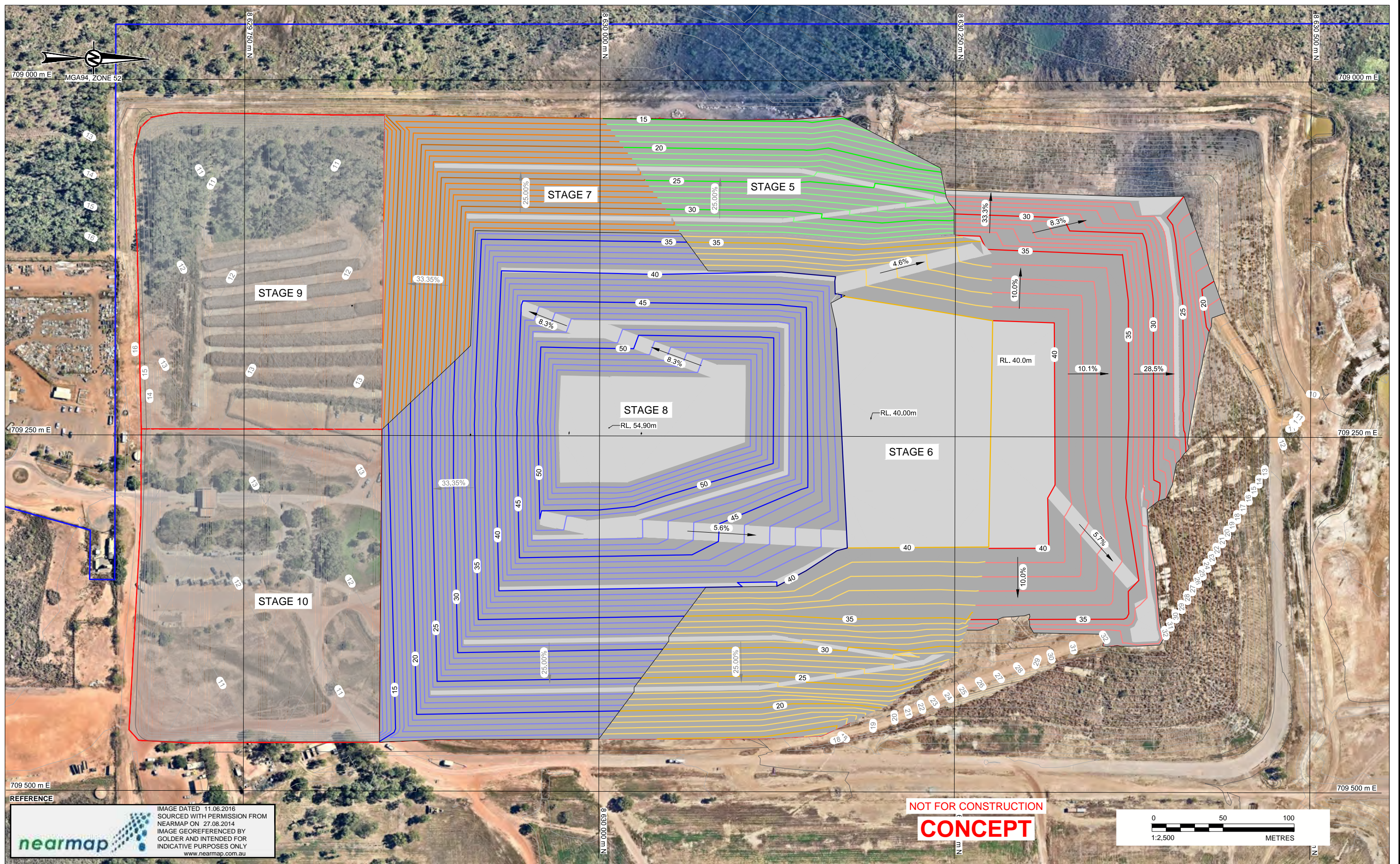
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LEGEND

	STAGE 3 AND 4 INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
	STAGE 5 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
	STAGE 6 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
	STAGE 7 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
	FUTURE LANDFILL STAGES
	LANDFILL OPERATIONS BOUNDARY

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CONSULTANT 	TITLE STAGE 7 DEVELOPMENT AND INTERIM LANDFORM PLAN
YYYY-MM-DD 2016-08-15	PROJECT NO. 1526230
DESIGNED SRM	DOC 020
PREPARED MMC	REV. 0
REVIEWED JSB	FIGURE F010
APPROVED JSB	

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LEGEND

	STAGE 3 AND 4 INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
	STAGE 5 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
	STAGE 6 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
	STAGE 7 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
	STAGE 8 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
	FUTURE LANDFILL STAGES
	LANDFILL OPERATIONS BOUNDARY

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APPROVED	JSB

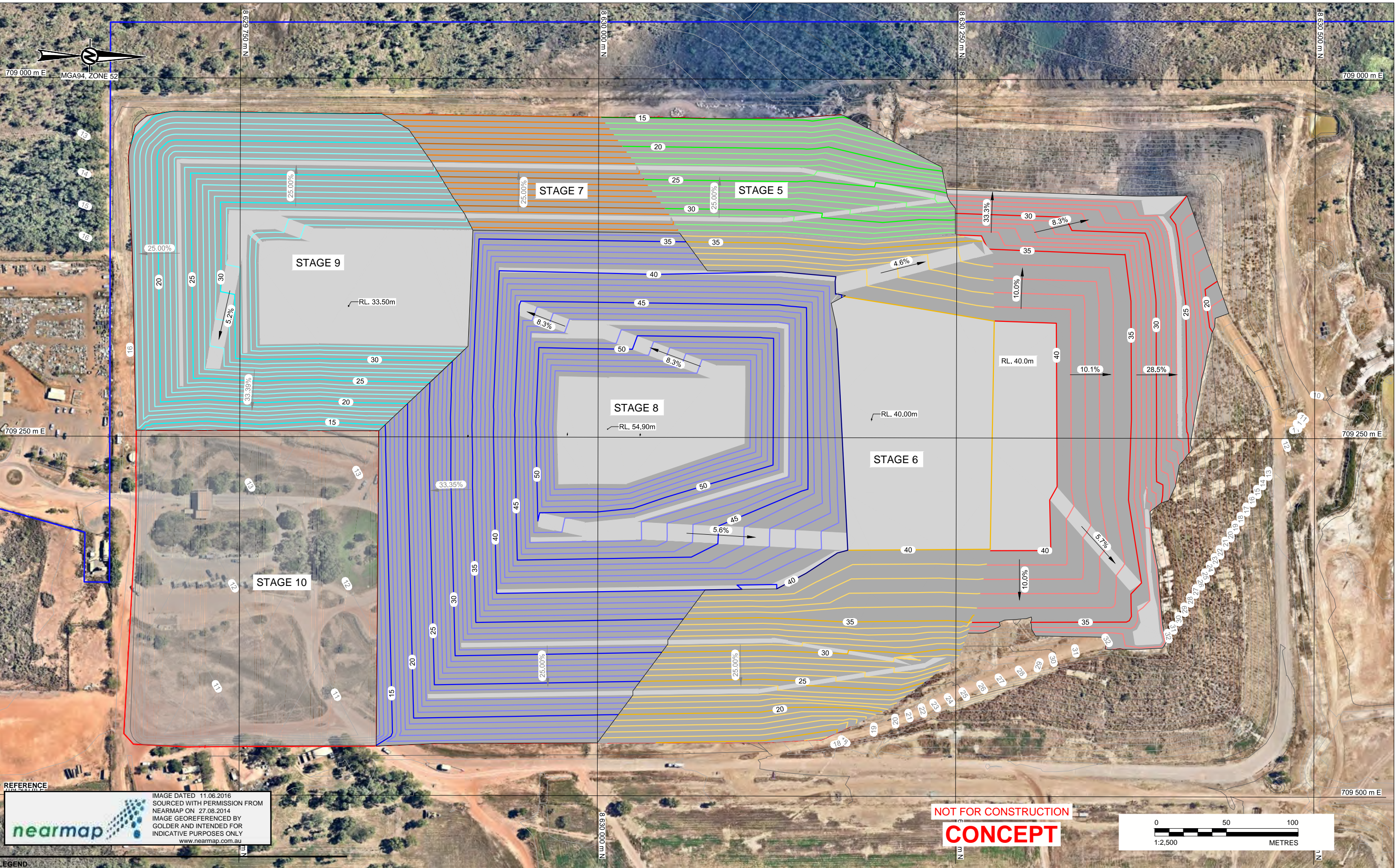
PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
GENERAL WASTE LANDFILL DEVELOPMENT PLAN


TITLE
STAGE 8 DEVELOPMENT AND INTERIM LANDFORM PLAN

PROJECT NO.	DOC	REV.
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FIGURE
F011

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LEGEND

—	STAGE 3 AND 4 INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
—	STAGE 5 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
—	STAGE 6 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
—	STAGE 7 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
—	STAGE 8 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
—	STAGE 9 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
—	FUTURE LANDFILL STAGES
—	LANDFILL OPERATIONS BOUNDARY

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PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
GENERAL WASTE LANDFILL DEVELOPMENT PLAN

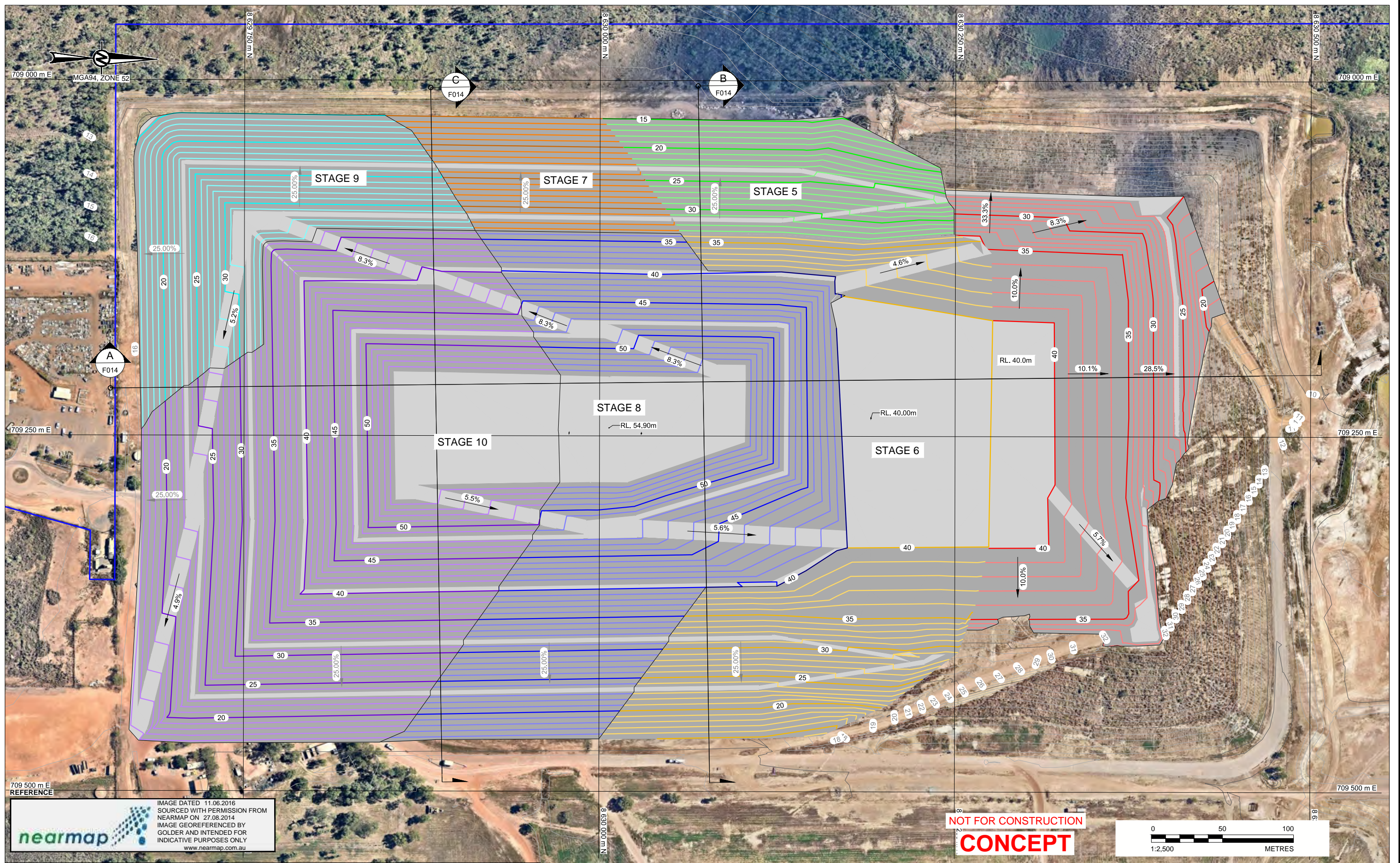
TITLE
STAGE 9 DEVELOPMENT AND INTERIM LANDFORM PLAN

PROJECT NO.	DOC	REV.
1526230	020	0

FIGURE
F012

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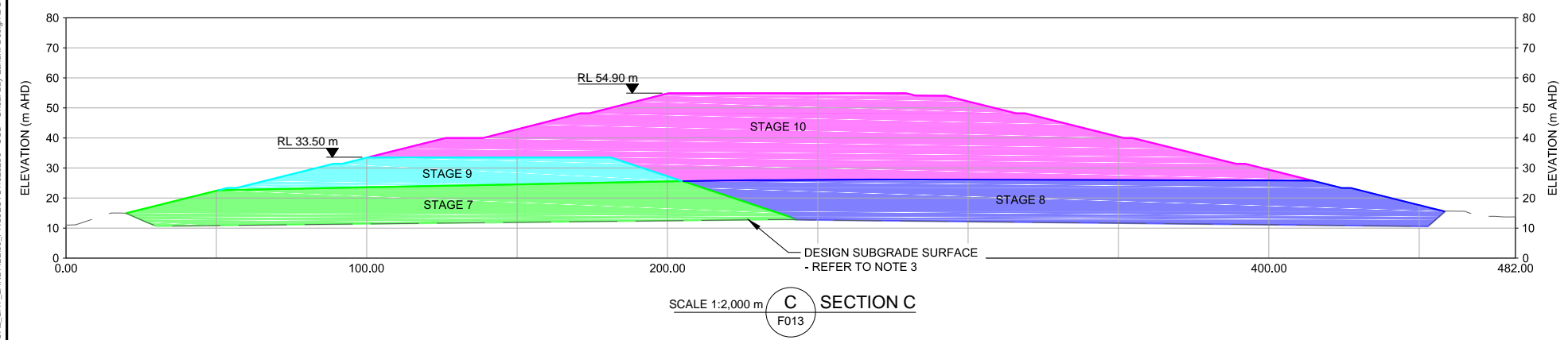
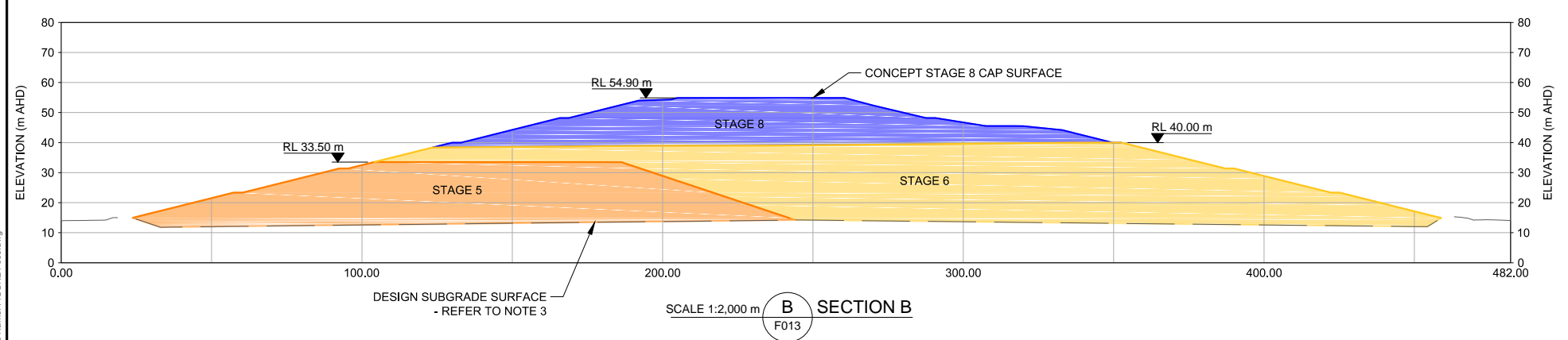
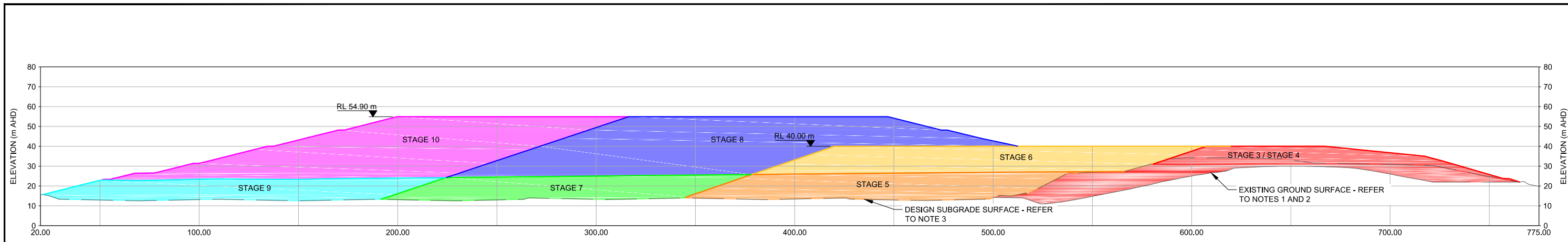
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GENERAL WASTE LANDFILL DEVELOPMENT PLAN

TITLE
STAGE 10 DEVELOPMENT AND INTERIM LANDFORM PLAN

PROJECT NO.	DOC	REV.
1526230	020	0

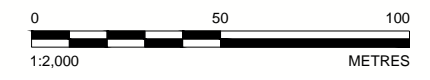
FIGURE
F013

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- NOTES:**
- EXISTING GROUND SURFACE COMPRISES THE FOLLOWING:
 - SEPTEMBER 2015 SURVEY WITHIN THE FOOTPRINT OF STAGE 3 / STAGE 4. SURVEY BY EARL JAMES & ASSOCIATES ON 29 SEPTEMBER 2015, DRAWING TITLE "VOLUMES - END OF MONTH - SEPTEMBER 29 2015", DRAWING NUMBER 15/5209/126, CAD FILE NAME "5209-126 (3D INFO)".
 - AUGUST 2015 SURVEY IN AREAS OUTSIDE THE FOOTPRINT OF STAGE 3/STAGE 4. SURVEY BY AUSURV SURVEYORS P/L COMPLETED ON 1 AUGUST 2015, DRAWING TITLE "DETAIL SURVEY SHOAL BAY WASTE MANAGEMENT FACILITY", DRAWING NUMBER 15-0099-1, CAD FILE NAME "15-0099 SHOAL BAY LANDFILL".
 - EXISTING TOP OF STAGE 3 / STAGE 4 SURFACE IS BASED ON 28 JUNE 2016 SURVEY.
 - DESIGN SUBGRADE SURFACES IS THE DESIGN SUBGRADE SURFACE OPTION A DRAINING DOWN TOWARDS EAST AND WEST PRESENTED IN GOLDRER DOCUMENT 152630-006-L-REV1.

- LEGEND**
- STAGE 3 / STAGE 4 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
 - STAGE 5 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
 - STAGE 6 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
 - STAGE 7 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
 - STAGE 8 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
 - STAGE 9 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
 - STAGE 10 CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS



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CONSULTANT 	TITLE TYPICAL GENERAL WASTE INTERIM STAGE LANDFORMS AND FINAL LANDFORM SECTIONS																		
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YYYY-MM-DD	2016-08-15																		
DESIGNED	SRM																		
PREPARED	MMC																		
REVIEWED	JSB																		
APPROVED	JSB																		
PROJECT NO.	DOC	REV.	FIGURE																
1526230	020	0	F014																

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3.8 Surface Areas and Airspace Capacity

Based upon the adopted stage floor option (Figure 5) and the final landform option (Figure 7), estimated surface areas and airspace capacity for each future general waste stage are summarised in Table 1.

Table 1: Stage 5 to Stage 10 Surface Areas and Airspace Capacity

Stage	Base Liner Area (m ²)	Estimated Airspace (m ³)	Interim Capping Area (m ²)	Final Capping Area (m ²)
Stage 5	36,500	510,000	49,900	16,800
Stage 6	37,900	950,000	87,600	49,700
Stage 7	33,900	450,000	43,500	11,700
Stage 8	33,700	1,220,000	93,400	66,500
Stage 9	38,400	525,000	49,500	27,500
Stage 10	38,200	1,180,000	84,400	86,500
Totals	218,600	4,835,000	408,200	258,700

3.9 Final Capping

3.9.1 Capping System

The NT EPA Landfill Guidelines require that final capping be designed such that infiltration through the cap does not exceed the calculated seepage rate through the landfill liner and include an indicative cap design with combined thickness of approximately 2.2 m (including interim cover) as shown on Figure 15.

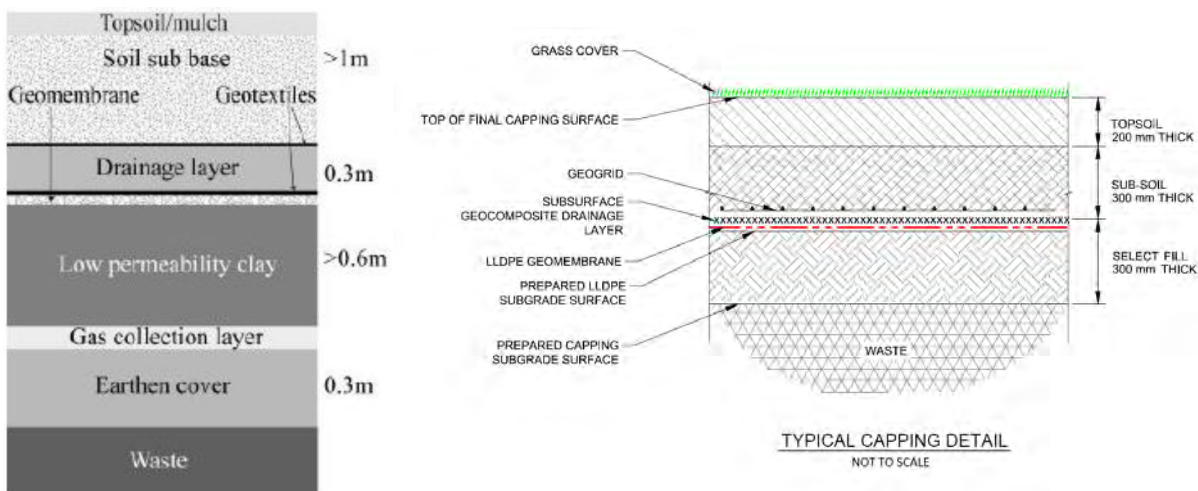


Figure 15: Final Capping Option Profiles

Based recent experience with the design and construction of final capping systems for regional landfill sites with tropical climate conditions located in Northern Queensland, Golder propose an alternative solution based on use of a geomembrane liner within a combined thickness of approximately 0.8 m (including interim cover) as shown on Figure 15. Detailed design for final capping would need to consider:

- Geocomposite drainage layer. This is a geosynthetic drainage layer encased in a filtration geotextile, with typical thickness in the order of 30 mm. This is thinner than the 0.3 m thick drainage layer of sandy soil or gravel indicated in the NT EPA Guidelines. Detailed design will need to consider anticipated flow rates for selection of an appropriately sized geocomposite drainage material.



- Liner low density polyethylene (LLDPE) geomembrane. LLDPE materials have higher strain tolerance compared to high density polyethylene (HDPE) geomembrane materials; LLDPE materials are considered favourable for geomembrane liners in landfill caps due to their capacity to withstand differential settlement of the underlying waste. The NT EPA Guidelines also include a geomembrane.
- Geosynthetic clay liner (GCL). Detailed design should consider whether a GCL is required underneath the geomembrane to achieve the NT EPA Guideline requirement that final capping be designed such that infiltration through the cap does not exceed the calculated seepage rate through the landfill liner. If a GCL is required, there may be value in considering a combined coated product to replace the geomembrane that provides protection against wetting and drying cycles and root penetration.
- Gas collection system. Detailed design should consider inclusion of a gas collection system incorporating passive gas relief strips (e.g. geocomposite drainage material) underneath the geosynthetic liner elements, connected to gas vents. This system would be intended to provide a means of passive gas management to be used when active gas collection is no longer commercially viable.

3.9.2 Capping Stages

To reduce long term leachate generation rates, it is strongly recommended that construction of final capping is implemented in regular stages in parallel with the construction of new general waste stage cells. Proposed final capping stages are presented as follows:

- Figure 16: Stage A Final Capping
- Figure 17: Stage B Final Capping
- Figure 18: Stage C Final Capping
- Figure 19: Stage D Final Capping
- Figure 21: Stage E Final Capping

4.0 FUTURE STAGE DEVELOPMENT AND FILLING SCHEDULE

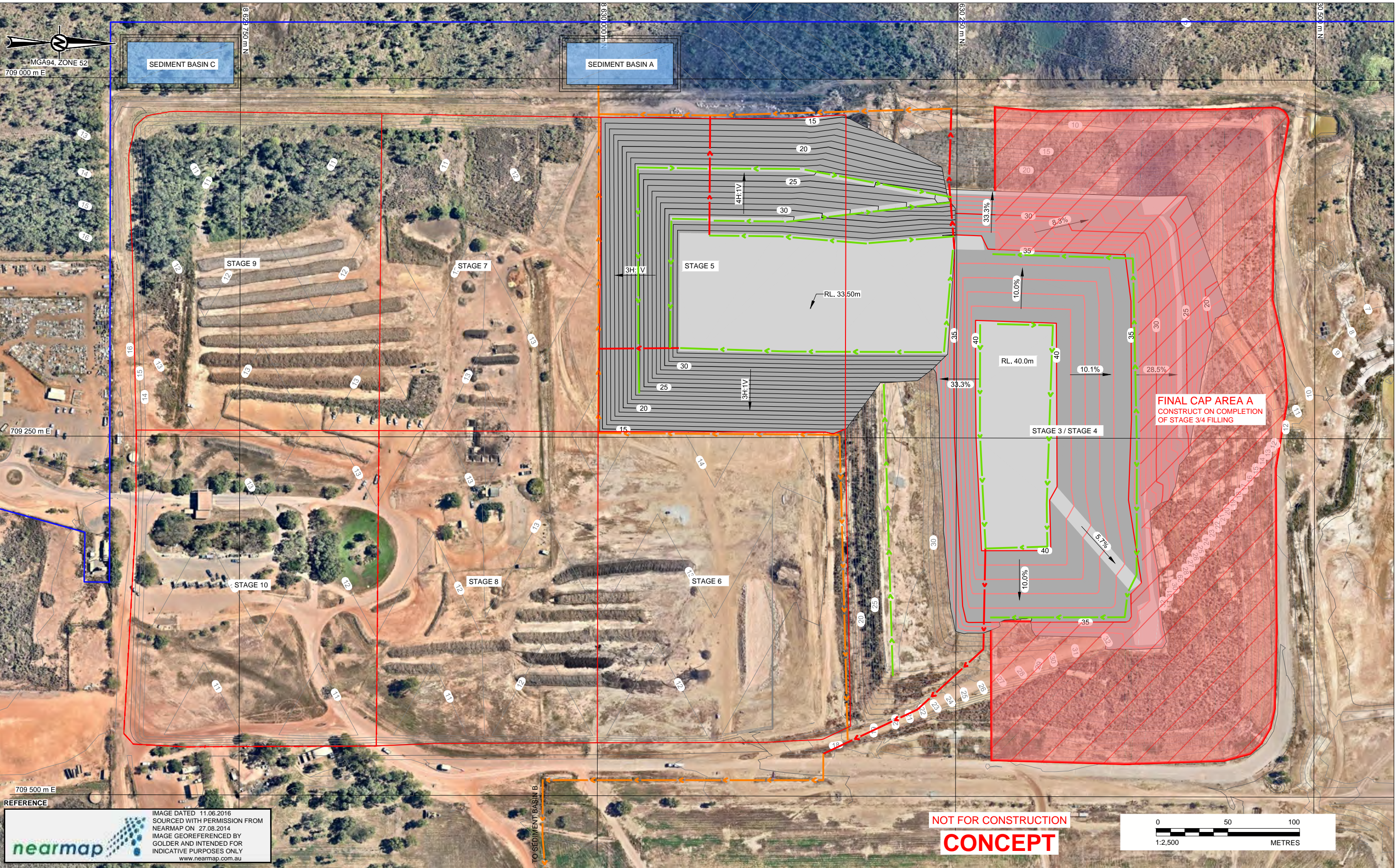
A sensitively assessment for nominal timeframes for use of the available airspace capacity for each future general waste stage is presented in Figure 22 using a range of waste density (0.6 m³/t to 0.9m³/t) and monthly disposal rates (12,000 m³/m to 20,000 m³/month).

Based on the “Lower Range Filling Rate” and “Upper Range Filling Rate” adopted in Section 2.4, the nominal lifespan of each future stage is summarised in Table 2.

Table 2: Stage 5 to Stage 10 Nominal Lifespan Ranges

Stage	Estimated Airspace (m ³)	Lower Range Filling Rate Lifespan	Upper Range Filling Rate Lifespan
Stage 5	510,000	35 months	27 months
Stage 6	950,000	65 months	50 months
Stage 7	450,000	31 months	23 months
Stage 8	1,220,000	83 months	64 months
Stage 9	525,000	36 months	28 months
Stage 10	1,180,000	81 months	62 months
Totals	4,835,000	331 months	254 months

Table 3 presents a combined nominal schedule for the construction, filling and final capping of each future general waste stage for both the above Lower and Upper Range filling rate lifespans.



REFERENCE

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- LEGEND**
- FINAL CAP AREA A
 - CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
 - LANDFILL OPERATIONS BOUNDARY
 - ROCK LINED CHUTE
 - SWALE (IMPACTED RUNOFF)
 - PERIMETER DRAIN (IMPACTED WATER)

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 APPROVED JSB

PROJECT
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GENERAL WASTE LANDFILL DEVELOPMENT PLAN

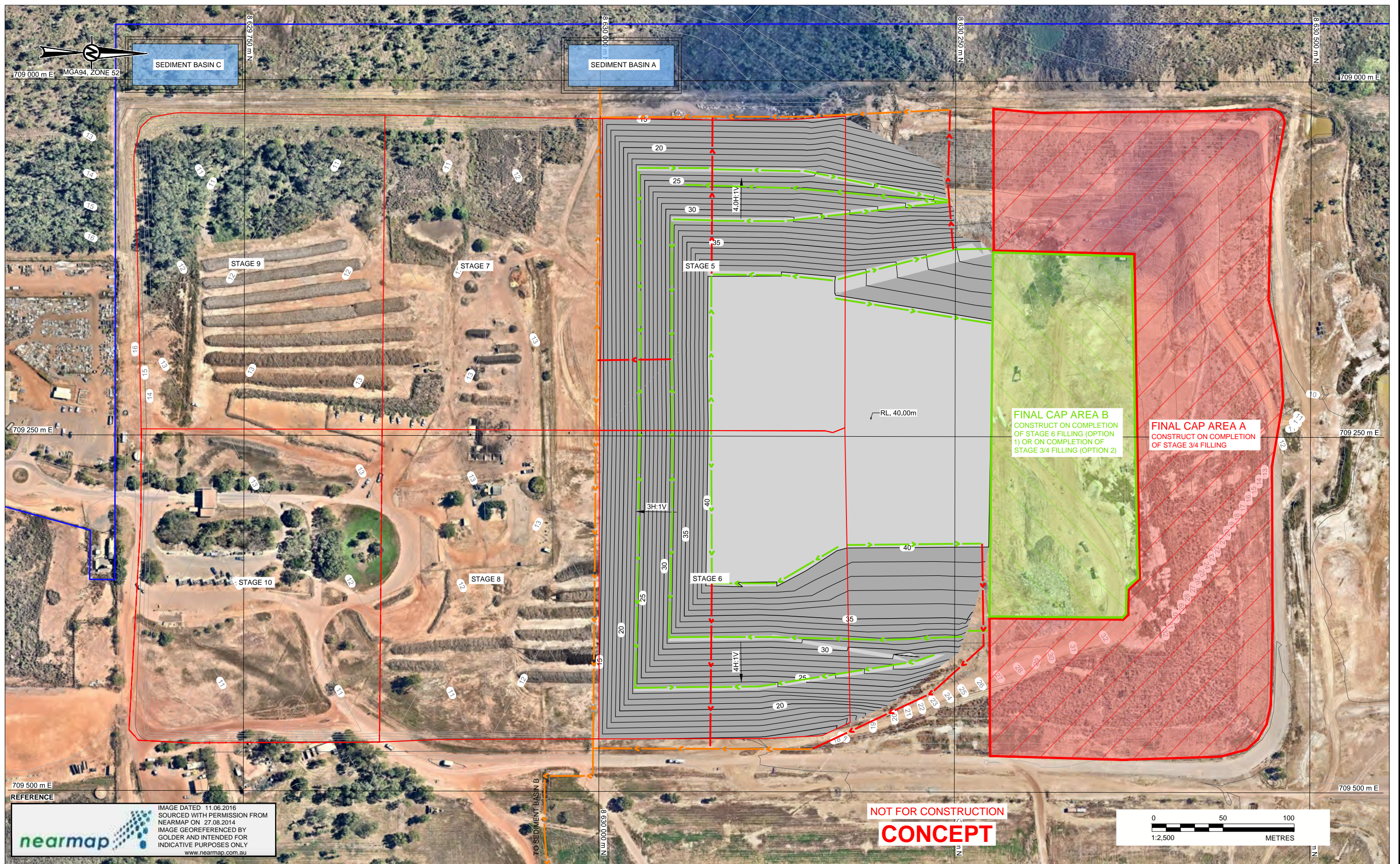
TITLE
**STAGE A FINAL CAPPING AND INTERIM STORMWATER
MANAGEMENT PLAN**

PROJECT NO. 1526230
 DOC 020
 REV. 0

FIGURE
F016

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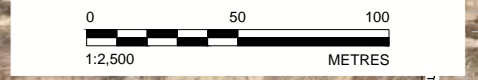
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LEGEND	
	FINAL CAP AREA A
	FINAL CAP AREA B
	CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
	LANDFILL OPERATIONS BOUNDARY
	ROCK LINED CHUTE
	SWALE (IMPACTED RUNOFF)
	PERIMETER DRAIN (IMPACTED WATER)

NOT FOR CONSTRUCTION
CONCEPT



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PROJECT
 SHOAL BAY WASTE MANAGEMENT FACILITY
 GENERAL WASTE LANDFILL DEVELOPMENT PLAN

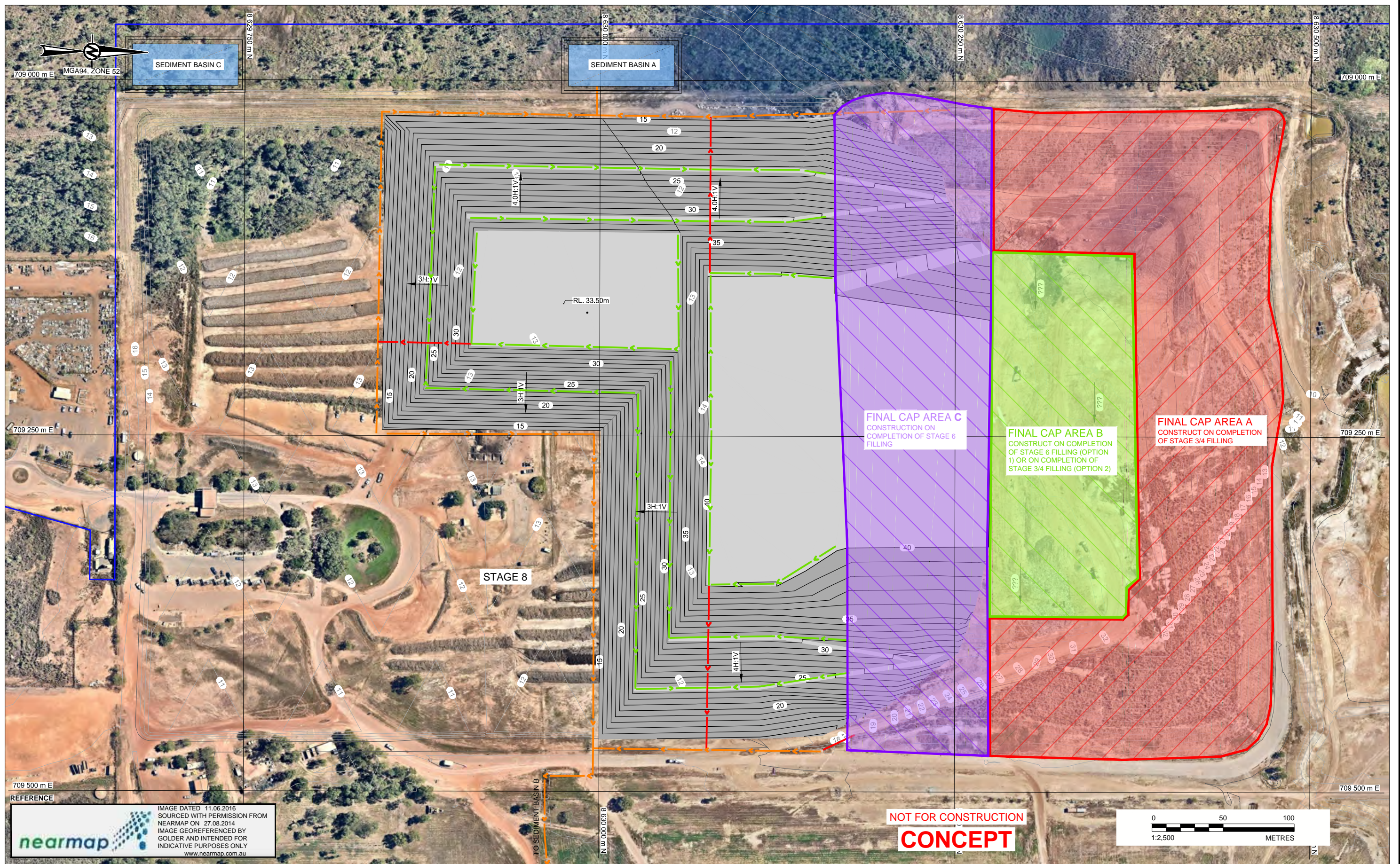
TITLE
**STAGE B FINAL CAPPING AND INTERIM STORMWATER
 MANAGEMENT PLAN**

PROJECT NO.	DOC	REV.
1526230	020	0

FIGURE
F017

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LEGEND	
	FINAL CAP AREA A
	FINAL CAP AREA B
	FINAL CAP AREA C
	CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
	ROCK LINED CHUTE
	SWALE (IMPACTED RUNOFF)
	PERIMETER DRAIN (IMPACTED WATER)
	LANDFILL OPERATIONS BOUNDARY

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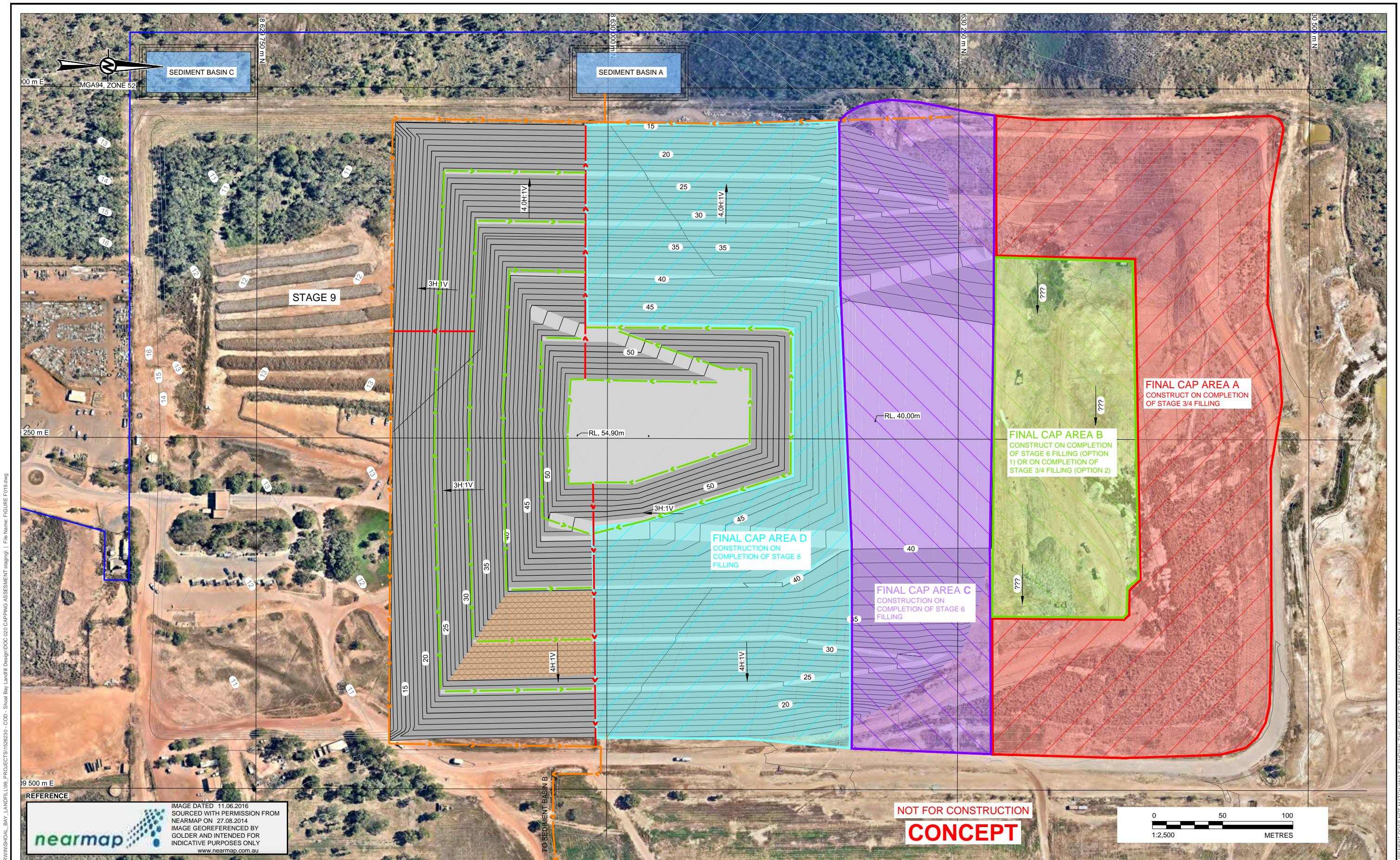
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 SHOAL BAY WASTE MANAGEMENT FACILITY
 GENERAL WASTE LANDFILL DEVELOPMENT PLAN

TITLE
STAGE C FINAL CAPPING AND INTERIM STORMWATER MANAGEMENT PLAN

PROJECT NO.	DOC	REV.
1526230	020	0

FIGURE
F018

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LEGEND	
	FINAL CAP AREA A
	FINAL CAP AREA B
	FINAL CAP AREA C
	FINAL CAP AREA D
	CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
	ROCK LINED CHUTE
	SWALE (IMPACTED RUNOFF)
	PERIMETER DRAIN (IMPACTED WATER)
	LANDFILL OPERATIONS BOUNDARY
	ADDITIONAL EROSION CONTROL AREA

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DESIGNED	SRM
PREPARED	MMC
REVIEWED	JSB
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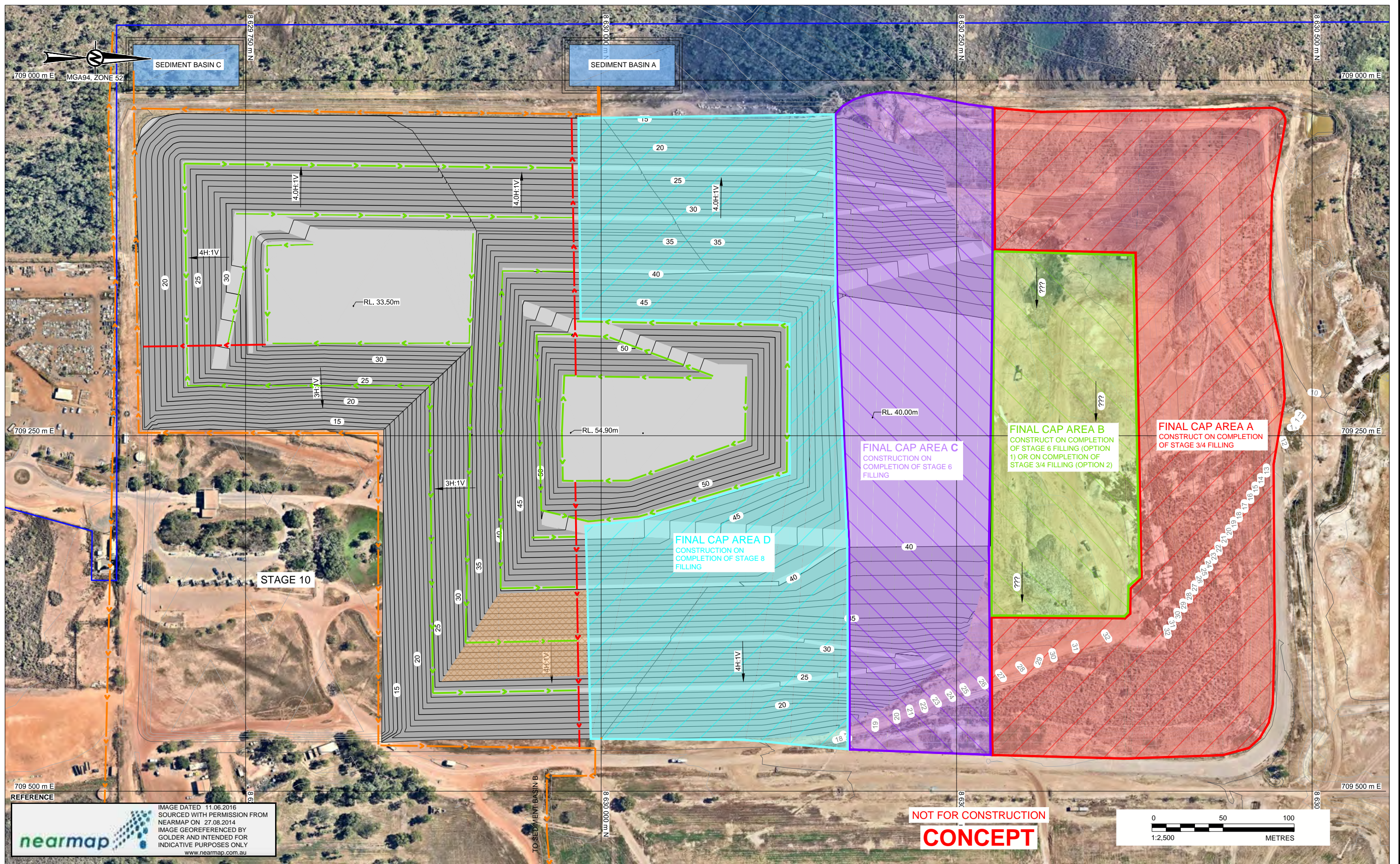
PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
GENERAL WASTE LANDFILL DEVELOPMENT PLAN

TITLE
**STAGE D FINAL CAPPING AND INTERIM STORMWATER
MANAGEMENT PLAN**

PROJECT NO.	DOC	REV.
1526230	020	0

FIGURE
F019

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LEGEND	
	FINAL CAP AREA A
	FINAL CAP AREA B
	FINAL CAP AREA C
	FINAL CAP AREA D
	CONCEPT INTERIM AND FINAL WASTE LANDFORM, 1m CONTOURS
	ROCK LINED CHUTE
	SWALE (IMPACTED RUNOFF)
	PERIMETER DRAIN (IMPACTED WATER)
	LANDFILL OPERATIONS BOUNDARY
	ADDITIONAL EROSION CONTROL AREA

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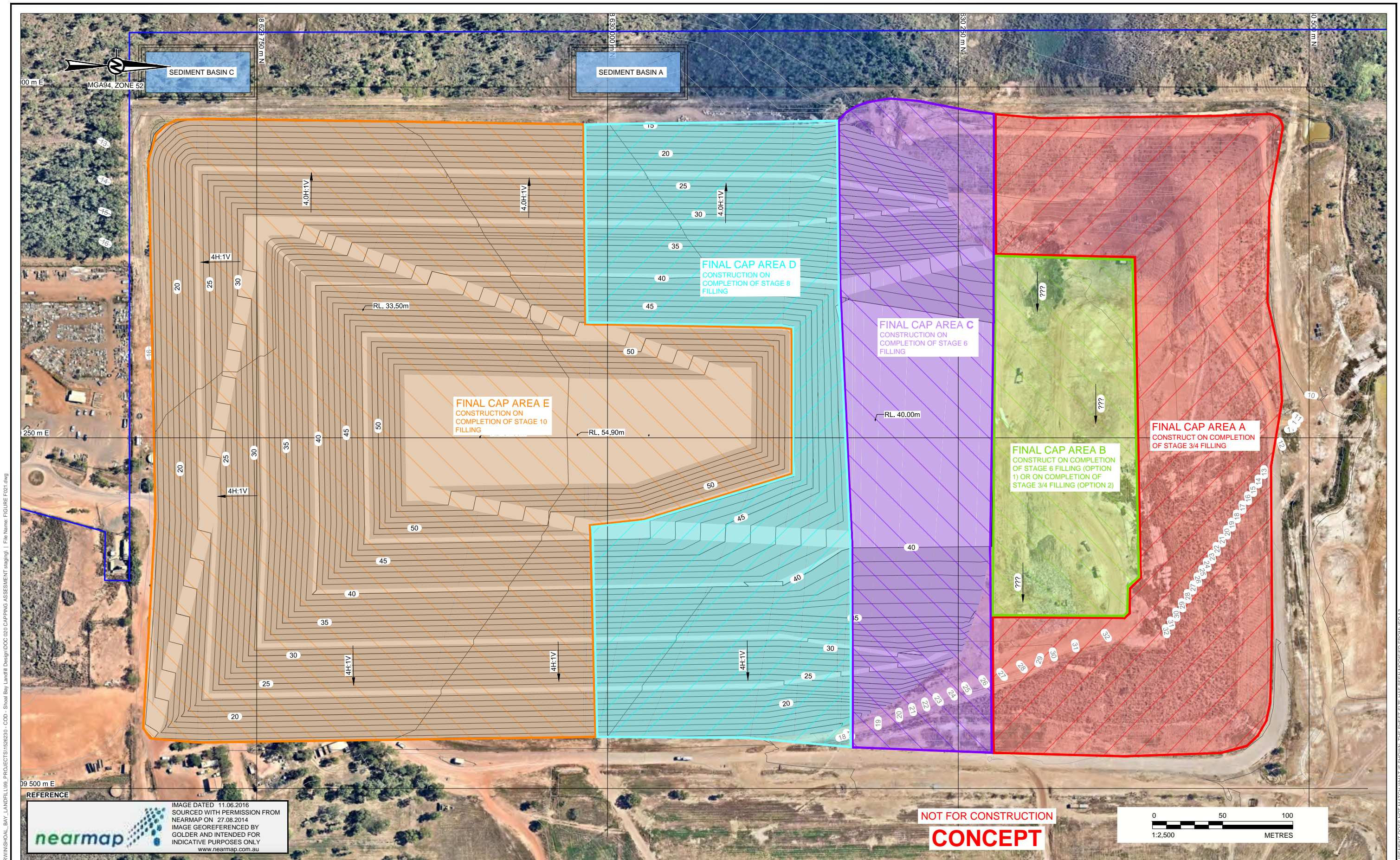
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APPROVED	JSB

PROJECT
 SHOAL BAY WASTE MANAGEMENT FACILITY
 GENERAL WASTE LANDFILL DEVELOPMENT PLAN

TITLE
STAGE E INTERIM STORMWATER MANAGEMENT PLAN

PROJECT NO.	DOC	REV.	FIGURE
1526230	020	0	F020

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LEGEND

	FINAL CAP AREA A		LANDFILL OPERATIONS BOUNDARY
	FINAL CAP AREA B		
	FINAL CAP AREA C		
	FINAL CAP AREA D		
	FINAL CAP AREA E		

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CONSULTANT 	TITLE STAGE E FINAL CAPPING PLAN
DESIGNED SRM	PROJECT NO. 1526230
PREPARED MMC	DOC 020
REVIEWED JSB	REV. 0
APPROVED JSB	FIGURE F021

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GENERAL WASTE LANDFILL DEVELOPMENT PLAN

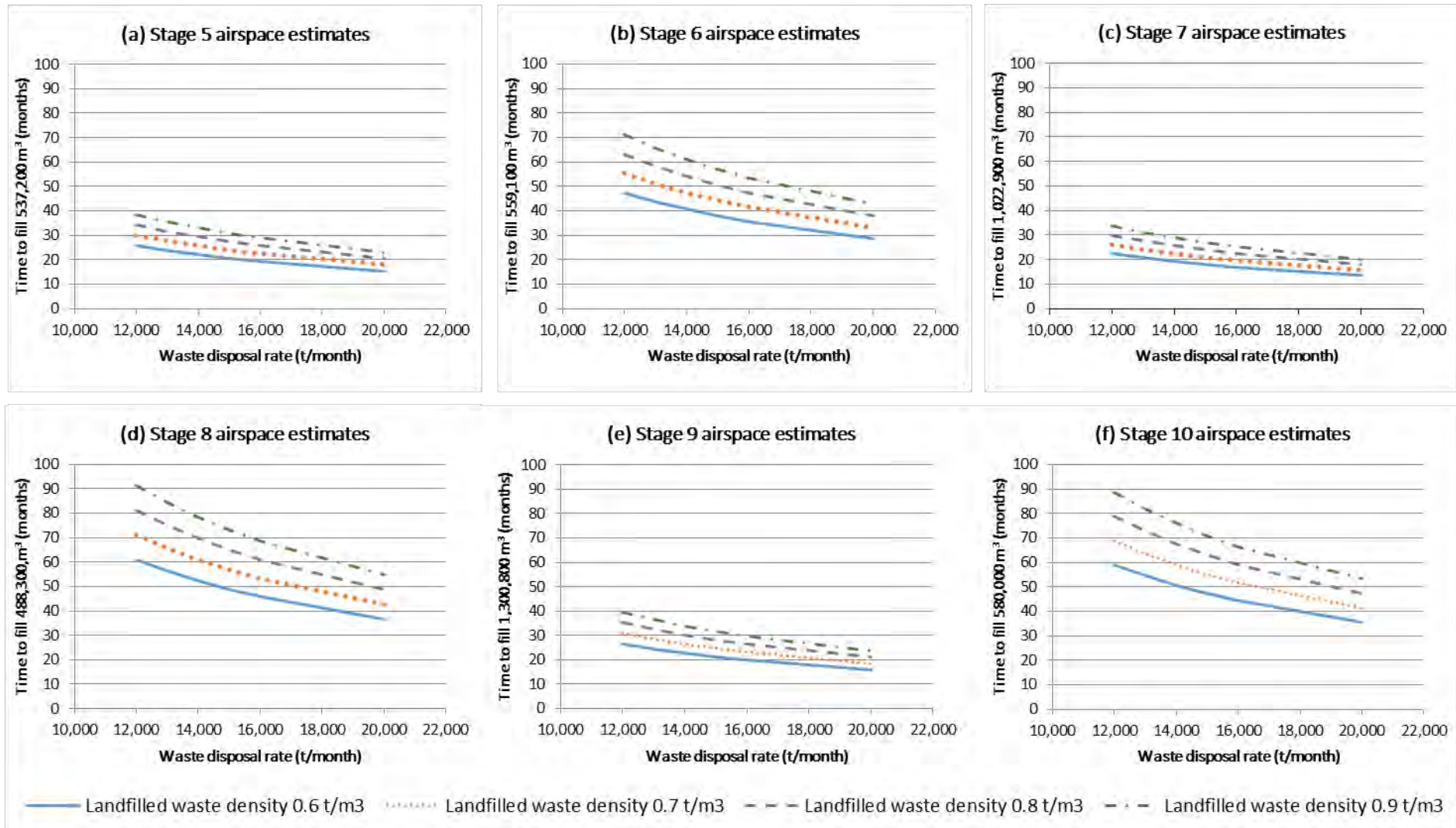


Figure 22: Stage Filling Lifespan Sensitivity Review



GENERAL WASTE LANDFILL DEVELOPMENT PLAN

Table 3: Stage 5 to Stage 10 Stage Construction, Filling and Final Capping Schedule.

		Indicative scheduling of activities – Low Filling Rate			Indicative scheduling of activities – High Filling Rate			
		Construction	Filling	Capping	Construction	Filling	Capping	
2016	Q3	Stage 5	Stage 3 / Stage 4			Stage 3 / Stage 4		
	Q4							
2017	Q1							
	Q2							Stage 5
	Q3							Stage 5
	Q4							
2018	Q1	Stage 6	Stage 5		Stage 6	Stage 5		
	Q2							
	Q3							
	Q4							
2019	Q1							
	Q2							Stage 6
	Q3							Stage 6
	Q4							Capping Area A*
2020	Q1							
	Q2							
	Q3							Capping Area B*
	Q4							
2021	Q1					Stage 5 (2 months) and Stage 6		
	Q2							
	Q3							
	Q4							
2022	Q1		Stage 5 (11 months) and Stage 6					
	Q2							Stage 7
	Q3							
	Q4							
2023	Q1							
	Q2							Stage 7
	Q3							Stage 7
	Q4							Stage 6 (4 months) and Stage 7
2024	Q1	Stage 7			Stage 8	Stage 7	Capping Area C*	
	Q2							
	Q3							
	Q4							
2025	Q1							
	Q2							Stage 7
	Q3							Stage 7
	Q4							Stage 6 (4 months) and Stage 7
2026	Q1	Stage 8	Stage 7	Capping Area C*				
	Q2							
	Q3							
	Q4							
2027	Q1							
	Q2							Stage 8
	Q3							Stage 8
	Q4							
2028	Q1					Stage 7 (3 months) and Stage 8		
	Q2							
	Q3							
	Q4							
2029	Q1				Stage 9			
	Q2							
	Q3							
	Q4							
2030	Q1		Stage 7 (10 months) and Stage 8					
	Q2							Stage 9
	Q3							Stage 9
	Q4							
2031	Q1				Stage 10	Stage 8 (7 months) and Stage 9		
	Q2							
	Q3							
	Q4							
2032	Q1		Stage 8			Stage 9		
	Q2							Stage 10



GENERAL WASTE LANDFILL DEVELOPMENT PLAN

		Indicative scheduling of activities – Low Filling Rate			Indicative scheduling of activities – High Filling Rate		
2033	Q3	Stage 9					
	Q4						
	Q1						
	Q2						
2034	Q3	Stage 9					
	Q4						
	Q1						
	Q2						
2035	Q3	Stage 8 (10 months) and Stage 9					
	Q4						
	Q1						
	Q2						
2036	Q3	Stage 10	Stage 9	Capping Area D			
	Q4						
	Q1						
	Q2						
2037	Q3	Stage 10					
	Q4						
	Q1						
	Q2						
2038	Q3					Capping Area E	
	Q4						
	Q1						
	Q2						
2039	Q3						
	Q4						
	Q1						
	Q2						
2040	Q3	Stage 9 (10 months) and Stage 10 to completion of filling Stage 10 in Oct 2044					
	Q4						
	Q1						
	Q2						
2041	Q3						
	Q4						
	Q1						
	Q2						
2042	Q3						
	Q4						
	Q1						
	Q2						
2043	Q3						
	Q4						
	Q1						
	Q2						
2044	Q3						
	Q4						
	Q1						
	Q2						
2045	Q3			Capping Area E			
	Q4						
	Q1						
	Q2						

Note: *Capping Episode B to occur at the time of Capping Episode A or at the time of Capping Episode C.



5.0 STORMWATER MANAGEMENT

5.1 General Approach

The goals for stormwater management for the future landfill stages are to:

- a) Divert run-off from outside active landfill stages around the disturbed areas so it does not require sediment containment treatment; and
- b) Collect run-off within the active landfill stages (including areas with interim capping), that has not come into contact with waste, and treat the collected water in sediment basins.

Please note that surface water that comes into contact with waste is to be treated as leachate.

5.2 Stormwater Drains

Indicative drainage pathways for each of Stages 5 to 10 during filling are shown on Figure 16 to Figure 20. Surface water runoff from active landfill stages (including areas of interim capping) is collected in swale drains at the crest of the landforms and on the batters, and drained to the toe of the batters via rock-lined chutes.

The rock-lined chutes discharge to swale drains at the toe of the batters, and these swales drain to sediment basins. Diversion drains collect runoff from outside the active area for discharge to the environment. Considerations for design of the proposed drains are provided below:

- **Swale drains:** Swales are positioned at the crest of the design landforms, above berms on the batters (spaced at approximately 35 m), along the toe of the batters, and between toe drains and the sediment ponds.

The swales are intended to be graded at approximately 2% to allow for “self-cleaning” such that sediment does not build up in the drains, while managing risks of erosion of drains associated with higher velocity discharge at steeper grades. Detailed design will need to consider the appropriate drainage gradient to manage these risks.

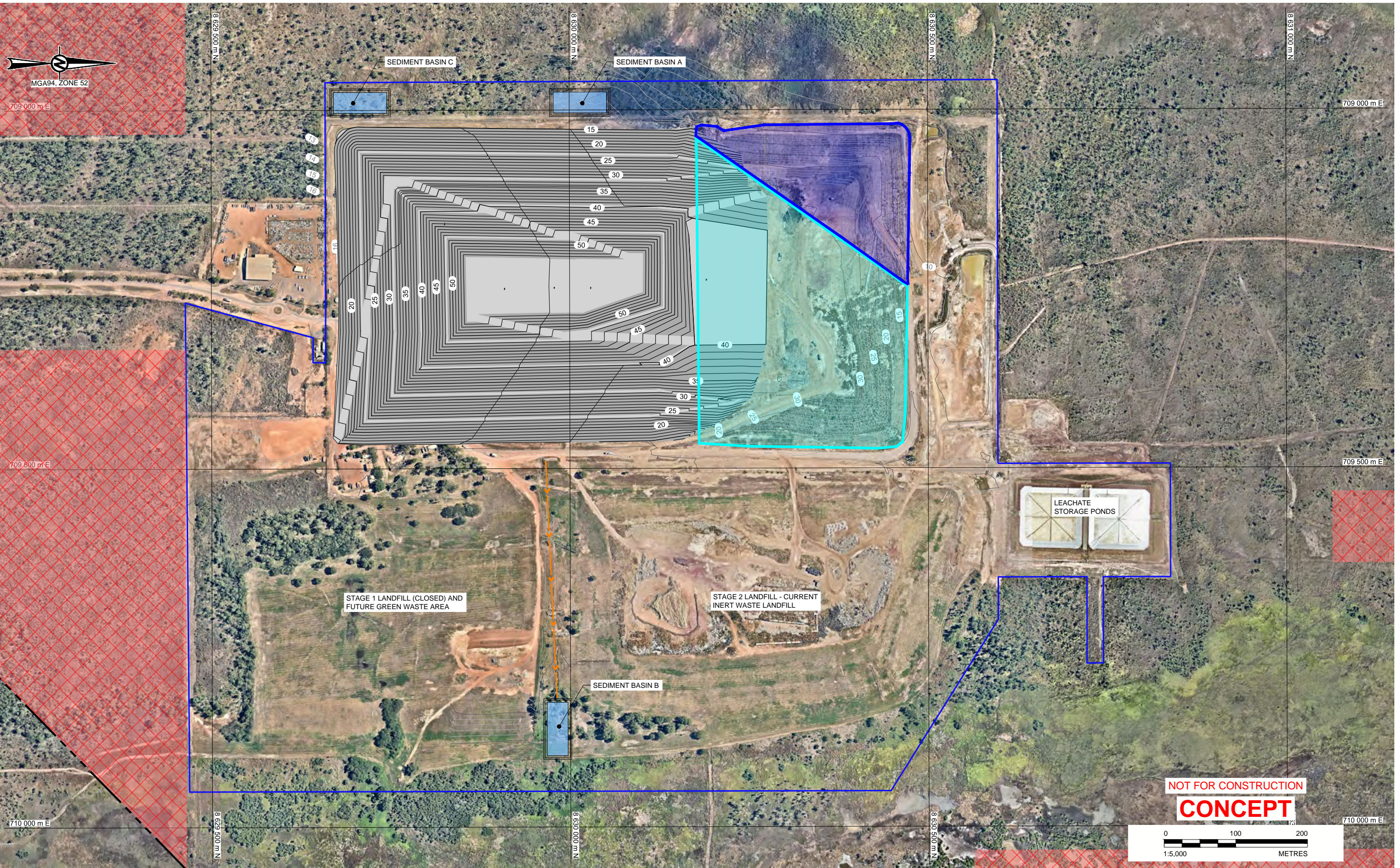
Proposed alignment of the swale drains requires that they drain around corners at approximately 90 degree angles. Detailed design will need to consider appropriate geometry and erosion protection at these locations.

- **Rock-lined chutes:** Rock-lined chutes are intended to discharge runoff collected in the swales down the batter faces at a gradient of approximately 14° (4H:1V batters) to 18° (3H:1V batters). Detailed design will need to consider erosion protection at the inlets, outlets and faces of these rock-lined chutes. Positioning of the rock-lined chutes is intended to limit the number of chutes on temporary batters; diverting runoff to permanent batters where practical, to allow for use of chutes during multiple stages of filling.
- **Diversion drains:** Diversion drains are swales intended to collect surface water runoff from outside the active area, to manage the quantity of runoff requiring treatment in the sediment basins. The diversion drains are intended to discharge to the environment. Detailed design of these drains will need to consider appropriate erosion protection and discharge locations.

5.3 Sediment Basins

Indicative locations of sediment basins are shown on Figure 23 (refer also to Figure 16 to Figure 20). Indicative sizing of the sediment basins is summarised in Table 4. The sediment ponds have been sized based on the International Erosion Control Association (IECA) *Best Practice Erosion and Sediment Control 2008*².

² Sizing assumed a Group D soil type and Type F/D basin conditions in accordance with the IECA Guidelines.



NOT FOR CONSTRUCTION
CONCEPT



REFERENCE

nearmap
 IMAGE DATED 11.06.2016
 SOURCED WITH PERMISSION FROM NEARMAP ON 27.08.2014
 IMAGE GEOREFERENCED BY GOLDBER AND INTENDED FOR INDICATIVE PURPOSES ONLY
 www.nearmap.com.au

1. LEASE AREA BOUNDARY IS BASED ON CADASTRAL BOUNDARIES IN CADD FILE "CADASTRE_SHOALBAYREGION.DXF".
 2. UNEXPLODED ORDNANCE CLEARANCE AREA IS BASED ON BOUNDARIES IN DRAWING TITLE "RAAF BOMBING RANGE LEASE AREA FOR DARWIN CITY COUNCIL LOT 3952", DRAWING DATED 25 AUGUST 1999, DRAWING NUMBER DA00350_1, FILE NAME "20100043_20140908_145851_01948_3536.PDF", MAPINFO FILES "EXCLUSION" AND COUNCIL LEASE.

LEGEND

- UNCLEARED UNEXPLODED ORDNANCE AREA
- ACTIVE LANDFILL STAGE 3
- ACTIVE LANDFILL STAGE 4
- FUTURE SEDIMENT PONDS
- LANDFILL OPERATIONS BOUNDARY
- PERIMETER DRAIN

CLIENT
CITY OF DARWIN

CONSULTANT



YYYY-MM-DD 2016-08-15
 DESIGNED SRM
 PREPARED MMC
 REVIEWED JSB
 APPROVED JSB

PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
GENERAL WASTE LANDFILL DEVELOPMENT PLAN

TITLE
FUTURE SEDIMENT PONDS

PROJECT NO. 1526230 DOC 020 REV. 0 FIGURE F023

Path: \\golder\pgr\pgr\Barrabere\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\09_PROJECTS\11026230 - COD - Shoal Bay Landfill Design\DOC 020_CAPPING_ASSESSMENT_staging_1 File Name: FIGURE F023.dwg

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3



Table 4: Sediment Basin Concept Sizing.

	Sediment Basin A	Sediment Basin B	Sediment Basin C
Floor dimensions	16 m x 56m	15.5 m x 55 m	18 m x 58 m
Internal batter gradient	1V:3H	1V:3H	1V:3H
Storage volume	2657 m ³	2961 m ³	1656 m ³
Storage depth	1.65 m	1.90 m	0.95 m
Freeboard*	0.30 m	0.30 m	0.30 m
Dimensions at crest**	28 m x 68 m	28.5 m x 68.5 m	25.5 m x 65.5 m

Notes: *Appropriate freeboard should be confirmed during detailed design, with consideration of wave runup and spillway sizing.

**Ponds are intended to have a length:width ratio of 3:1 to facilitate settlement.

6.0 IMPORTANT INFORMATION

Your attention is drawn to the document – “Important Information”, which is included in Appendix A of this report. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by Golder Associates, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

GOLDER ASSOCIATES PTY LTD

Stephanie Magor
Civil & Environmental Engineer

James Begg
Principal Geo-Environmental Engineer

SRM/JSB/hh/ow

A.B.N. 64 006 107 857

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\\golder.gds\gap\cairns\jobs\design\2015\1526230 - cod - shoal bay landfill design\corr out\1526230-020-r-rev0_concept design\1526230-020-r-rev0 - shoal bay general waste landfill development plan.docx



APPENDIX A

Important Information

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

For more information, visit golder.com

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Darwin, Northern Territory 0800
Australia

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Appendix L PFAS Soil Stockpile on Stage 2



Figure 1. Shoal Bay Waste Management Facility

 - Location of PFAS impacted soil on Stage 2



28 April 2020

Jade Leask
Senior Climate Change & Environmental Officer
City of Darwin
Civic Centre, Harry Chan Avenue
Darwin NT 0800

Our ref: 12529989

Dear Jade

Shoal Bay Landfill Soil Sampling Soil Stockpile PFAS Assessment

1 Introduction and purpose

GHD Pty Ltd (GHD) was engaged by City of Darwin to undertake sampling from a soil stockpile at Shoal Bay Waste Management Facility (SBWMF). The stockpile volume was estimated (by City of Darwin) to be 1,200 m³. City of Darwin required laboratory testing of the stockpile for PFAS compounds to determine whether the soil can be used as cover material at the SBWMF.

The purpose of this document is to present the results of the sampling study in relation to PFAS guidance which will assist in informing City of Darwin on the use of the soil for cover material.

Details of the sampling are presented in Section 2 and discussion of the results are presented in Section 3.

1.1 Disclaimer

This letter: has been prepared by GHD for City of Darwin and may only be used and relied on by City of Darwin for the purpose agreed between GHD and the City of Darwin as set out in section 1 of this document.

GHD otherwise disclaims responsibility to any person other than City of Darwin arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this letter were limited to those specifically detailed in the letter and are subject to the scope limitations set out in the letter.

The opinions, conclusions and any recommendations in this letter are based on conditions encountered and information reviewed at the date of preparation of the letter. GHD has no responsibility or obligation to update this letter to account for events or changes occurring subsequent to the date that the letter was prepared.

The opinions, conclusions and any recommendations in this letter are based on assumptions made by GHD described in throughout this document. GHD disclaims liability arising from any of the assumptions being incorrect.

The opinions, conclusions and any recommendations in this letter are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this letter are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this letter.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this letter. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this letter if the site conditions change.

2 Sampling

The stockpile samples were collected on 8 April 2020. Fieldwork was undertaken in accordance with standard GHD procedures.

The stockpile was observed to be around 10 m high, 5 m wide and 15 m long. The stockpile was heavily overgrown with weeds/vegetation with one side being so dense with vegetation that it was not accessible. The inaccessible side was in close proximity (1-2 m) to a landfill cell that contained various waste materials.

A total of twelve samples were collected from the stockpile using a trowel, seven along the accessible side and five from the top of the stockpile. Soil samples were spaced at 1-2 m intervals and collected from a depth of approximately 0.01 m below the stockpile surface. The soil composition was fine to medium grained sand with some areas having gravel on the surface.

Samples were collected into laboratory supplied sample jars, placed into a small esky container and transported under standard chain of custody to ALS Environmental in Sydney.

3 Results

On advice from City of Darwin, the stockpile sample results were compared against the landfill acceptance criteria for a lined landfill within the PFAS National Environmental Management Plan, 2018. The results were below the acceptance criteria indicating that the stockpile is suitable for use as cover material.

The results and the relevant acceptance criteria are tabulated in Attachment A. The laboratory results are provided in Attachment B.

4 Closing

Thank you for choosing GHD. If you have any questions on this letter, please contact Terry Widdowson on the number below or Terry.Widdowson@ghd.com.

Sincerely
GHD Pty Ltd



Terry Widdowson

Technical Director – Contamination, Assessment and Remediation
+61 427 398 578



Carlos Sylianteng

Project Manager
+61 477525121

Attachment A

Attachment B

Airservices Australia Water Sampling
Attachment A - Summary analytical results table

Project name/number: 12529989			Sample Date:	8/04/2020	8/04/2020	8/04/2020	8/04/2020	8/04/2020	8/04/2020	8/04/2020	8/04/2020	8/04/2020	8/04/2020	8/04/2020	9/04/2020
MATRIX: Soil			Sample ID:	ES2012113-001	ES2012113-002	ES2012113-003	ES2012113-004	ES2012113-005	ES2012113-006	ES2012113-007	ES2012113-008	ES2012113-009	ES2012113-010	ES2012113-011	ES2012113-012
Analyte grouping/Analyte	Unit	Limit of reporting	PFAS NEMP - Landfill Acceptance Criteria (lined landfill)												
EA055 Moisture Content (Dried @ 105-110°C)															
Moisture Content	%	0.1		8.2	10.4	21.1	8.2	11.7	12.8	10	10.7	10.7	10.4	11	12.2
Perfluoroalkyl Sulfonic Acids															
Perfluorobutane sulfonic acid (PFBS)	mg/kg	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Perfluorohexane sulfonic acid (PFHxS)	mg/kg	0.0002	0.0009	0.0007	0.001	0.0005	0.0023	0.0005	0.0003	0.0011	0.0014	0.0026	0.001	0.0007	
Perfluorooctane sulfonic acid (PFOS)	mg/kg	0.0002	0.0274	0.0131	0.0089	0.0062	0.0244	0.0053	0.0045	0.0278	0.0238	0.0236	0.0206	0.0169	
Perfluoroalkyl Carboxylic Acids															
Perfluorobutanoic acid (PFBA)	mg/kg	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Perfluoropentanoic acid (PFPeA)	mg/kg	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Perfluorohexanoic acid (PFHxA)	mg/kg	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0002	0.0003	0.0005	<0.0002	0.0003	
Perfluoroheptanoic acid (PFHpA)	mg/kg	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Perfluorooctanoic acid (PFOA)	mg/kg	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0004	<0.0002	<0.0002	0.0003	0.0005	0.0007	<0.0002	0.0004	
Fluorotelomer Sulfonic Acids															
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	mg/kg	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	mg/kg	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	mg/kg	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	mg/kg	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
PFAS Sums															
Sum of PFHxS and PFOS	mg/kg	0.0002	50 mg/kg	0.0283	0.0138	0.099	0.067	0.0267	0.0058	0.0048	0.0289	0.0252	0.0262	0.0216	0.0176
Sum of PFAS (WA DER List)	mg/kg	0.0002	50 mg/kg	0.0283	0.0138	0.099	0.067	0.0273	0.0058	0.0048	0.0294	0.026	0.0274	0.0216	0.0183

CERTIFICATE OF ANALYSIS

Work Order : **ES2012113**
Client : **GHD PTY LTD**
Contact : **TERRY WIDDOWSON**
Address : **LEVEL 5 66 SMITH STREET**
DARWIN NT, AUSTRALIA 0800

Telephone : **----**
Project : **12529989**
Order number : **----**
C-O-C number : **----**
Sampler : **KALEB THOMAS**
Site : **Shoal Bay Sampling**
Quote number : **EN/005/19**
No. of samples received : **12**
No. of samples analysed : **12**

Page : 1 of 6
Laboratory : Environmental Division Sydney
Contact : Angus Harding
Address : 277-289 Woodpark Road Smithfield NSW Australia 2164

Telephone : +61 2 8784 8555
Date Samples Received : 09-Apr-2020 08:00
Date Analysis Commenced : 14-Apr-2020
Issue Date : 17-Apr-2020 11:45



This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Celine Conceicao	Senior Spectroscopist	Sydney Inorganics, Smithfield, NSW
Franco Lentini	LCMS Coordinator	Sydney Inorganics, Smithfield, NSW
Franco Lentini	LCMS Coordinator	Sydney Organics, Smithfield, NSW



General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EP231: Stable isotope enriched internal standards are added to samples prior to extraction. Target compounds have a direct analogous internal standard with the exception of PFPeS, PFHpA, PFDS, PFTrDA and 10:2 FTS. These compounds use an internal standard that is chemically related and has a retention time close to that of the target compound. The DQO for internal standard response is 50-150% of that established at initial calibration. PFOS is quantified using a certified, traceable standard consisting of linear and branched PFOS isomers. These practices are in line with recommendations in the National Environmental Management Plan for PFAS (Australian HEPA) and also conform to QSM 5.3 (US DoD) requirements.



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	SS001_0.0_200408	SS002_0.0_200408	SS003_0.0_200408	SS004_0.0_200408	SS005_0.0_200408
Client sampling date / time				08-Apr-2020 09:00	08-Apr-2020 09:00	08-Apr-2020 09:00	08-Apr-2020 09:00	08-Apr-2020 09:00	08-Apr-2020 09:00
Compound	CAS Number	LOR	Unit	ES2012113-001	ES2012113-002	ES2012113-003	ES2012113-004	ES2012113-005	
				Result	Result	Result	Result	Result	
EA055: Moisture Content (Dried @ 105-110°C)									
Moisture Content	----	0.1	%	8.2	10.4	21.1	8.2	11.7	
EP231A: Perfluoroalkyl Sulfonic Acids									
Perfluorobutane sulfonic acid (PFBS)	375-73-5	0.0002	mg/kg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Perfluorohexane sulfonic acid (PFHxS)	355-46-4	0.0002	mg/kg	0.0009	0.0007	0.0010	0.0005	0.0023	
Perfluorooctane sulfonic acid (PFOS)	1763-23-1	0.0002	mg/kg	0.0274	0.0131	0.0089	0.0062	0.0244	
EP231B: Perfluoroalkyl Carboxylic Acids									
Perfluorobutanoic acid (PFBA)	375-22-4	0.001	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001	
Perfluoropentanoic acid (PFPeA)	2706-90-3	0.0002	mg/kg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Perfluorohexanoic acid (PFHxA)	307-24-4	0.0002	mg/kg	<0.0002	<0.0002	<0.0002	<0.0002	0.0002	
Perfluoroheptanoic acid (PFHpA)	375-85-9	0.0002	mg/kg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	
Perfluorooctanoic acid (PFOA)	335-67-1	0.0002	mg/kg	<0.0002	<0.0002	<0.0002	<0.0002	0.0004	
EP231D: (n:2) Fluorotelomer Sulfonic Acids									
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	757124-72-4	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	27619-97-2	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	39108-34-4	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	120226-60-0	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	
EP231P: PFAS Sums									
Sum of PFHxS and PFOS	355-46-4/1763-23-1	0.0002	mg/kg	0.0283	0.0138	0.0099	0.0067	0.0267	
Sum of PFAS (WA DER List)	----	0.0002	mg/kg	0.0283	0.0138	0.0099	0.0067	0.0273	
EP231S: PFAS Surrogate									
13C4-PFOS	----	0.0002	%	92.5	85.0	91.5	84.5	82.0	
13C8-PFOA	----	0.0002	%	103	104	102	101	102	



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	SS006_0.0_200408	SS007_0.0_200408	SS008_0.0_200408	SS009_0.0_200408	SS010_0.0_200408
Client sampling date / time				08-Apr-2020 09:00	08-Apr-2020 09:00	08-Apr-2020 09:00	08-Apr-2020 09:00	08-Apr-2020 09:00	08-Apr-2020 09:00
Compound	CAS Number	LOR	Unit	ES2012113-006	ES2012113-007	ES2012113-008	ES2012113-009	ES2012113-010	ES2012113-010
				Result	Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)									
Moisture Content	----	0.1	%	12.8	10.0	10.7	10.7	10.4	10.4
EP231A: Perfluoroalkyl Sulfonic Acids									
Perfluorobutane sulfonic acid (PFBS)	375-73-5	0.0002	mg/kg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Perfluorohexane sulfonic acid (PFHxS)	355-46-4	0.0002	mg/kg	0.0005	0.0003	0.0011	0.0014	0.0026	0.0026
Perfluorooctane sulfonic acid (PFOS)	1763-23-1	0.0002	mg/kg	0.0053	0.0045	0.0278	0.0238	0.0236	0.0236
EP231B: Perfluoroalkyl Carboxylic Acids									
Perfluorobutanoic acid (PFBA)	375-22-4	0.001	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Perfluoropentanoic acid (PFPeA)	2706-90-3	0.0002	mg/kg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Perfluorohexanoic acid (PFHxA)	307-24-4	0.0002	mg/kg	<0.0002	<0.0002	0.0002	0.0003	0.0005	0.0005
Perfluoroheptanoic acid (PFHpA)	375-85-9	0.0002	mg/kg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Perfluorooctanoic acid (PFOA)	335-67-1	0.0002	mg/kg	<0.0002	<0.0002	0.0003	0.0005	0.0007	0.0007
EP231D: (n:2) Fluorotelomer Sulfonic Acids									
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	757124-72-4	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	27619-97-2	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	39108-34-4	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	120226-60-0	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
EP231P: PFAS Sums									
Sum of PFHxS and PFOS	355-46-4/1763-23-1	0.0002	mg/kg	0.0058	0.0048	0.0289	0.0252	0.0262	0.0262
Sum of PFAS (WA DER List)	----	0.0002	mg/kg	0.0058	0.0048	0.0294	0.0260	0.0274	0.0274
EP231S: PFAS Surrogate									
13C4-PFOS	----	0.0002	%	90.5	95.5	86.5	94.5	80.5	80.5
13C8-PFOA	----	0.0002	%	102	104	104	104	104	104



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID			SS011_0.0_200408	SS012_0.0_200408	----	----	----	
Client sampling date / time			08-Apr-2020 09:00			08-Apr-2020 09:00			----	----	----
Compound	CAS Number	LOR	Unit	ES2012113-011	ES2012113-012	-----	-----	-----	-----	-----	
				Result	Result	----	----	----	----	----	
EA055: Moisture Content (Dried @ 105-110°C)											
Moisture Content	----	0.1	%	11.0	12.2	----	----	----	----	----	
EP231A: Perfluoroalkyl Sulfonic Acids											
Perfluorobutane sulfonic acid (PFBS)	375-73-5	0.0002	mg/kg	<0.0002	<0.0002	----	----	----	----	----	
Perfluorohexane sulfonic acid (PFHxS)	355-46-4	0.0002	mg/kg	0.0010	0.0007	----	----	----	----	----	
Perfluorooctane sulfonic acid (PFOS)	1763-23-1	0.0002	mg/kg	0.0206	0.0169	----	----	----	----	----	
EP231B: Perfluoroalkyl Carboxylic Acids											
Perfluorobutanoic acid (PFBA)	375-22-4	0.001	mg/kg	<0.001	<0.001	----	----	----	----	----	
Perfluoropentanoic acid (PFPeA)	2706-90-3	0.0002	mg/kg	<0.0002	<0.0002	----	----	----	----	----	
Perfluorohexanoic acid (PFHxA)	307-24-4	0.0002	mg/kg	<0.0002	0.0003	----	----	----	----	----	
Perfluoroheptanoic acid (PFHpA)	375-85-9	0.0002	mg/kg	<0.0002	<0.0002	----	----	----	----	----	
Perfluorooctanoic acid (PFOA)	335-67-1	0.0002	mg/kg	<0.0002	0.0004	----	----	----	----	----	
EP231D: (n:2) Fluorotelomer Sulfonic Acids											
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	757124-72-4	0.0005	mg/kg	<0.0005	<0.0005	----	----	----	----	----	
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	27619-97-2	0.0005	mg/kg	<0.0005	<0.0005	----	----	----	----	----	
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	39108-34-4	0.0005	mg/kg	<0.0005	<0.0005	----	----	----	----	----	
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	120226-60-0	0.0005	mg/kg	<0.0005	<0.0005	----	----	----	----	----	
EP231P: PFAS Sums											
Sum of PFHxS and PFOS	355-46-4/1763-23-1	0.0002	mg/kg	0.0216	0.0176	----	----	----	----	----	
Sum of PFAS (WA DER List)	----	0.0002	mg/kg	0.0216	0.0183	----	----	----	----	----	
EP231S: PFAS Surrogate											
13C4-PFOS	----	0.0002	%	78.0	83.5	----	----	----	----	----	
13C8-PFOA	----	0.0002	%	92.0	92.5	----	----	----	----	----	



Surrogate Control Limits

Sub-Matrix: SOIL		Recovery Limits (%)	
Compound	CAS Number	Low	High
EP231S: PFAS Surrogate			
13C4-PFOS	----	60	120
13C8-PFOA	----	60	120



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CERTIFICATE OF ANALYSIS 312939

Client Details

Client	Darwin City Council
Attention	Emma Smith
Address	

Sample Details

Your Reference	<u>Darwin City Council- Stage 2 Stockpile PFAS Leach</u>
Number of Samples	10 Soil
Date samples received	13/12/2022
Date completed instructions received	13/12/2022

Analysis Details

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

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

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

Report Details

Date results requested by 20/12/2022

Date of Issue 21/12/2022

NATA Accreditation Number 2901. This document shall not be reproduced except in full.

Accredited for compliance with ISO/IEC 17025 - Testing. **Tests not covered by NATA are denoted with ***

Results Approved By

Phalak Inthakesone, Organics Development Manager, Sydney

Authorised By

Nancy Zhang, Laboratory Manager

Client Reference: Darwin City Council- Stage 2 Stockpile PFAS Leach

PFAS in ASLP Short						
Our Reference		312939-1	312939-2	312939-3	312939-4	312939-5
Your Reference	UNITS	S1	S2	S3	S4	S5
Depth		0.3	0.3	0.3	0.3	0.3
Date Sampled		12/12/2022	12/12/2022	12/12/2022	12/12/2022	12/12/2022
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	16/12/2022	16/12/2022	16/12/2022	16/12/2022	16/12/2022
Date analysed	-	16/12/2022	16/12/2022	16/12/2022	16/12/2022	16/12/2022
pH of final Leachate	pH units	8.0	8.2	8.1	8.0	8.6
Perfluorohexanesulfonic acid - PFHxS	µg/L	0.01	<0.01	0.02	0.01	0.03
Perfluorooctanesulfonic acid PFOS	µg/L	0.07	0.09	0.43	0.14	0.12
Perfluorooctanoic acid PFOA	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01
6:2 FTS	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01
8:2 FTS	µg/L	<0.02	<0.02	<0.02	<0.02	<0.02
Surrogate ¹³ C ₈ PFOS	%	104	103	100	103	105
Surrogate ¹³ C ₂ PFOA	%	95	97	100	97	100
Extracted ISTD ¹⁸ O ₂ PFHxS	%	102	100	106	106	106
Extracted ISTD ¹³ C ₄ PFOS	%	100	100	104	104	102
Extracted ISTD ¹³ C ₄ PFOA	%	107	106	103	106	105
Extracted ISTD ¹³ C ₂ 6:2FTS	%	114	115	119	110	111
Extracted ISTD ¹³ C ₂ 8:2FTS	%	125	128	126	126	127
Total Positive PFHxS & PFOS	µg/L	0.08	0.09	0.45	0.16	0.15
Total Positive PFOS & PFOA	µg/L	0.07	0.09	0.43	0.14	0.12
Total Positive PFAS	µg/L	0.08	0.09	0.45	0.16	0.15

Client Reference: Darwin City Council- Stage 2 Stockpile PFAS Leach

PFAS in ASLP Short						
Our Reference		312939-6	312939-7	312939-8	312939-9	312939-10
Your Reference	UNITS	S6	S7	S8	S9	S10
Depth		0.3	0.3	0.3	0.3	0.3
Date Sampled		12/12/2022	12/12/2022	12/12/2022	12/12/2022	12/12/2022
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	16/12/2022	16/12/2022	16/12/2022	16/12/2022	16/12/2022
Date analysed	-	16/12/2022	16/12/2022	16/12/2022	16/12/2022	16/12/2022
pH of final Leachate	pH units	8.1	8.4	8.5	8.8	8.7
Perfluorohexanesulfonic acid - PFHxS	µg/L	0.02	0.01	0.01	<0.01	<0.01
Perfluorooctanesulfonic acid PFOS	µg/L	0.12	0.24	0.27	0.06	0.10
Perfluorooctanoic acid PFOA	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01
6:2 FTS	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01
8:2 FTS	µg/L	<0.02	<0.02	<0.02	<0.02	<0.02
Surrogate ¹³ C ₈ PFOS	%	100	105	101	102	104
Surrogate ¹³ C ₂ PFOA	%	101	102	105	106	103
Extracted ISTD ¹⁸ O ₂ PFHxS	%	103	108	110	106	105
Extracted ISTD ¹³ C ₄ PFOS	%	103	102	106	106	106
Extracted ISTD ¹³ C ₄ PFOA	%	103	106	102	105	103
Extracted ISTD ¹³ C ₂ 6:2FTS	%	112	116	112	119	118
Extracted ISTD ¹³ C ₂ 8:2FTS	%	127	126	132	126	128
Total Positive PFHxS & PFOS	µg/L	0.13	0.25	0.28	0.06	0.10
Total Positive PFOS & PFOA	µg/L	0.12	0.24	0.27	0.06	0.10
Total Positive PFAS	µg/L	0.13	0.25	0.28	0.06	0.10

Client Reference: Darwin City Council- Stage 2 Stockpile PFAS Leach

Method ID	Methodology Summary
Inorg-001	<p>pH - Measured using pH meter and electrode in accordance with APHA latest edition, 4500-H+. Please note that the results for water analyses are indicative only, as analysis outside of the APHA storage times.</p>
Org-029	<p>Soil samples are extracted with basified Methanol. Waters and soil extracts are directly injected and/or concentrated/extracted using SPE. TCLPs/ASLP leachates are centrifuged, the supernatant is then analysed (including amendment with solvent) - as per the option in AS4439.3.</p> <p>Analysis is undertaken with LC-MS/MS.</p> <p>PFAS results include the sum of branched and linear isomers where applicable.</p> <p>Please note that PFAS results are corrected for Extracted Internal Standards (QSM 5.4 Table B-15 terminology), which are mass labelled analytes added prior to sample preparation to assess matrix effects and verify processing of the sample. PFAS analytes without a commercially available mass labelled analogue are corrected vs a closely eluting mass labelled PFAS compound. Surrogates are also reported, in this context they are mass labelled PFAS compounds added prior to extraction but are used as monitoring compounds only (not used for result correction). Envicarb (or similar) is used discretionally to remove interfering matrix components.</p> <p>Please contact the laboratory if estimates of Measurement Uncertainty are required as per WA DER.</p>

Client Reference: Darwin City Council- Stage 2 Stockpile PFAS Leach

Method ID	Methodology Summary
Org-029A	<p>Soil samples are extracted with basified Methanol. Waters and soil extracts are directly injected and/or concentrated/extracted using SPE. TCLPs/ASLP leachates are centrifuged, the supernatant is then analysed (including amendment with solvent) - as per the option in AS4439.3.</p> <p>Analysis is undertaken with LC-MS/MS</p> <p>PFAS results include the sum of branched and linear isomers where applicable.</p> <p>Please note that PFAS results are corrected for Extracted Internal Standards (QSM 5.4 Table B-15 terminology), which are mass labelled analytes added prior to sample preparation to assess matrix effects and verify processing of the sample. PFAS analytes without a commercially available mass labelled analogue are corrected vs a closely eluting mass labelled PFAS compound. Surrogates are also reported, in this context they are mass labelled PFAS compounds added prior to extraction but are used as monitoring compounds only (not used for result correction). Envicarb (or similar) is used discretionally to remove interfering matrix components.</p> <p>TOPA analyses use a pre-spiked, labelled internal standard PFAS precursor to assess the oxidation efficiency. The efficiency of removal by oxidation is recorded in the report. Additionally, dilutions applied (if required) to ensure sufficient precursor oxidation are also recorded and are available on request.</p> <p>Please contact the laboratory if estimates of Measurement Uncertainty are required as per WA DER.</p>

Client Reference: Darwin City Council- Stage 2 Stockpile PFAS Leach

QUALITY CONTROL: PFAS in ASLP Short						Duplicate		Spike Recovery %		
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W1	312939-2
Date prepared	-			16/12/2022	1	16/12/2022	16/12/2022		16/12/2022	16/12/2022
Date analysed	-			16/12/2022	1	16/12/2022	16/12/2022		16/12/2022	16/12/2022
Perfluorohexanesulfonic acid - PFHxS	µg/L	0.01	Org-029A	<0.01	1	0.01	0.01	0	104	102
Perfluorooctanesulfonic acid PFOS	µg/L	0.01	Org-029A	<0.01	1	0.07	0.07	0	98	98
Perfluorooctanoic acid PFOA	µg/L	0.01	Org-029A	<0.01	1	<0.01	<0.01	0	102	108
6:2 FTS	µg/L	0.01	Org-029A	<0.01	1	<0.01	<0.01	0	98	102
8:2 FTS	µg/L	0.02	Org-029A	<0.02	1	<0.02	<0.02	0	90	91
Surrogate ¹³ C ₈ PFOS	%		Org-029A	103	1	104	103	1	101	101
Surrogate ¹³ C ₂ PFOA	%		Org-029A	99	1	95	100	5	99	100
Extracted ISTD ¹⁸ O ₂ PFHxS	%		Org-029A	101	1	102	104	2	99	104
Extracted ISTD ¹³ C ₄ PFOS	%		Org-029A	100	1	100	101	1	101	102
Extracted ISTD ¹³ C ₄ PFOA	%		Org-029A	105	1	107	107	0	103	98
Extracted ISTD ¹³ C ₂ 6:2FTS	%		Org-029A	115	1	114	112	2	107	109
Extracted ISTD ¹³ C ₂ 8:2FTS	%		Org-029A	125	1	125	120	4	119	121

Result Definitions

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

Quality Control Definitions

Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.
Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.	
The recommended maximums for analytes in urine are taken from "2018 TLVs and BEIs", as published by ACGIH (where available). Limit provided for Nickel is a precautionary guideline as per Position Paper prepared by AIOH Exposure Standards Committee, 2016.	
Guideline limits for Rinse Water Quality reported as per analytical requirements and specifications of AS 4187, Amdt 2 2019, Table 7.2	

Laboratory Acceptance Criteria

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

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

Spikes for Physical and Aggregate Tests are not applicable.

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

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

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

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

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

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

Where matrix spike recoveries fall below the lower limit of the acceptance criteria (e.g. for non-labile or standard Organics <60%), positive result(s) in the parent sample will subsequently have a higher than typical estimated uncertainty (MU estimates supplied on request) and in these circumstances the sample result is likely biased significantly low.

Measurement Uncertainty estimates are available for most tests upon request.

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

Samples for Microbiological analysis (not Amoeba forms) received outside of the 2-8°C temperature range do not meet the ideal cooling conditions as stated in AS2031-2012.



Appendix M Sea Level Rise Map

DARWIN AREA STORM SURGE INUNDATION for 2100

Estimated HAT Primary Storm Secondary Storm Extreme Storm
 (Highest Surge Zone Surge Zone Surge Extent
 Astronomical Tide) (100 Year ARI) (1,000 Year ARI) (10,000 Year ARI)



The technical information forming the basis of this storm surge inundation mapping is contained in the following reports prepared for the NT Government by Systems Engineering Australia Pty Ltd (SEA):

1. Darwin Storm Tide Mapping Study - 2006
2. High Resolution Storm Tide and Climate Change Impacts Study - 2010

Using the storm surge levels and estimates of Highest Astronomical Tide (HAT) from the above studies, the inundation and HAT extents for the projected mean sea level in 2100 were developed by GHD Pty Ltd in 2014 based on the latest topographic information (2009 and 2011). This map is produced by the NT Government for the Darwin area based on the storm surge inundation and HAT extents.

The map shows the total storm surge (technical terminology is storm tide) hazard risk due to tropical cyclones in terms of the ocean water level comprising the combined effects of astronomical tide plus storm surge plus wave setup for two statistical Average Recurrence Intervals (ARI). It also shows the estimated HAT extent. The 'Primary Storm Surge Zone' shown on the map refers to the extent of inundation for a storm tide event of 100 year ARI (with approximately a 40% chance of exceedance within any 50 year period). The 'Secondary Storm Surge Zone' shown on the map refers to the further extent of inundation for a storm tide event of 1000 year ARI (with approximately a 5% chance of exceedance within any 50 year period). The extents do not include the possible effects of very localised wave runup.

Average Recurrence Interval (ARI) is also called Return Period of the Risk and is defined as the 'average' number of years between successive events of the same or greater magnitude. The ARI of a storm tide event gives no indication of when a storm tide of that magnitude may occur.

Highest Astronomical Tide (HAT) is the highest ocean level expected due to any combination of astronomical conditions alone and has an equivalent ARI of approximately 18.6 years. The HAT extent is used in this map as the reference for storm surge inundation. It is based on estimates of HAT levels derived from numerical hydrodynamic modelling that has not been verified by long term in situ measurements.

For detailed interpretation of this map and further information contact:
 Water Resources NT, Department of Land Resource Management
 4th Floor Goyder Centre, 25 Chung Wah Terrace,
 Palmerston, Northern Territory
 T: (08) 8999 4455 Email: waterresources@nt.gov.au
 PO Box 496, Palmerston, NT, 0831

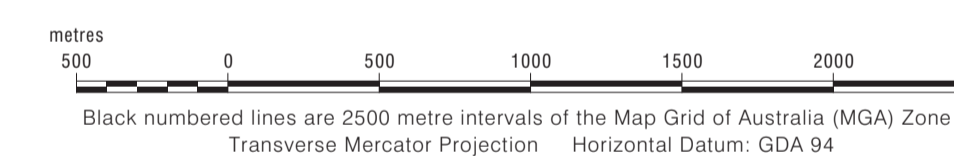
Storm surge reports and maps are available on www.nt.gov.au/floods
 This map produced November 2014, supersedes all previous versions.

GENERAL FEATURES

- Local Government Area
- Property / Road Boundaries
- Suburbs / Localities
- Major Road
- Minor Road
- Park / Reserve
- Railway
- Gas pipeline
- Watercourse, Lake or Lagoon
- Mangroves

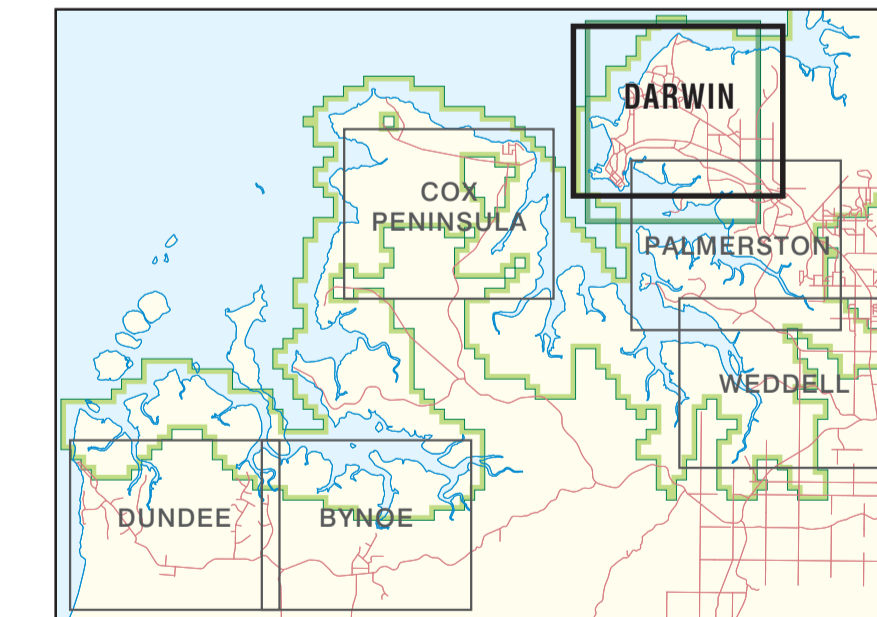
Data Source:
 Cadastre, road centrelines and administrative information
 Northern Territory Department of Lands, Planning and the Environment.

Map prepared by:
 Spatial Data and Mapping, Water Resources NT,
 Department of Land Resource Management,
 Goyder Centre, Chung Wah Terrace, Palmerston,
 Northern Territory of Australia.

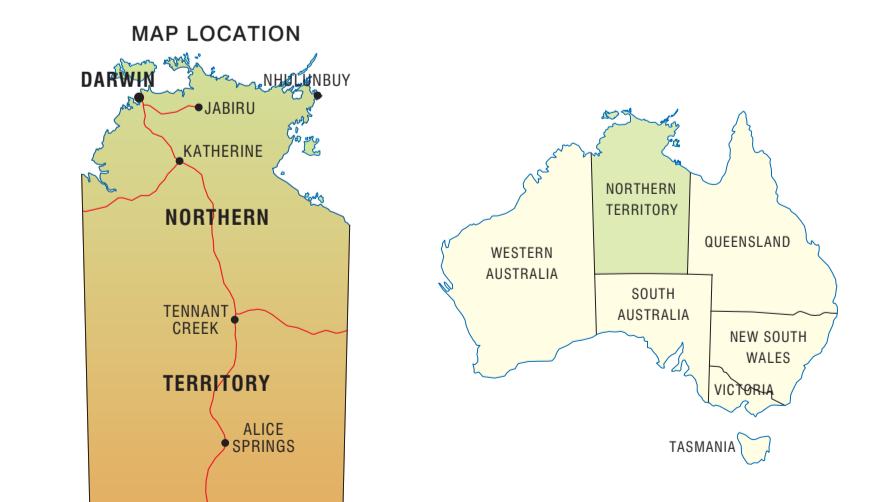


This map was produced on the Geocentric Datum of Australia 1994 (GDA 94)

INDEX TO DARWIN REGION STORM SURGE MAPS



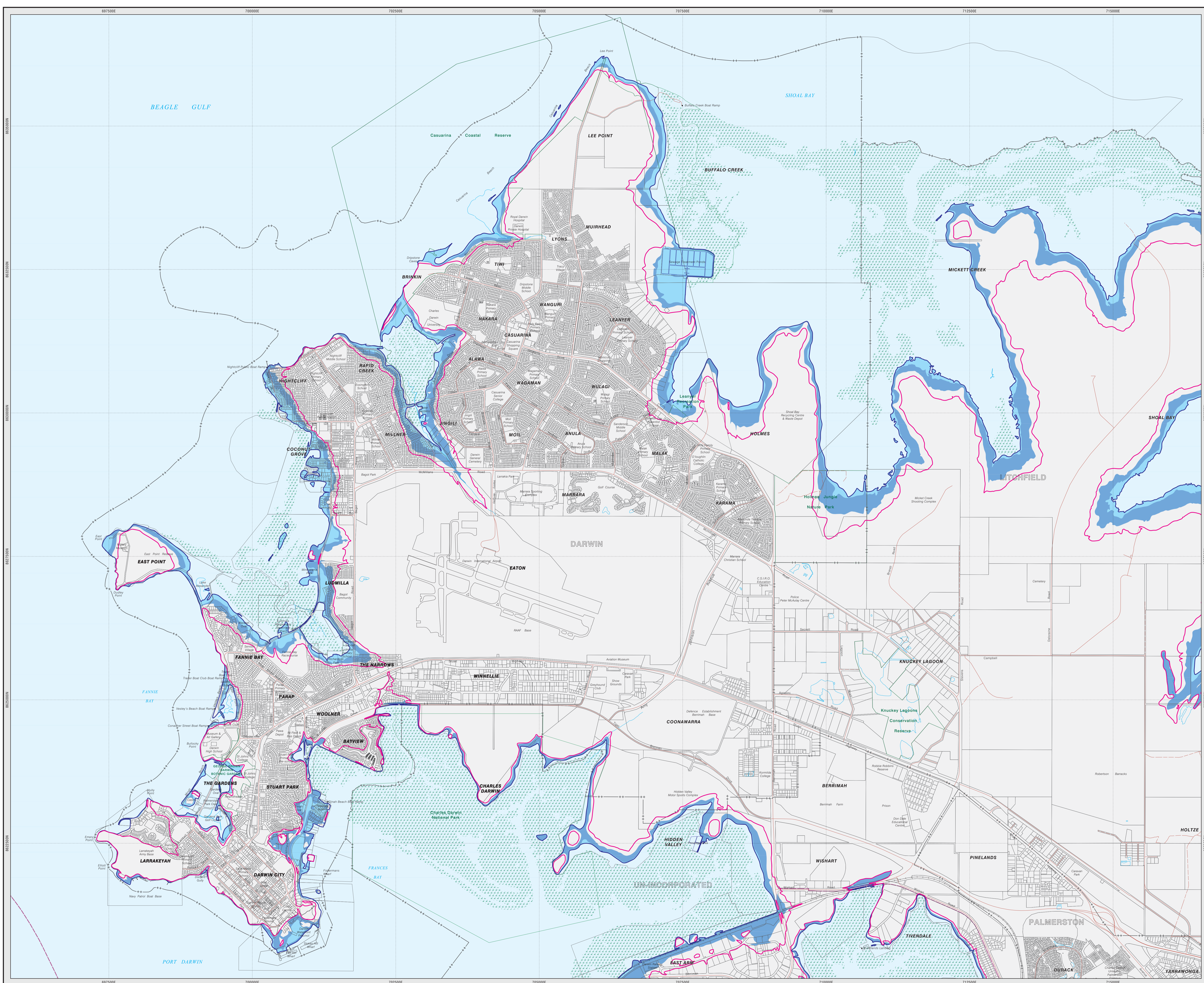
Extent of topographic information 2009 2011



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Appendix N Ecological Information



Appendix N1 Remnant Vegetation



Appendix N2 Ecological Risk Assessment



Report

Shoal Bay Waste Disposal Site Ecological Risk Assessment

AUSTRALIA



Shoal Bay Waste Disposal Site



21/3/2016
42214019/R004/3

Prepared for:
John Holland Pty Ltd

Prepared by URS Australia Pty Ltd



DOCUMENT PRODUCTION / APPROVAL RECORD

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Shoal Bay Waste Disposal Site
Ecological Risk Assessment

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INTRODUCTION

URS Australia Pty Ltd (URS) was commissioned by John Holland Pty Ltd (JH) to prepare an ecological risk assessment (ERA) to support the revised conceptual site model (CSM) for the Shoal Bay Waste Disposal Facility (the site) as required by the NT EPA *Guidelines for the siting, design and management of solid waste disposal sites in the Northern Territory* (2013).

This ERA assesses the potential for ecological receptors to be impacted by contaminants from the site according to the migration and exposure pathways identified in the CSM. The CSM is made up of a series of schematic diagrams identifying primary contamination sources and potential migration and exposure pathways both on and off site.

2 BACKGROUND

John Holland Pty Ltd (JH) holds Environmental Protection Licence (EPL12-08) to operate the municipal landfill known as Shoal Bay Waste Disposal Site (the site) in Karama under contract by the City of Darwin (Council) until 31 December 2019. The site is operated by Territoria Civil, a business unit of JH, which operates under a third party certified, ISO14001 Environmental Management System maintained by JH.

2.1 Site description

Shoal Bay is a municipal waste disposal site servicing domestic and commercial customers in the Darwin area. The site has a lined putrescible waste landfill cell (Stages 3 and 4), inert waste landfill cell (Stage 2), transfer station, recycle shop and mulching facility. The site layout is presented in Figure 2-1.

Currently, Stage 1 (south-east) is capped and no longer in use. Stage 2 (north-east) was also closed and capped, but was returned into an operating cell for inert waste (including asbestos) only several years ago. Stage 3 is currently in use for municipal and commercial waste, and also receives some listed and quarantine waste which are subject to special deep burial. Green waste processing and composting area occurs on a pad to the south-west of the site. Located at the southern end of the site, the chemical storage facility provides a facility for the short-term storage of domestic chemicals received at the Shoal Bay Waste Disposal Site.

2.2 Site context

The site is located approximately 12 kilometres (km) north east of the Darwin Central Business District in a northern suburb of Darwin within lot 3952, Town of Sanderson. The site is bound to the north and east by floodplains / wetlands and mangroves of Leanyer Swamp, to the south by Holmes Jungle Nature Reserve, and to the west by bushland. The nearest residential area is Karama, about 1.3 km to the south west, with a bushland buffer in between. The former Leanyer Landfill is approximately 800 m to the west of the site.

2.2.1 Topography

The topography in the vicinity of the site is undulating with elevations between 7 m Australian Height Datum (AHD) and 33.6 mAHD and broadly slopes east toward the floodplain at the south end of the site and west at the north of the site (URS, 2015). Stages 2, 3 and 4 and to a lesser extent the green waste area, form mounds at the site with Stage 3 reaching the highest elevation of 33.6 mAHD.

2.2.2 Groundwater

Groundwater typically flows along hydraulic gradient following original contours of the site (URS, 2015). Groundwater levels are influenced by seasonal variation in rainfall (wet season) and tidal variation, in particular king tides. Groundwater quality is highly variable in terms of salinity, pH, metals and nutrient levels.

2.2.3 Surface water, drainage and storage

Overland flow is east from the eastern portion of the site toward the floodplain and west on the western portion of the site, following topography (URS, 2015). Localised flows occur on the landfill mounds following surface grades. Surface water management includes a surface water drainage system, made up of open drains and stormwater structures, where surface water is diverted away from the waste where possible.

2.3 Site water management

The Darwin region experiences a monsoonal climate with distinct wet and dry seasons. Based on records from the Bureau of Meteorology for Darwin Airport weather station, Darwin receives, on average, 1,727 millimetre (mm) of rainfall annually, with nearly all of that falling during the months of December to April.

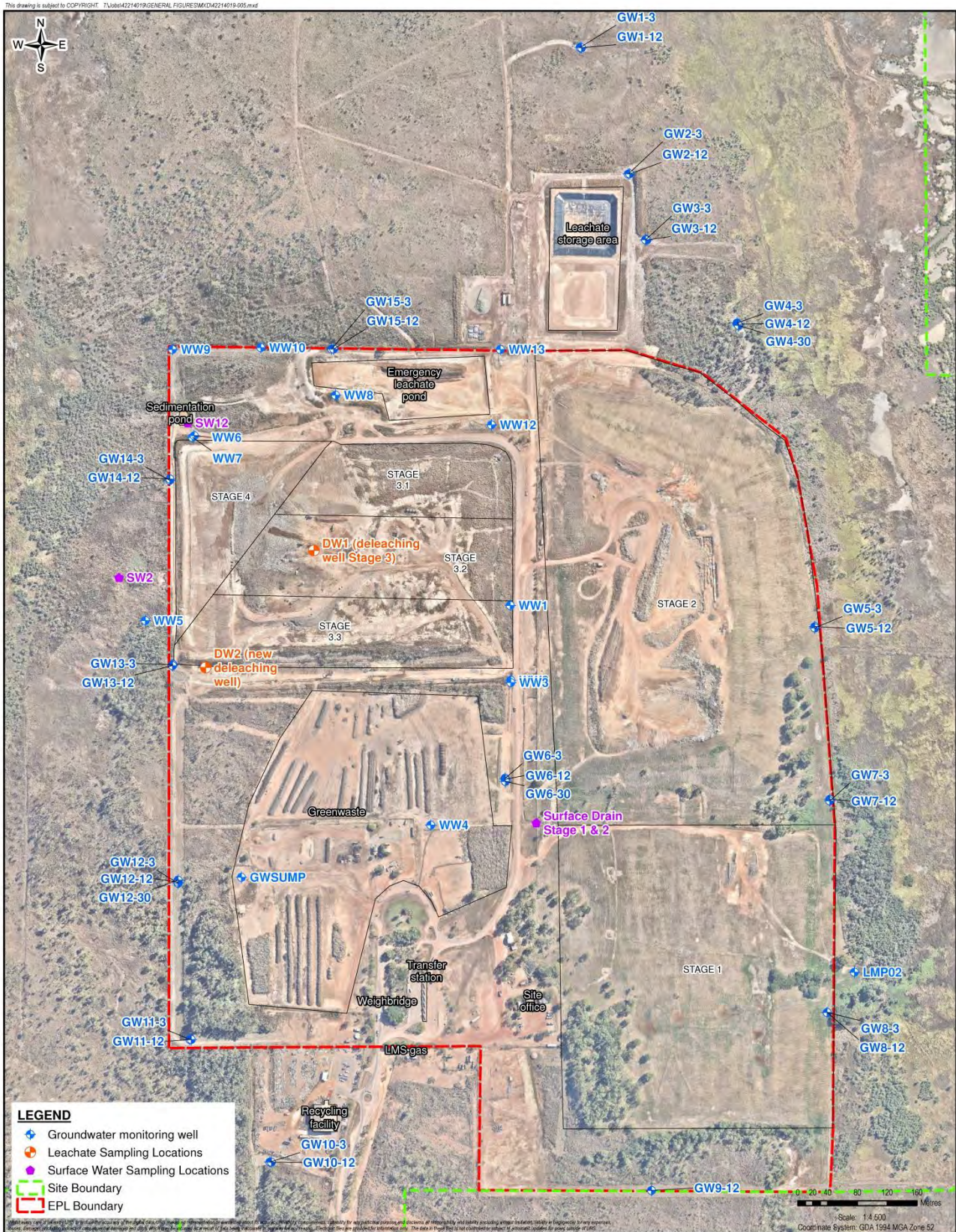
2.3.1 Stages 1 and 2 (LMP02)

For the older and unlined cells that make up stages 1 (capped landfill) and 2 (inert landfill), leachate is collected via an underground leachate collection drain running north to south along the eastern edge of Stage 1 and 2. Leachate drains to a leachate collection chamber ('LMP02') where it is pumped back onto the rehabilitated surface of Stage 1.

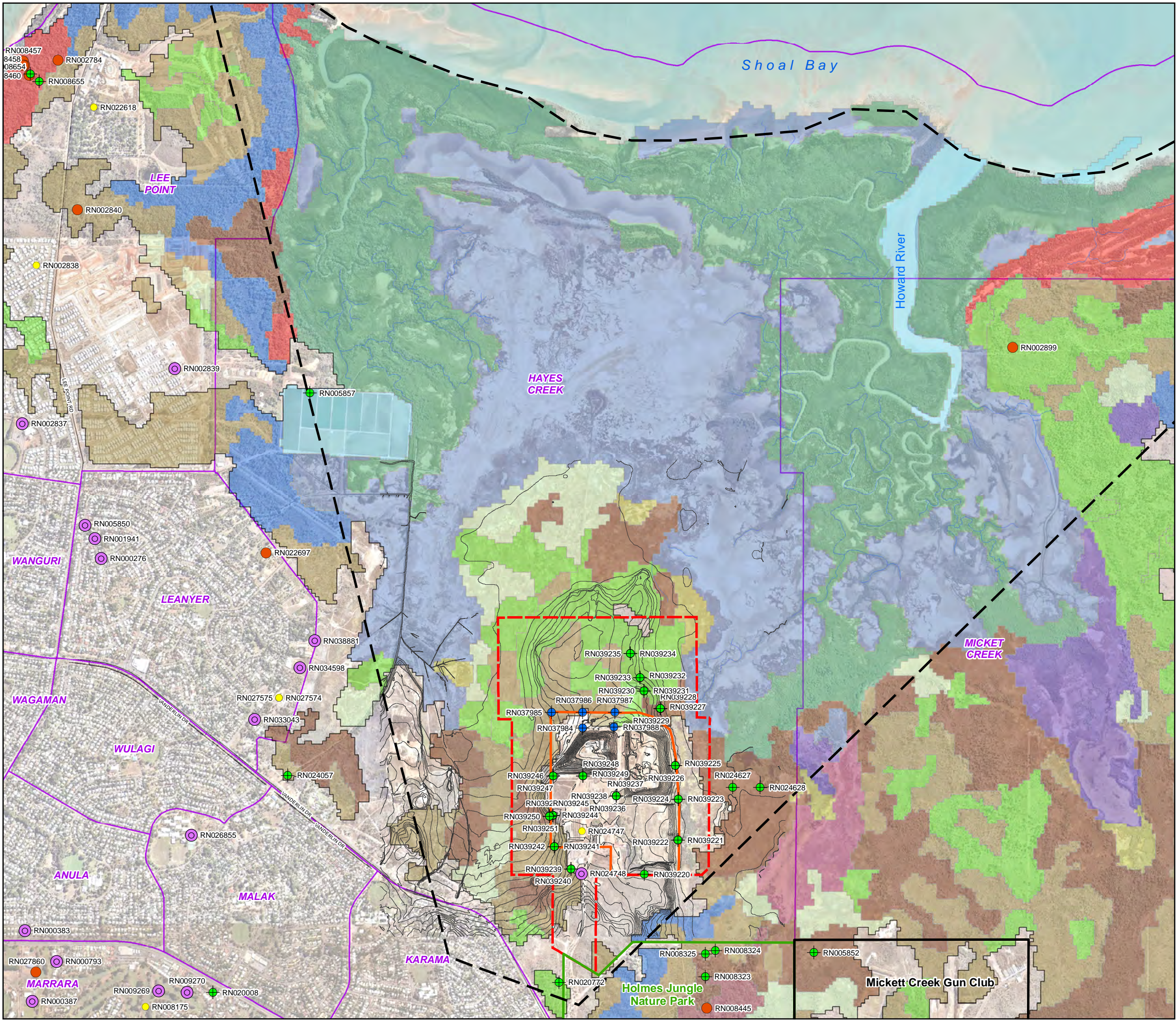
During the wet season, leachate becomes mixed with groundwater; this generates large volumes of impacted waters that are unable to be retained on site (groundwater levels increase by several metres). Under normal circumstances, Territoria Civil maintains and operates the existing leachate collection infrastructure and pumping to minimise leachate overflow; however Territoria Civil and Council accept that the collection chamber may overflow during the wet season. Council is responsible for any activities undertaken to investigate leachate, for monitoring of water quality and for any remedial work if required.

Territoria Civil is also responsible for the management of stormwater flowing from the surfaces of stages 1 and 2, including the provision of open drains, protection works and the maintenance of existing and new stormwater structures.

Figure 2-1 Site layout and monitoring locations showing conceptual site model features



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LEGEND

NT Bores

- Unclassified
- ⊕ Investigation
- ⊕ Monitoring
- None
- Production

Substantial UXO Risk

▭ Suburbs

▭ Site Boundary

▭ EPL Boundary

Vegetation Key

- Cleared land
- Drainage open woodland
- Dry Rainforest
- Eucalypt open forest
- Eucalypt open woodland
- Eucalypt woodland
- Floodplain
- Grassy swamp
- Mangrove forest
- Melaleuca swamp
- Riparian open forest
- Samphire
- Spring rainforest
- Water

N

DATUM GDA 1994, PROJECTION MGA ZONE 52

0 300 600 1,200

Metres

1:25,000 (when printed at A3)

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JOHN HOLLAND

SHOAL BAY WASTE
 DISPOSAL SITE -
 ECOLOGICAL RISK ASSESSMENT

SITE AND SURROUNDS

URS Figure: **2.2**
 Rev. A A3

2.3.2 Stage 3 (SW2)

The leachate management system for the lined cell in stage 3 was designed to minimise the release of leachate into the environment, and to optimise the moisture content in the landfill. Leachate drains through the waste and collects in slotted pipes in the subsoil drainage layer at the base of the liner. The leachate then drains to a leachate collection chamber (“DW”), where it is either pumped back onto Stage 3 for re-injection into the waste mass, irrigated over the surfaces of stage 3 to facilitate partial evaporation or sent to dedicated lined ponds. Leachate will only be discharged into the environment in consultation with Council and NT EPA.

Territoria Civil is responsible for the supervision, operation and maintenance of all wells, pumps and distribution pipework for the collection and redistribution of leachate within the stage 3 landfill.

Stormwater management, including the design, construction and maintenance of the surface water drainage system on the site, has been designed so that surface water is diverted away from the waste wherever possible. Territoria Civil is responsible for management of stormwater flowing from the surfaces of all stages, including maintenance of open drains, protection works and stormwater structures.

3 OBJECTIVE AND SCOPE OF WORK

NT EPA issued JH with EPL12-08 to authorise landfill activities with the objective to ensure landfill operations do not adversely impact the environment. It is a requirement of the authorisation that JH develop, from a desktop study, a detailed conceptual site model of the proposed premise, and its surrounds and an ecological risk assessment, with an interpretation and summary of findings. This ERA addresses this requirement.

The objective of this ERA is to review and confirm the potential risks to ecological values presented by the new CSM. This scope of work will deliver an ERA based on the updated CSM for Shoal Bay Waste Disposal Site that evaluates the potential for the flood plain and associated ecosystems to be impacted from both surface water runoff and groundwater migration of landfill leachate, green waste leachate or spills in hazardous chemical storage areas.

4 METHODOLOGY

4.1 Desktop review

A desktop review of ecological data and literature was undertaken to characterise the broad ecological values and identify the potential presence of conservation significant flora and fauna species and vegetation communities within the outfall areas. Existing ecological data was compiled through review of the following key references:

- 1992 vegetation survey (Dames and Moore)
- 2002 weed and vegetation survey (SMEC)
- 2005 weed and vegetation survey (SMEC)
- 2009 weed survey (Macmahon, now Territoria Civil)
- 2011 ecological assessment of outfall areas (GHD)
- 2015 site observations (AECOM).

Based on the findings of this review, the potential ecological values of the site were described.

4.2 Ecological risk assessment

The ERA process assesses the potential risk posed by contaminant on the local ecosystems. There are no relevant quantified guidelines to measure impacts on ecological receptors. It is the sensitivity or vulnerability of the environmental value and magnitude of the impact that are important. A qualitative risk assessment was used based on AS/NZS 31000:2009 Risk Management – Principles and Guidelines. The potential for environmental values (identified in section 5.0) to be contaminated by the pathways identified in the CSM was assessed during normal and abnormal operations and any potential emergency situations. Criteria used to rank the sensitivity and magnitudes of potential impacts are set out in Table 4-1 and Table 4-2 respectively.

Table 4-1 Sensitivity criteria

Sensitivity	Description
High	<p>The environmental value is listed on a recognised or statutory state, national or international register as being of conservation significance.</p> <p>The environmental value is intact and retains its intrinsic value.</p> <p>The environmental value is unique to the environment in which it occurs. It is isolated to the affected system/area, which is poorly represented in the region, territory, country or the world.</p> <p>It has not been exposed to threatening processes, or they have not had a noticeable impact on the integrity of the environmental value; contamination would have an adverse effect on the value.</p>
Moderate	<p>The environmental value is recorded as being important at a regional level, and may have been nominated for listing on recognised or statutory registers.</p> <p>The environmental value is in a moderate to good condition despite it being exposed to threatening processes. It retains many of its intrinsic characteristics and structural elements.</p> <p>It is relatively well represented in the systems/areas in which it occurs but its abundance and distribution are limited by threatening processes.</p>

Sensitivity	Description
	Threatening processes have reduced its resilience to change; consequently, changes resulting from contamination may lead to degradation of the prescribed value. Replacement of losses is possible due to its abundance and distribution.
Low	The environmental value is not listed on any recognised or statutory register. It might be recognised locally by relevant suitably qualified experts or organisations e.g. historical societies. The environmental value is in a poor to moderate condition as a result of threatening processes, which have degraded its intrinsic value. It is not unique or rare and numerous representative examples exist throughout the system/area. It is abundant and widely distributed throughout the host systems/areas. There is no detectable response to change or change does not result in further degradation of the environmental value. Replacement of losses is achievable due to its abundance and wide distribution.

Table 4-2 Magnitude criteria

Magnitude	Description
High	An impact that is widespread, long lasting and results in substantial and possibly irreversible change to the environmental value. Avoidance through appropriate design responses or the implementation of site-specific environmental management controls are required to address the impact.
Moderate	An impact that extends beyond the area of disturbance but is contained within the region where the project is being developed. The impacts are short term and result in changes that can be ameliorated with specific environmental management controls.
Low	A localised impact that is temporary or short term and either unlikely to be detectable or could be effectively mitigated through standard environmental management controls.
Negligible	Insignificant, such that it may be safely disregarded.

The level of risk of each environmental impact was assessed by combining the sensitivity and magnitude criteria in a risk assessment process as shown in Table 3. The risk of potential impact was assessed by estimating sensitivity and magnitude of potential impacts, and identifying appropriate mitigation and management controls to reduce the risk to acceptable levels to protect the environmental value.

Table 4-3 Significance matrix

Magnitude	Sensitivity		
	High	Moderate	Low
High	Major	High	Moderate
Moderate	High	Moderate	Low
Low	Moderate	Low	Negligible

5 ENVIRONMENTAL VALUES

In June 2011, GHD was commissioned by Council to conduct an ecological assessment, including a vegetation survey, of the outfall areas at the site. The outfall areas include:

- Stage 1 leachate pump (“LMP02”)
- Stage 3 Drain (“SW2”)
- Green waste runoff sump (“GWSUMP”).

Each site was visited and records taken of the dominant vegetation and flora species presence, and records were kept of any threatened species of flora and fauna. The general status and condition of the habitats and threats to the aquatic environment were assessed with reference to similar habitat in and around the landfill that were not subject to the effect of the outfall. A summary of GHD’s findings are provided below.

5.1 Ecology values

5.1.1 Stage 1 leachate pump outfall area (LMP02)

The pump is located on the edge of a floodplain, with outfall water likely to flow out and onto the flood plain. The soil (clay) on the edge of the floodplain away from the outfall was dry on the surface but retained significant moisture immediately below the surface. There was no permanent surface water in the general area of the outfall, and no temporary surface water at the time of the inspection. Growing plants were lush and healthy.

Water leaving the outfall during the wet season would flow through naturally occurring open woodland of the native *Pandanus spiralis*. The ground layer vegetation inside the woodland was primarily made up of centro (*Centrosema molle*) (a vine), stinking passionfruit vines (*Passiflora foetida*), and mission grass (*Pennistenum polystachion*). *Acacia auriculiformis* and *Albizia* sp. occurred towards the landward margin of the woodland. The floodplain perimeter of the woodland was bounded by thick growth of *Ludwigia hyssopifolia*, mission grass and various small shrubs. Mission grass, stinking passion fruit and centro are introduced plant species.

No threatened species were observed.

5.1.2 Stage 3 drain (currently decommissioned) (SW2)

The drain outfall was located on the edge of a floodplain, with outfall water likely to flow out and onto the flood plain. The soil (clay) on the edge of the floodplain away from the outfall was dry on the surface but retained some moisture immediately below the surface. There was no permanent surface water in the general area of the outfall, and no temporary surface water at the time of the inspection. Understory plants were senescing as is usual for drying sites early in the dry season.

Water leaving the outfall during the wet season would flow through naturally occurring open woodland of the native *Pandanus spiralis*. The ground layer vegetation inside the woodland included Gamba grass (*Andropogon gayanus*) and mission grass with stinking passionfruit vines (*Passiflora foetida*). Gamba grass, mission grass, and sticking passion fruit are introduced weed species.

No threatened species were observed.

5.1.3 Green waste runoff sump (GWSUMP)

The drain outfall is located on the edge of grassland, with outfall water likely to flow out and onto the grassland. The soil (clay) on the edge of the grassland away from the outfall was dry on the surface and retained little moisture immediately below the surface. There was no permanent surface in the general area of the outfall, and no temporary surface water at the time of the inspection. Understory plants were senescing as is usual for drying sites early in the dry season.

Water leaving the outfall during the wet season would flow through grassland composed largely of Gamba grass (*Andropogon gayanus*) and mission grass. The drain does not lead to pandanus woodland although there are a few scattered pandanus.

No threatened species were observed.

5.1.4 Summary of ecology values

The dominating feature of the ecology of the three outfall areas is the dominating presence of introduced species of plant: most notably Gamba grass and mission grass, Centro and stinking passionfruit. This is supplemented with additional species, especially at the Stage 1 Pump. Stage 1 was the first stage of the landfill. The dominance of introduced plants is a characteristic of the area, not just the landfill location. The photos on the following page provide vistas of the surrounding area on and off the landfill area showing the overwhelming presence of introduced weeds, particularly mission and Gamba grasses.

The landfill is a focus for Darwin residents seeking to dispose of their garden refuse. It is inevitable that propagules have and will continue to escape and colonise areas adjacent to the landfill. Moist areas such as those chosen for the Stage 1 and Stage 3 outfalls are particularly prone to invasion by cultivars.

The dominance of introduced plants is not caused by the outfalls.

Flows from the outfalls are apparently largely restricted to the wet season and are likely to be highly diluted by natural flows and rainfall, possibly limiting potential for accumulation of contaminants. The outfalls seem unlikely to pose a risk to the seasonally aquatic floodplain environment. Growth of plants at the Stage 1 pump where soils were moist was lush and seemingly healthy. The two drier sites had large biomasses of naturally senescing introduced weeds.

The native habitats around the outfalls do not seem likely to provide optimum habitat for native threatened species.

A summary of flora species recorded from the Project area is provided below in Table 5-1.

Table 5-1 Flora species recorded from the site

Species Name	Status	Predominant habitat	Data Source
<i>Acacia auriculiformis</i>	Native	Terrestrial	GHD, 2011
<i>Aeschynomene americana</i>	Introduced	Wetland	Macmahon, 2009
<i>Albizia sp.</i>	Native	Terrestrial	GHD, 2011
<i>Alysicarpus vaginalis</i>	Introduced	Terrestrial	Macmahon, 2009
<i>Andropogon gyanus</i>	Introduced	Terrestrial	GHD, 2011
<i>Avicennia marina</i>	Native	Wetland	Dames & Moore, 1992
<i>Centrosema molle</i>	Introduced	Terrestrial	GHD, 2011
<i>Ceratopteris thalictroides</i>	Native	Wetland	Dames & Moore, 1992
<i>Chloris inflata</i>	Introduced	Terrestrial	Macmahon, 2009; Dames & Moore, 1992
<i>Crinum sp.</i>	Native	Wetland	Dames & Moore, 1992
<i>Cyperus javanicus</i>	Native	Wetland	Dames & Moore, 1992
<i>Desmodium tortuosum</i>	Introduced	Terrestrial	Macmahon, 2009
<i>Dichanthium tenuiculum</i>	Native	Terrestrial	Dames & Moore, 1992
<i>Echinochloa colona</i>	Introduced	Terrestrial	Dames & Moore, 1992
<i>Eriachne burkittii</i>	Native	Wetland	Dames & Moore, 1992
<i>Euphorbia heterophylla</i>	Introduced	Terrestrial	Macmahon, 2009
<i>Euphorbia hirta</i>	Introduced	Terrestrial	Macmahon, 2009
<i>Fimbristylis acuminata</i>	Native	Wetland	Dames & Moore, 1992
<i>Fimbristylis littoralis</i>	Native	Wetland	Dames & Moore, 1992
<i>Fimbristylis sp.</i>	Native	Wetland	Dames & Moore, 1992
<i>Fuirena ciliaris</i>	Native	Wetland	Dames & Moore, 1992
<i>Imperata cylindrica</i>	Native	Terrestrial	Dames & Moore, 1992
<i>Ipomoea coptica</i>	Native	Terrestrial	Dames & Moore, 1992
<i>Ischaemum australe arundinaceum</i>	Native	Wetland	Dames & Moore, 1992
<i>Leucaena leucocephala</i>	Introduced	Terrestrial	Macmahon, 2009
<i>Ludwigia hyssopifolia</i>	Native	Wetland	GHD, 2011
<i>Ludwigia octovalvis</i>	Native	Wetland	Dames & Moore, 1992
<i>Ludwigia perennis</i>	Native	Wetland	Dames & Moore, 1992
<i>Malachra fasciata lineariloba</i>	Introduced	Terrestrial	Dames & Moore, 1992
<i>Melaleuca nervosa</i>	Native	Wetland	Dames & Moore, 1992
<i>Merremia aegyptia</i>	Introduced	Terrestrial	Macmahon, 2009
<i>Murdannia graminea</i>	Native	Wetland	Dames & Moore, 1992
<i>Pandanus spiralis</i>	Native	Wetland	GHD, 2011
<i>Panicum trachyrhachis</i>	Native	Wetland	Dames & Moore, 1992
<i>Paspalum scrobiculatum</i>	Introduced	Wetland	Dames & Moore, 1992
<i>Passiflora foetida</i>	Introduced	Terrestrial	GHD, 2011, Macmahon, 2009; Dames & Moore, 1992
<i>Pennisetum pedicellatum</i>	Introduced	Terrestrial	Macmahon, 2009
<i>Pennisetum polystachion</i>	Introduced	Terrestrial	GHD, 2011; SMEC, 2005
<i>Schoenoplectus litoralis</i>	Native	Wetland	Dames & Moore, 1992

Species Name	Status	Predominant habitat	Data Source
<i>Senna obtusifolia</i>	Introduced	Terrestrial	Macmahon, 2009; SMEC 2005
<i>Sida acuta</i>	Introduced	Terrestrial	SMEC, 2005
<i>Sida cordifolia</i>	Introduced	Terrestrial	SMEC, 2005
<i>Stachytarpheta cayennensis</i>	Introduced	Terrestrial	SMEC, 2005
<i>Stylosanthes hamata</i>	Introduced	Terrestrial	Macmahon, 2009
<i>Vernonia cinerea</i>	Native	Terrestrial	Dames & Moore, 1992
<i>Vigna lanceolata filiformis</i>	Native	Terrestrial	Dames & Moore, 1992
<i>Whiteochloa airoides</i>	Native	Terrestrial	Dames & Moore, 1992

6 ECOLOGICAL RISK ASSESSMENT

Based on the methodology in Section 4.0, the ERA presented in Table 6-1 has been developed using potential impacts, receptors and mitigation measures described below.

6.1 Potential impacts

The revised CSM (URS, 2015) for the site identified the following sources of contamination with the potential to impact the waters of the floodplain east of the Site and their flora and fauna ecosystems:

- Landfill leachate from the degradation of waste contained within the former and current landfilled waste cells and the lined leachate storage pond.
- Green waste leachate from green waste storage and composting activities in the south-west area of the site.
- Spills and/or leaks from stored chemicals at the chemical storage facility (at the south end of the site).

A release of leachate into the environment could potentially impact on the groundwater on site, and eventually off site (with groundwater movement) towards Shoal Bay.

The hydraulic gradient of the groundwater system reduces from the edge of the landfill eastwards towards the coast, as shown in (Figure 5, URS 2015). The hydrogeological investigation indicated that the hydraulic conductivities are variable. The greatest hydraulic conductivity values are around 0.5 m/day and the hydraulic gradient beyond the edge of the landfill is around 0.001. Therefore the Darcy velocity is 0.005 m/day and the particle velocity is 0.002 m/day, assuming a porosity of 25%. This means effectively that the leachate plume is migrating at a rate of 0.7 m/year. With the influence of attenuation through cation exchange (adsorption) and dilution, the effect at the nearest receptor in the coastal fringe is greatly diminished.

Stormwater that comes in contact with waste could travel off site and either seep into the soil or accumulate in surface water and potentially impact on native vegetation or local wildlife (through consumption) or, during floods, move into the floodplains and ultimately into Shoal Bay. However, due to natural attenuation, it is unlikely that leachate from the landfill would be detectable in the waters of Shoal Bay and/or impact on the marine aquatic environment. Water Quality Objectives for the Darwin Harbour Region (NRETAS, February 2010), provide relevant indicators, guideline levels and Water Quality Objectives (ANZECC 2000, 95% species protection for marine waters) to maintain the health of aquatic ecosystems.

6.1.1 Assessment of Leachate Impact

The impact of leachate on groundwater can be assessed through comparison of the ratios between leachate (L) ions, such as K^+ , NH_4^+ and NO_3^- and ions that are more prevalent in natural (N) groundwaters (Ca^{2+} , Na^+ and Mg^{2+}). The ratio is determined as follows:

$$L/N = (K^+ + NH_4^+ + NO_3^-) / (Ca^{2+} + Na^+ + Mg^{2+}) * 100$$

The L/N ratio is generally less than 10 for natural groundwaters whereas leachate or leachate impacted groundwaters exhibit a ration greater than 10.

The L/N ratios are plotted in **Chart 6-1** below.

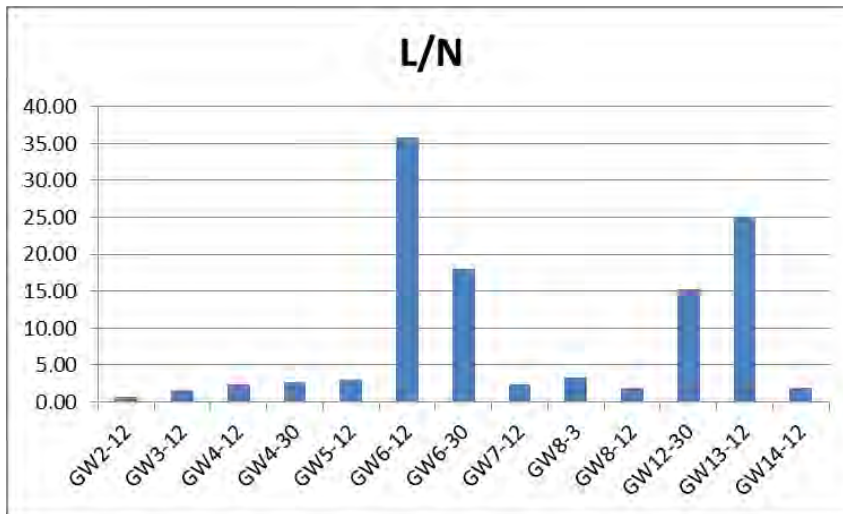


Chart 6-1 L/N Ratios – Shoal Bay Monitoring Bores

The plot shows that most bores exhibit natural groundwater quality, but GW6-12, GW6-30, GW12-30 and GW13-12 all exhibit chemistry indicative of leachate impacts.

This ERA assesses the potential for these contamination sources to impact on ecological receptors via pathways that include (but are not necessarily limited to):

- Infiltration of leachate, leachate impacted or otherwise impacted water to the groundwater system
- Overland drainage of leachate, leachate impacted or otherwise impacted water to surface water bodies (i.e. via seepage through landfill or off the green waste area and/or tide waters entering flood plain)
- Potentially contaminated groundwater base flow or discharge (from LMP02, SW2 or GWSUMP) to flood plain and associated ecosystem.

As the area is quite inaccessible, it is considered unlikely that the general public would come in contact with any contaminated surface water, and as a result, the following pathways are not relevant to the ERA.

- Direct or indirect exposure to water users of groundwater / surface water usage for beneficial uses precluded by contaminants of potential concern, particularly downgradient of the site; and
- Direct exposure (dermal contact, accidental ingestion) of on-site personnel and visitors to leachate, leachate impacted waters or otherwise impacted waters.

6.2 Receptors

The waters of the floodplain east of the site and the Hayes Creek floodplain west of the site and their flora and fauna ecosystems are potential receptors for contaminants migrating off site as a result of potential site activities.

As described in Section 5.0, the ecology values of the site are dominated by introduced flora species. No threatened flora or fauna species were recorded during the field surveys and the

habitat values of the project area are considered unlikely to provide optimum habitat for threatened species.

The flora species of the site have been categorised into terrestrial and wetland receptors (Table 5-1). These broad categories allow a high level assessment of potential impacts to ecology values.

6.3 Mitigation

The Project Environmental Management Plan (PEMP) (Territoria Civil, 2011) for Shoal Bay Waste Disposal Site provides a framework for implementing environmental management practices and procedures to manage and minimise potential environmental impacts from landfill activities.

The following environmental control plans provide detailed mitigation and monitoring measures for management of specific environmental issues considered in this ERA.

- Water quality environmental control plan
- Stormwater erosion and sediment control environmental control plan
- Wastes, litter and hazardous substances environmental control plan
- Potential environmental nuisance issues environmental control plan
- Flora and weed environmental control plan
- Pest and vector environmental control plan.

Outcomes of this ERA will inform future revisions of the PEMP.

Table 6-1 Ecological risk assessment

Potential impact	Receptor	Sensitivity	Pre-mitigated risk		Mitigation measures	Residual risk	
			Magnitude	Significance		Magnitude	Significance
Infiltration of leachate, leachate impacted or otherwise impacted water to the groundwater system	Terrestrial	Low	Moderate	Low	<ul style="list-style-type: none"> - Waste only accepted into the lined cells. Only inert waste is accepted in unlined cells. - Apply daily cover, temporary cover and capping. - Install diversion control measures as appropriate to separate clean stormwater from operational areas (such as bunds, swales, grading). - Maintain and repair leachate collection systems as required. - Daily and/ or weekly visual inspections by Supervisor and HSEQ Advisor. - Daily monitoring of the leachate collection system to ensure it is functioning appropriately: <ul style="list-style-type: none"> • No leachate springs • No leachate moving off site • Leachate pumps working • Any leachate pumped back onto Stage 1 and 3 infiltrating back into landfill areas and not draining off site. - In case of leachate has the potential to contaminate groundwater, surface water or migrate off site, notify and liaise with Council and NT EPA and develop an appropriate action plan. For example repair any batter erosion, monitor the water quality, improve the leachate collection system, etc. - Additional inspection of leachate control structures after storm events. - Implement groundwater monitoring program. 	Low	Negligible
	Wetland	Moderate	Moderate	Moderate		Low	Low
Overland drainage of leachate, leachate impacted or otherwise impacted water to surface water bodies (i.e. via seepage through landfill or off the green waste area and /or tide waters entering flood plain)	Terrestrial	Low	Moderate	Low		Low	Negligible
	Wetland	Moderate	Moderate	Moderate		Low	Low
Potentially contaminated groundwater base flow or discharge (from LMP02, SW2 or GWSUMP) to flood plain and associated ecosystem	Terrestrial	Low	Moderate	Low		Low	Negligible
	Wetland	Moderate	Moderate	Moderate		Low	Low

Potential impact	Receptor	Sensitivity	Pre-mitigated risk		Mitigation measures	Residual risk	
			Magnitude	Significance		Magnitude	Significance
Spills and/or leaks of stored chemicals	Terrestrial	Low	Moderate	Low	<ul style="list-style-type: none"> - Hazardous substances on site to be stored appropriately within bunded and impervious areas in accordance with MSDS. Diesel Tank storage to meet AS 1940. - Any leaking container will be placed into a larger container, and placed in the chemical storage unit immediately. - When 40% available capacity left, Territoria Civil contacts Council for appropriate disposal. - Follow the Project Emergency Response Plan for emergency situations such as spills (including 6 monthly drills). - Unidentified or unlisted chemicals are not accepted unless special approval from Council and NT EPA. - Illegal dumped materials should be stored in chemical storage unit immediately. - The waste oil tank is maintained by Territoria Civil on a concrete surface and steel bund area, and spills cleaned up. Council to empty the tank regularly to avoid overfilling. 	Low	Negligible
	Wetland	Moderate	Low	Low		Low	Low

7 CONCLUSIONS AND RECOMMENDATIONS

This ERA has been prepared using available information on site conditions, ecology values and landfill activities to assess the potential risk for ecology receptors to be impacted (contaminated) according to the new CSM (URS, 2015). The ERA demonstrates that sufficient mitigation and monitoring measures have been identified in PRMP to manage risks to acceptable level. Where a trend towards increasing contaminant levels in groundwater or surface waters is detected, Territoria Civil will report in the Quarterly Environment Reports and liaise with Council and NT EPA as appropriate.

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