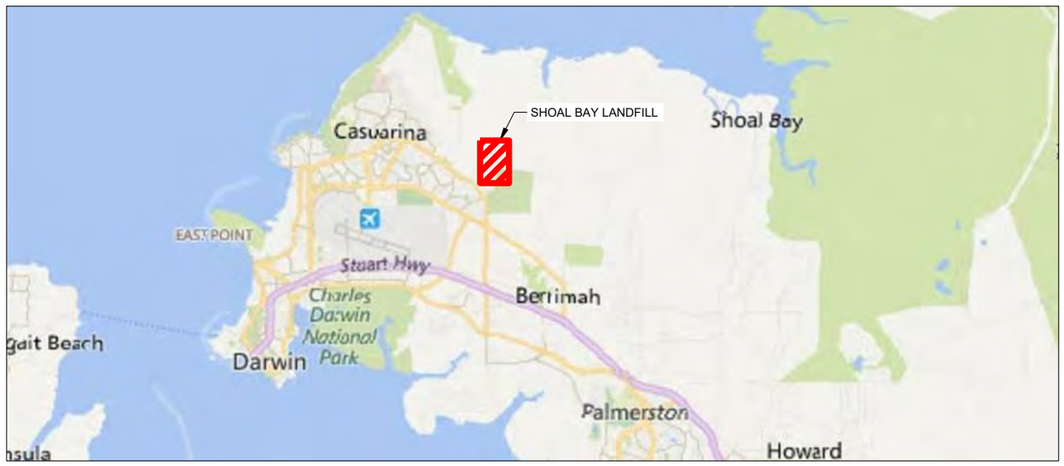
APPENDIX D

Key Stage 3/4 Final Capping Design Drawings

SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

SITE PLAN
SCALE 1:5,000 m



LOCALITY PLAN
NOT TO SCALE

DRAWING INDEX

DRG No.	TITLE
001	LOCALITY PLAN, DRAWING INDEX AND COVER SHEET
002	EXISTING CONDITIONS
003	GENERAL ARRANGMENT PLAN - TOP OF RESHAPED WASTE
004	CUT FILL PLAN - TOP OF RESHAPED WASTE
005	GENERAL ARRANGMENT PLAN - TOP OF CAPPING
006	GENERAL ARRANGMENT PLAN - CAPPING REINFORCEMENT
007	GENERAL ARRANGMENT PLAN - PASSIVE GAS
008	GENERAL ARRANGMENT PLAN - SUB-SURFACE WATER MANAGEMENT
009	GENERAL ARRANGMENT PLAN - SURFACEWATER MANAGEMENT
010	LANDFILL SITE SECTIONS
011	SUB-SURFACE WATER MANAGEMENT - SECTIONS AND DETAILS
012	ANCHOR TRENCH AND LINER CONNECTION SECTIONS AND DETAILS - (SHEET 1 OF 2)
013	ANCHOR TRENCH AND LINER CONNECTION SECTIONS AND DETAILS - (SHEET 2 OF 2)
014	PASSIVE GAS SECTIONS AND DETAIL - SHEET 1 OF 2
015	PASSIVE GAS SECTIONS AND DETAIL - SHEET 2 OF 2
016	CAPPING SYSTEM PENETRATION DETAILS
017	STORMWATER CHUTE INLET - SECTIONS AND DETAILS
018	STORMWATER CHUTE OUTLET - SECTIONS AND DETAILS
019	NORTHERN DIVERSION BUND - LAYOUT PLAN AND LONGITUDINAL SECTION
020	REINFORCEMENT AT CORNERS - TYPICAL SECTIONS AND DETAILS

GENERAL NOTES

1. THESE NOTES APPLY TO ALL DRAWINGS IN THE SET UNLESS NOTED OTHERWISE AND SHALL BE READ IN CONJUNCTION WITH THE SPECIFICATION.
2. ALL LEVELS ARE IN METRES TO AUSTRALIAN HEIGHT DATUM (AHD).
3. ALL CO-ORDINATES ARE IN METRES TO MAP GRID OF AUSTRALIA (MGA94, ZONE 52).
4. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.
5. DIMENSIONS AND LOCATION OF EXISTING STRUCTURES SHALL BE CONFIRMED ON SITE BY THE CONTRACTOR PRIOR TO COMMENCEMENT OF WORKS.
6. LOCATION AND DEPTH OF ALL SERVICES TO BE VERIFIED BY THE CONTRACTOR PRIOR TO COMMENCEMENT OF WORKS.
7. EXISTING SURFACE LEVELS ON DRAWINGS SHALL BE VERIFIED ONSITE BY THE CONTRACTOR PRIOR TO THE COMMENCEMENT OF WORKS.
8. ANY DISCREPANCY BETWEEN THE CONTRACTORS VERIFICATION SURVEY AND THE DRAWINGS SHALL BE REFERRED TO THE DESIGNER PRIOR TO THE COMMENCEMENT OF THE WORKS.
9. DIMENSIONS SHALL NOT BE SCALED OFF DRAWINGS.
10. POTHOLING OF EXISTING CELLS REQUIRED TO CONFIRM AS BUILT LINER / ANCHOR TRENCH LOCATION/ELEVATION

REFERENCES

1. AERIAL IMAGERY FROM NEARMAP DATED 2020-08-26
2. 3D ELEVATION SURVEY DATA PROVIDED BY CITY OF DARWIN.
   - FILENAME: 11615-1B (triangles only).dwg
   - 3D FACES ON LAYER "_FYFE DTM WITH EJA TOE PICKUP" USED TO BUILD MODEL SURFACE
3. SURVEY FEATURES PROVIDED BY CITY OF DARWIN/DTA CONTRACTORS.
   - FILENAME: 2021.07.30-Capped-Surface.dwg
   - CAPTURE DATE: 2021-07-30
4. AS BUILT SURVEY DATA PROVIDED BY CITY OF DARWIN.
   - STAGE 3 - FILE NAME: 5209 2012-02-10 (MGA94).dwg
   - STAGE 4 - FILE NAME: 2981410 (Rainflap Survey).dwg
   - **NOTE:** AS BUILT ELEVATION DATA HAS BEEN LOWER 0.6 m UNIFORMLY TO ACCOMMODATE CHANGE FROM LOCAL SITE DATUM TO AHD.
5. PIVOT IRRIGATION SYSTEM RADIAL LIMITS TAKEN FROM "Shoal Bay Waste Facility Irrigation_REVE.dwg"
6. GAS FIELD INFRASTRUCTURE PIPELINES TAKEN FROM "50030-CA-003 Rev 7 - Shoal Bay Gas Field Layout MGA94 Z52.dwg" AND ALSO FROM "INSERT
7. PROPOSED GAS WELLS BASED ON PAGE 21 OF "Gas System: Installations Workplace Plan (WPP) – FM81" PDF "Shoalbay WPP final.pdf" MOVED TO SUIT NEW DESIGN

MATERIAL LIST

- UNIT 1 - SELECT FILL
- UNIT 2 - COVER SOIL
- UNIT 3 - AIR SUPPLY PIPE
- UNIT 4 - DRAINAGE AGGREGATE
- UNIT 5 - FILTER GEOTEXTILE
- UNIT 6 - GEOCOMPOSITE DRAIN
- UNIT 7 - CAPPING LINER
- UNIT 8 - REINFORCEMENT
- UNIT 9 - SEEPAGE PIPE (P)
- UNIT 10 - SOLID DRAINAGE PIPE
- UNIT 11 - LFG GEOCOMPOSITE STRIP DRAIN
- UNIT 12 - LFG PANEL DRAIN
- UNIT 13 - STAINLESS STEEL BELT CLAMP
- UNIT 14 - GALVANISED STEEL PIPE
- UNIT 15 - GAS RISER SLEEVE
- UNIT 16 - CEMENT STABILISED SAND
- UNIT 17 - ROCK FILLED WIRE BASKETS
- UNIT 18 - RIP RAP
- UNIT 19 - CONCRETE
- UNIT 20 - PAVEMENT MATERIAL
- UNIT 21 - GUIDE POSTS
- UNIT 22 - LEACHATE COLLECTION SUMPS
- UNIT 23 - FUTURE GAS WELL CHAMBER
- UNIT 24 - PASSIVE GAS VENT
- UNIT 25 - COVER SOIL
- UNIT 26 - SUBSURFACE DRAINAGE BLANKET
- UNIT 27 - TOPSOIL
- UNIT 28 - GRASS COVER (STAGE 4 ONLY) REVEGETATION BY OTHERS IN ALL OTHER AREAS
- UNIT 29 - COVER SOIL

ISSUED FOR
CONSTRUCTION

0 100 200
1:5,000 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
5	2021-09-06	RE-ISSUE	SW	ADGC	JSB	JSB	
4	2021-08-25	ISSUED FOR CONSTRUCTION	SW	BGK	JSB	JSB	
3	2021-06-11	ISSUED FOR CONSTRUCTION	BGK	BGK	SW	FWG	JSB
2	2021-03-30	ISSUED FOR TENDER	SW	BGK	FWG	JSB	
1	2020-12-22	ISSUED FOR TENDER	SW	SMW	FWG	JSB	
0	2020-12-10	ISSUE FOR CLIENT REVIEW	SW	SMW	FWG	JSB	

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MEMBER OF WSP

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PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

TITLE
LOCALITY PLAN, DRAWING INDEX AND COVER SHEET

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	1 of 20	001

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0

LEGEND

- EXISTING GROUND CONTOURS (2 m INTERVALS)
- TEST PIT LOCATION
- EXISTING GAS WELL
- UNIT 10 - SOLID DRAINAGE PIPE
- EXISTING LEACHATE SUMP
- EXISTING LEACHATE INTERCEPTION TRENCH
- EXISTING ABOVE GROUND WATER SUPPLY PIPE
- EXISTING UNDER GROUND WATER SUPPLY PIPE
- UNIT 3 - AIR SUPPLY PIPE
- LANDFILL STAGE BOUNDARY

NOTE(S)

1. REFER DRAWING 001 FOR SURVEY REFERENCES INFORMATION
2. THE CONTRACTOR SHALL UNDERTAKE A SURVEY OF THE EXISTING WASTE LANDFORM AND PROVIDE A REVISED WASTE PROFILE TO THE DESIGNER FOR APPROVAL PRIOR TO COMMENCEMENT OF THE WORKS. REFER TO TECHNICAL SPECIFICATION FOR DETAILS.

ISSUED FOR

CONSTRUCTION

0 50 100

1:2,000 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
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3	2021-06-11	ISSUED FOR CONSTRUCTION	BGK	BGK	SW	FWG	JSB
2	2021-03-30	ISSUED FOR TENDER	SW	BGK	FWG	JSB	
1	2020-12-22	ISSUED FOR TENDER	SW	SMW	FWG	JSB	
0	2020-12-10	ISSUE FOR CLIENT REVIEW	SW	SMW	FWG	JSB	

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PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

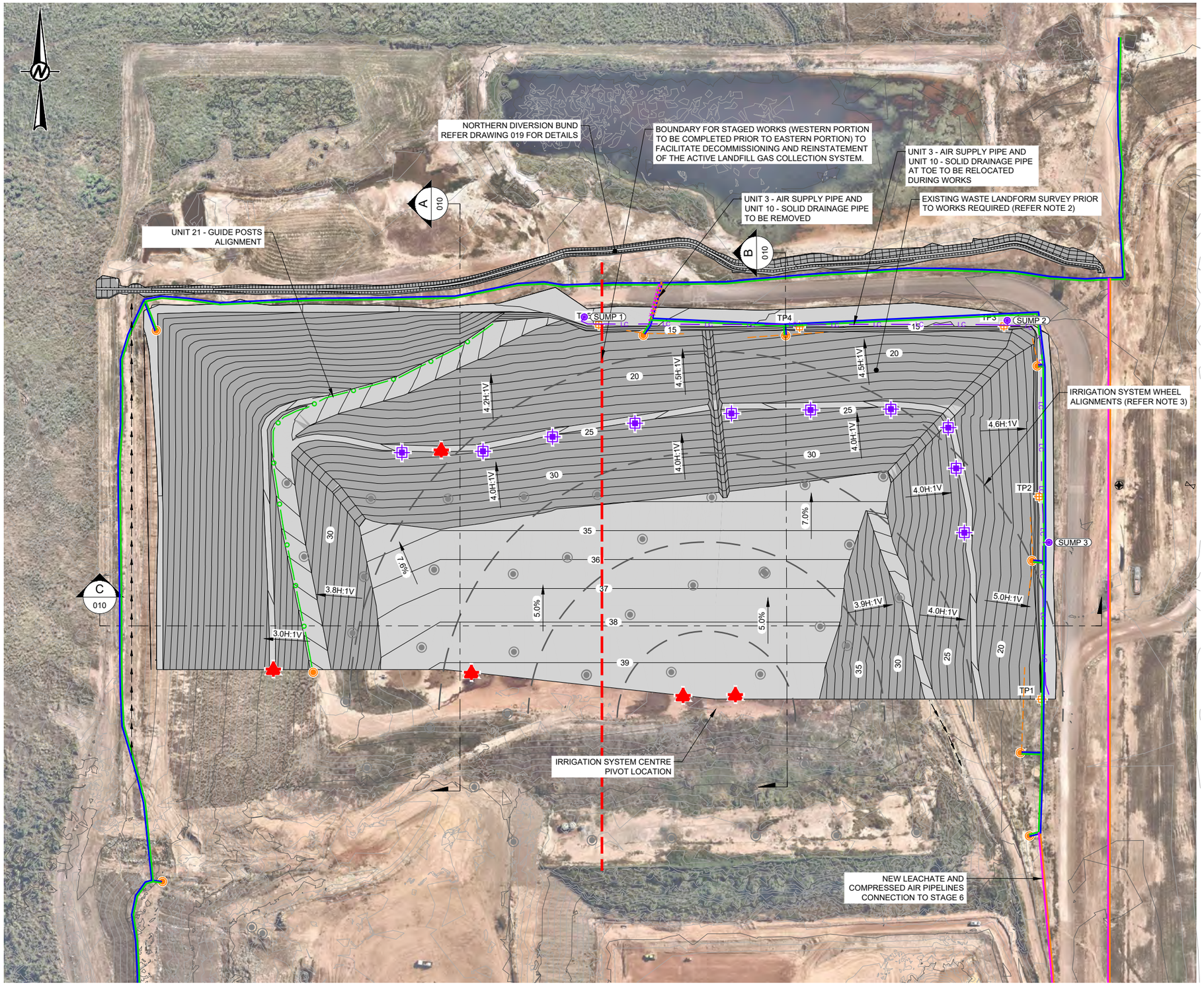
TITLE
EXISTING CONDITIONS

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	2 of 20	002

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

25 mm

0



LEGEND

- EXISTING GROUND CONTOURS (1 m INTERVALS)
- DESIGN CONTOURS (1 m INTERVALS)
- INDICATIVE IRRIGATION SYSTEM WHEEL PATH (LOCATION AND DESIGN BY OTHERS)
- EXISTING DRAIN
- LC — LEACHATE SEEPAGE PIPE
- UNIT 22 - LEACHATE COLLECTION SUMPS
- TEST PIT LOCATION
- EXISTING GAS WELL
- UNIT 10 - SOLID DRAINAGE PIPE
- EXISTING LEACHATE SUMP
- EXISTING LEACHATE INTERCEPTION TRENCH
- UNIT 3 - AIR SUPPLY PIPE
- UNIT 23 - PROPOSED FUTURE GAS WELLS (LOCATIONS TO BE CONFIRMED BY THE PRINCIPAL IN CONSULTATION WITH THE LANDFILL GAS CONTRACTOR PRIOR TO CAPPING CONSTRUCTION)
- NEW LEACHATE PIPE (BURIED)
- NEW COMPRESSED AIR LINE (BURIED)
- UNIT 24 - PASSIVE GAS VENT

NOTE(S)

1. REFER DRAWING 001 FOR SURVEY REFERENCES INFORMATION
2. THE CONTRACTOR SHALL UNDERTAKE A SURVEY OF THE EXISTING WASTE LANDFORM AND PROVIDE A REVISED WASTE PROFILE TO THE DESIGNER FOR APPROVAL PRIOR TO COMMENCEMENT OF THE WORKS. REFER TO TECHNICAL SPECIFICATION FOR DETAILS.
3. THE CONTRACTOR SHALL CONFIRM SET OUT OF IRRIGATION SYSTEM WHEEL PATH ALIGNMENTS (BY OTHERS) WITH THE SUPERINTENDENT PRIOR TO COMMENCEMENT OF THE WORKS. SET OUT SHALL CONSIDER THE EFFECTS OF GRADE CHANGE OF LANDFILL BATTERS ALONG THE FINAL WHEEL PATH ALIGNMENT.

LEACHATE COLLECTION SUMP SETOUT TABLE

POINT No.	EASTING (m)	NORTHING (m)
SUMP 1	709239.95	8630466.59
SUMP 2	709448.60	8630464.90
SUMP 3	709469.18	8630355.41

ISSUED FOR

CONSTRUCTION

0 50 100
1:2,000 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
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2	2021-03-30	ISSUED FOR TENDER	SW	BGK	FWG	JSB	
1	2020-12-22	ISSUED FOR TENDER	SW	SMW	FWG	JSB	
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PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

TITLE
GENERAL ARRANGMENT PLAN - TOP OF RESHAPED WASTE

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	3 of 20	003

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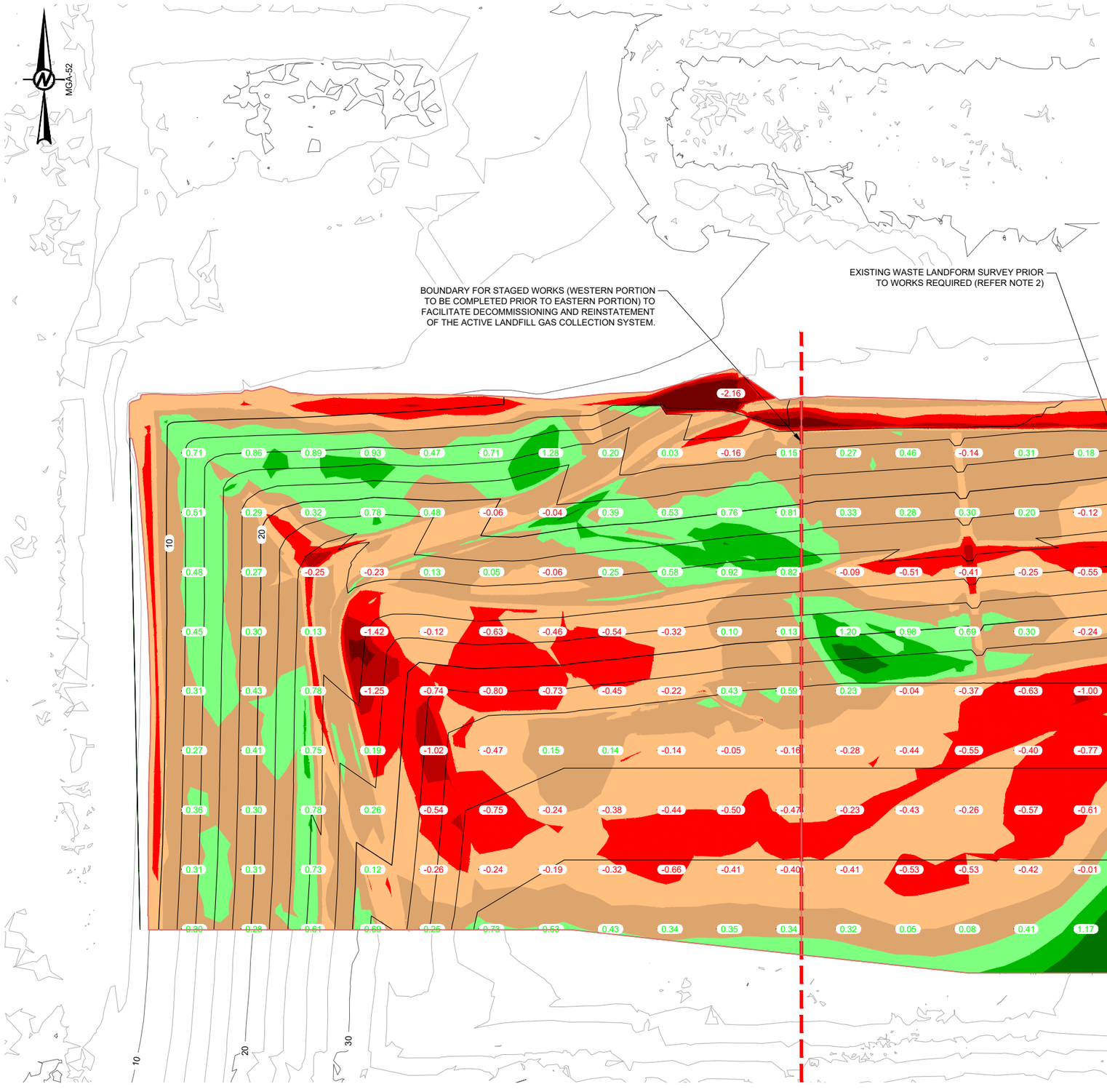

CUT FILL VOLUMES	
CUT (m³)	18,563
FILL (m³)	18,707

NOTE: VOLUMES ABOVE EXCLUDE ANCHOR TRENCHES AND OTHER EXCAVATIONS FOR LINEAR STRUCTURES

LEGEND

EXISTING GROUND CONTOURS (2 m INTERVALS)

DESIGN CONTOURS (2 m INTERVALS)

NOTE(S)

1. REFER DRAWING 001 FOR SURVEY REFERENCES INFORMATION
2. THE CONTRACTOR SHALL UNDERTAKE A SURVEY OF THE EXISTING WASTE LANDFORM AND PROVIDE A REVISED WASTE PROFILE TO THE DESIGNER FOR APPROVAL PRIOR TO COMMENCEMENT OF THE WORKS. REFER TO TECHNICAL SPECIFICATION FOR DETAILS.

CUT FILL WEST					
NUMBER	MIN. ELEV.	MAX. ELEV.	AREA	COLOR	VOLUME
1	-4.20	-1.50	326.07		208
2	-1.50	-1.00	697.26		307
3	-1.00	-0.50	5751.14		1456
4	-0.50	0.00	11453.76		6145
5	0.00	0.50	14087.42		7502
6	0.50	1.00	6804.61		1897
7	1.00	1.50	1096.86		155
8	1.50	1.60	2.11		0

CUT FILL EAST					
NUMBER	MIN. ELEV.	MAX. ELEV.	AREA	COLOR	VOLUME
1	-2.40	-1.50	276.30		64
2	-1.50	-1.00	1228.93		352
3	-1.00	-0.50	7469.70		2139
4	-0.50	0.00	13089.04		7892
5	0.00	0.50	15159.97		6402
6	0.50	1.00	3342.87		1706
7	1.00	1.50	1270.02		704
8	1.50	3.00	870.95		340

ISSUED FOR

CONSTRUCTION

0 25 50

1:1,500 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
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PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

TITLE
CUT FILL PLAN - TOP OF RESHAPED WASTE

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	4 of 20	004

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

25 mm

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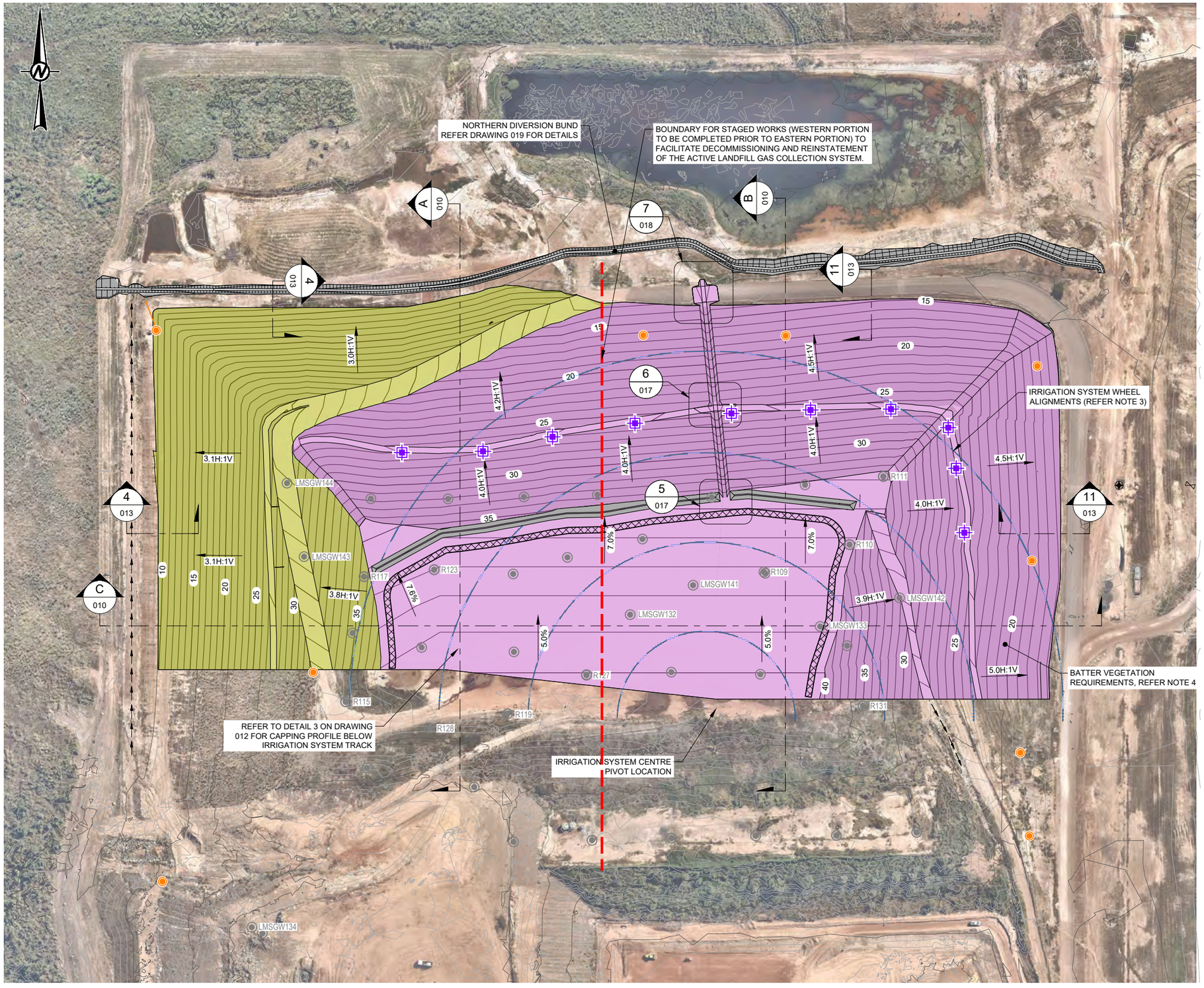

LEGEND

- EXISTING GROUND CONTOURS (1 m INTERVALS)
- DESIGN CONTOURS (1 m INTERVALS)
- INDICATIVE IRRIGATION SYSTEM WHEEL PATH (LOCATION AND DESIGN BY OTHERS)
- EXISTING GAS WELL
- EXISTING LEACHATE SUMP
- EXISTING DRAIN
- IRRIGATION TRACK CAPPING PROFILE
- 3 m WIDE ACCESS ROAD
- UNIT 23 - PROPOSED FUTURE GAS WELLS (LOCATIONS TO BE CONFIRMED BY THE PRINCIPAL IN CONSULTATION WITH THE LANDFILL GAS CONTRACTOR PRIOR TO CAPPING CONSTRUCTION)
- CAPPING PROFILE TYPE A
- CAPPING PROFILE TYPE B

NOTE(S)

1. REFER DRAWING 001 FOR SURVEY REFERENCES INFORMATION
2. THE CONTRACTOR SHALL UNDERTAKE A SURVEY OF THE EXISTING WASTE LANDFORM AND PROVIDE A REVISED WASTE PROFILE TO THE DESIGNER FOR APPROVAL PRIOR TO COMMENCEMENT OF THE WORKS. REFER TO TECHNICAL SPECIFICATION FOR DETAILS.
3. THE CONTRACTOR SHALL CONFIRM SET OUT OF IRRIGATION SYSTEM WHEEL PATH ALIGNMENTS (BY OTHERS) WITH THE SUPERINTENDENT PRIOR TO COMMENCEMENT OF THE WORKS. SET OUT SHALL CONSIDER THE EFFECTS OF GRADE CHANGE OF LANDFILL BATTERS ALONG THE FINAL WHEEL PATH ALIGNMENT.
4. THE DESIGN BASIS REQUIRES ESTABLISHMENT OF VETIVER GRASS ON BATTERS. THE USE OF OTHER VEGETATION SPECIES OR ABSENCE OF VEGETATION MAY NOT MEET THE DESIGN INTENT AND MUST BE REVIEWED BY THE DESIGNER AND APPROVED BY THE ENVIRONMENTAL AUDITOR.

ISSUED FOR

CONSTRUCTION

0 50 100

1:2,000 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
5	2021-09-06	RE-ISSUE	SW	ADGC	JSB	JSB	
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0	2020-12-10	ISSUE FOR CLIENT REVIEW	SW	SMW	FWG	JSB	

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PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

TITLE
GENERAL ARRANGMENT PLAN - TOP OF CAPPING

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	5 of 20	005

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

0 25 mm

LEGEND

- EXISTING GROUND CONTOURS (1 m INTERVALS)
- DESIGN CONTOURS (1 m INTERVALS)
- ANCHOR TRENCH TYPE A
- ANCHOR TRENCH TYPE B
- ANCHOR TRENCH TYPE C
- ANCHOR TRENCH TYPE D
- REINFORCEMENT TYPE A
- REINFORCEMENT TYPE B
- REINFORCEMENT TYPE C
- REINFORCEMENT TYPE D
- EXISTING GAS WELL
- EXISTING LEACHATE SUMP
- EXISTING DRAIN
- UNIT 23 - PROPOSED FUTURE GAS WELLS (LOCATIONS TO BE CONFIRMED BY THE PRINCIPAL IN CONSULTATION WITH THE LANDFILL GAS CONTRACTOR PRIOR TO CAPPING CONSTRUCTION)

BOUNDARY FOR STAGED WORKS (WESTERN PORTION TO BE COMPLETED PRIOR TO EASTERN PORTION) TO FACILITATE DECOMMISSIONING AND REINSTATEMENT OF THE ACTIVE LANDFILL GAS COLLECTION SYSTEM.

ANCHOR TRENCH TYPE D

ANCHOR TRENCH TYPE D

3.0H:1V
4.2H:1V
4.5H:1V
4.0H:1V
3.1H:1V
3.8H:1V
3.9H:1V
5.0H:1V
7.0%
7.6%
5.0%
15
20
25
30
35
36
37
38
39
E 012
H 013
D 012
G 013
F 012

NOTE(S)

1. CONTOURS AT CORNER RIDGES TO BE ADJUSTED AS PART OF ISSUED FOR CONSTRUCTION DRAWING SET.

ISSUED FOR
CONSTRUCTION

0 25 50
1:1,500 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
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PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

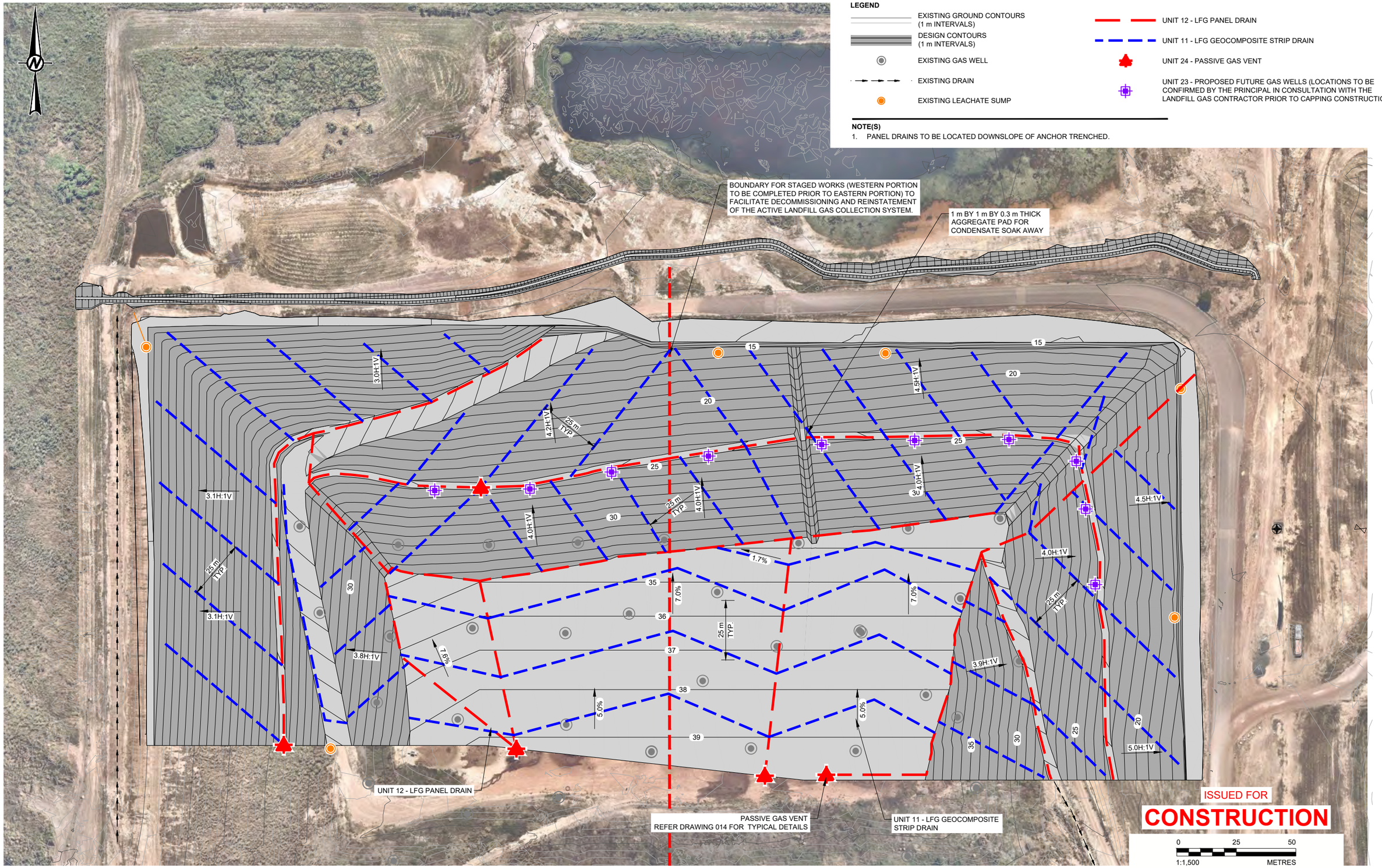
TITLE
GENERAL ARRANGMENT PLAN - CAPPING REINFORCEMENT

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	6 of 20	006

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

25 mm
0

Path: \\golder.gds\gap\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\99_PROJECTS\20145676 - Stage 3-4CappingConceptDesign\013-Stage3-4_CappingDetailedDesign\02_PRODUCTION\DWGs\ | File Name: 20145676-013-006.dwg | Last Edited By: arcadden Date: 2021-09-06 Time:12:00:11 PM | Printed By: ArCadden Date: 2021-09-06 Time:12:06:31 PM



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CLIENT
CITY OF DARWIN

PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

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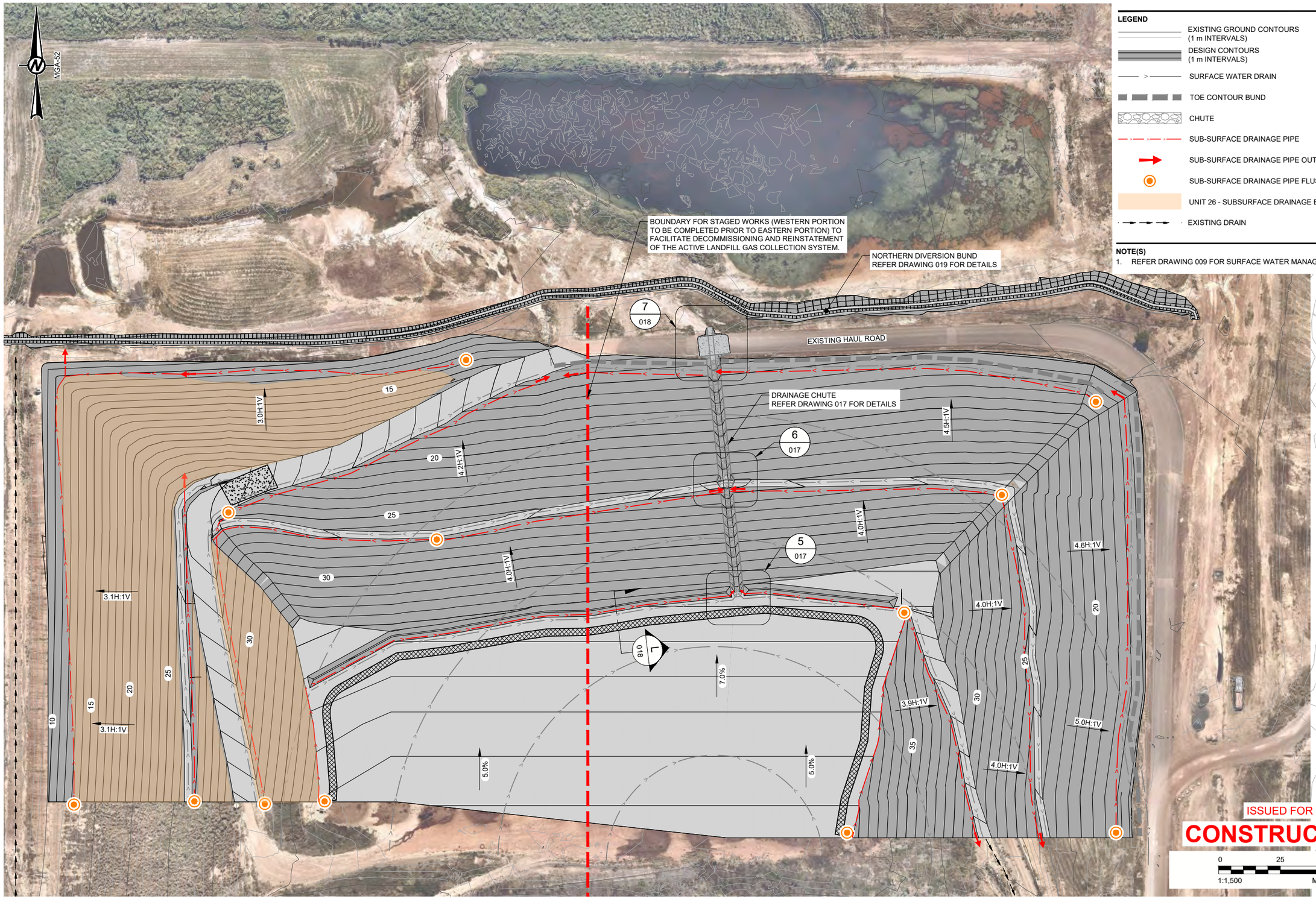
TITLE
GENERAL ARRANGMENT PLAN - PASSIVE GAS

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	7 of 20	007

Path: \\golder.gds\gap\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\99_PROJECTS\20145676 - Stage 3-4CappingConceptDesign\013-Stage3-4_CappingDetailedDesign\02_PRODUCTION\DWG\ | File Name: 20145676-013-007.dwg | Last Edited By: ancadden Date: 2021-09-06 Time:12:09:35 PM | Printed By: AnCadden Date: 2021-09-08 Time:12:06:52 PM



LEGEND

- EXISTING GROUND CONTOURS (1 m INTERVALS)
- DESIGN CONTOURS (1 m INTERVALS)
- SURFACE WATER DRAIN
- TOE CONTOUR BUND
- CHUTE
- SUB-SURFACE DRAINAGE PIPE
- SUB-SURFACE DRAINAGE PIPE OUTLETS
- SUB-SURFACE DRAINAGE PIPE FLUSH POINTS
- UNIT 26 - SUBSURFACE DRAINAGE BLANKET
- EXISTING DRAIN

NOTE(S)

1. REFER DRAWING 009 FOR SURFACE WATER MANAGEMENT LAYOUT

ISSUED FOR

CONSTRUCTION

0 25 50

1:1,500 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
5	2021-09-06	RE-ISSUE	SW	ADGC	JSB	JSB	
4	2021-08-25	ISSUED FOR CONSTRUCTION	SW	BGK	JSB	JSB	
3	2021-06-11	ISSUED FOR CONSTRUCTION	BGK	BGK	SW	FWG	JSB
2	2021-03-30	ISSUED FOR TENDER	SW	BGK	FWG	JSB	
1	2020-12-22	ISSUED FOR TENDER	SW	SMW	FWG	JSB	
0	2020-12-10	ISSUE FOR CLIENT REVIEW	SW	SMW	FWG	JSB	

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PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

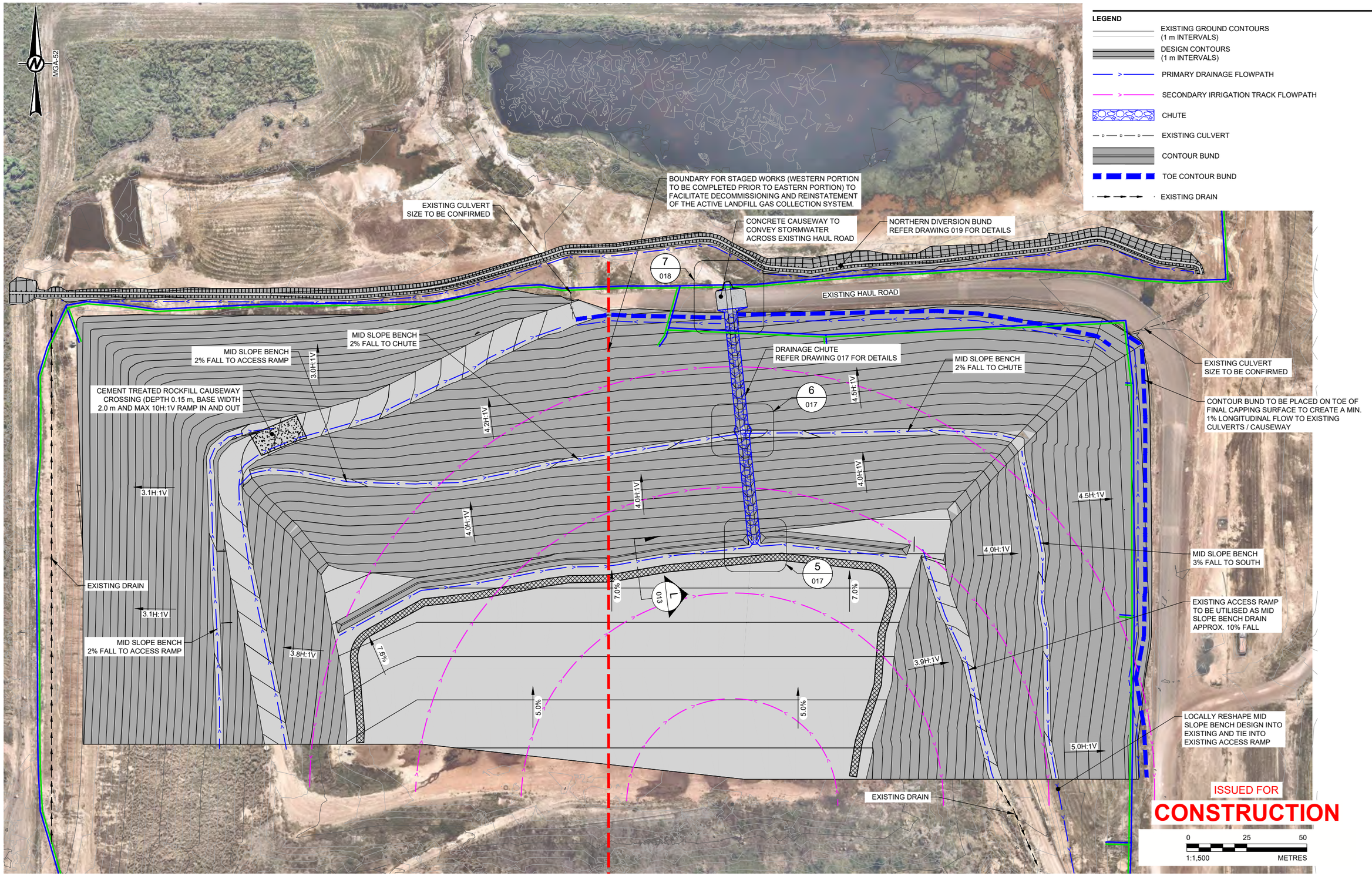
TITLE
GENERAL ARRANGMENT PLAN - SUB-SURFACE WATER MANAGEMENT

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	8 of 20	008

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

25 mm
0

Path: \\golder.gds\gae\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\99_PROJECTS\20145676 - Stage 3-4CappingConceptDesign\013-Stage3-4_CappingDetailedDesign\02_PRODUCTION\DWGS | File Name: 20145676-013-008.dwg | Last Edited By: anCadden Date: 2021-09-06 Time:12:00:48 PM | Printed By: AnCadden Date: 2021-09-06 Time:12:07:12 PM



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2	2021-03-30	ISSUED FOR TENDER	SW	BGK	FWG	JSB	
1	2020-12-22	ISSUED FOR TENDER	SW	SMW	FWG	JSB	
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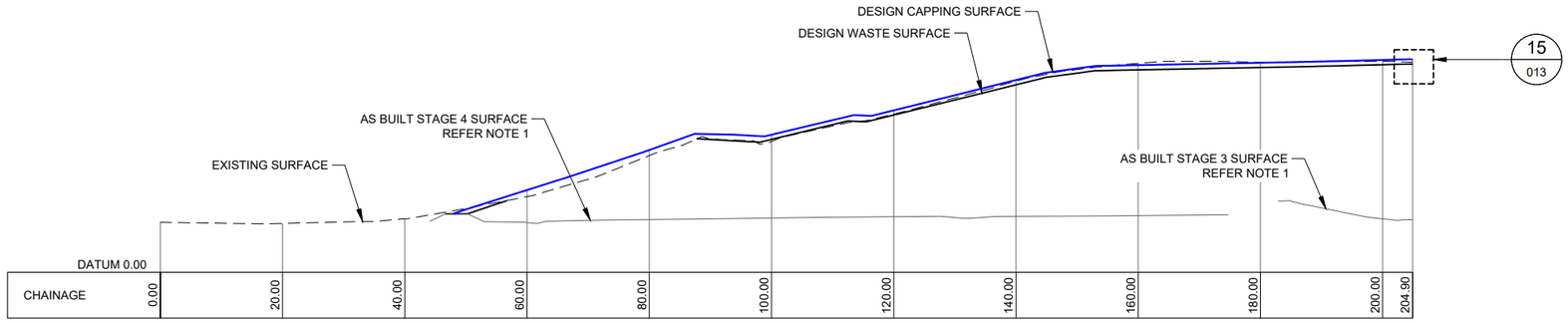
PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

TITLE
GENERAL ARRANGMENT PLAN - SURFACEWATER MANAGEMENT

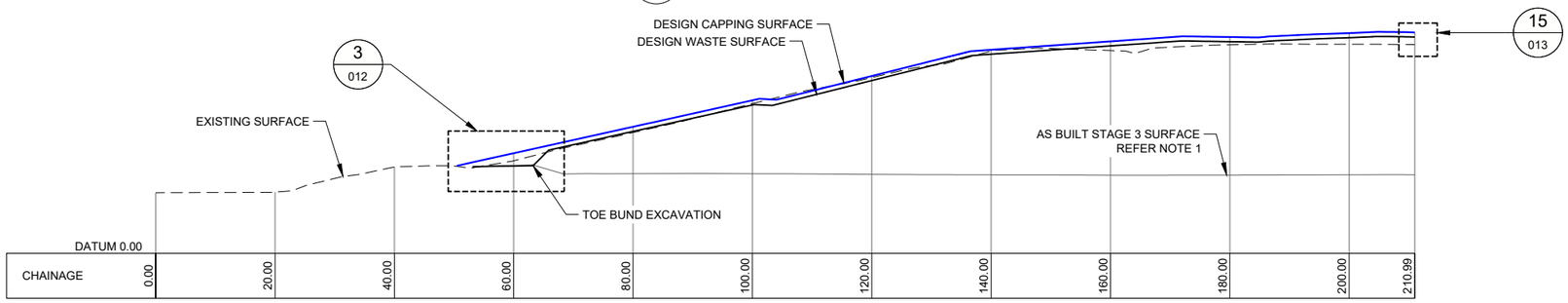
PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	9 of 20	009

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0

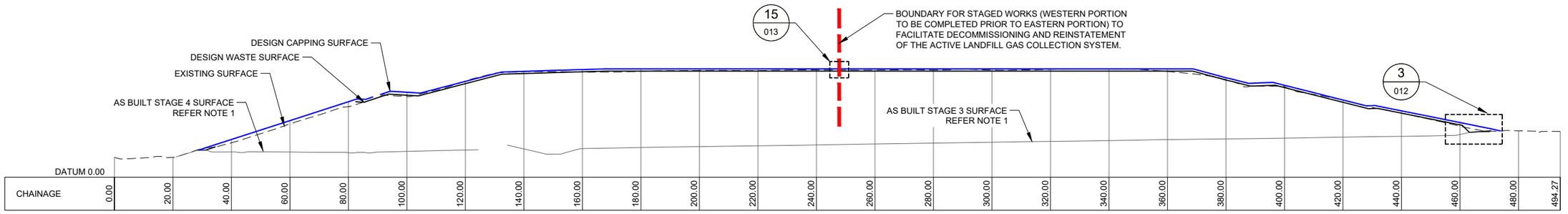
Path: \\golder.gds\gap\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\99_PROJECTS\20145676_-_Stage_3-4_Capping\Concept\Design\013-Stage3-4_Capping\Detailed\Design\02_PRODUCTION\DWGS\ | File Name: 20145676-013-009.dwg | Last Edited By: arcadden Date: 2021-09-06 Time:12:01:03 PM | Printed By: ArCadden Date: 2021-09-06 Time:12:07:31 PM



SCALE 1:1,000 M A 003 NORTH SOUTH ALIGNMENT



SCALE 1:1,000 M B 003 NORTH SOUTH ALIGNMENT



SCALE 1:1,500 m C 003 WEST EAST ALIGNMENT

NOTE(S)

1. AS BUILT SURVEY DATA PROVIDED BY CITY OF DARWIN.
   - STAGE 3 - FILE NAME: 5209 2012-02-10 (MGA94).dwg
   - STAGE 4 - FILE NAME: 2981410 (Rainflap Survey).dwg
   - **NOTE:** AS BUILT ELEVATION DATA HAS BEEN LOWER 0.6 m UNIFORMLY TO ACCOMMODATE CHANGE FROM LOCAL SITE DATUM TO AHD. POTHOLING OF EXISTING CELLS REQUIRED TO CONFIRM AS BUILT LINER / ANCHOR TRENCH LOCATION/ELEVATION
2. THE CONTRACTOR SHALL UNDERTAKE A SURVEY OF THE EXISTING WASTE LANDFORM AND PROVIDE A REVISED WASTE PROFILE TO THE DESIGNER FOR APPROVAL PRIOR TO COMMENCEMENT OF THE WORKS. REFER TO TECHNICAL SPECIFICATION FOR DETAILS

ISSUED FOR

CONSTRUCTION

0 25 50
1:1,000 METRES

0 25 50
1:1,500 METRES

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2	2021-03-30	ISSUED FOR TENDER	SW	BGK	FWG	JSB	
1	2020-12-22	ISSUED FOR TENDER	SW	SMW	FWG	JSB	
0	2020-12-10	ISSUE FOR CLIENT REVIEW	SW	SMW	FWG	JSB	

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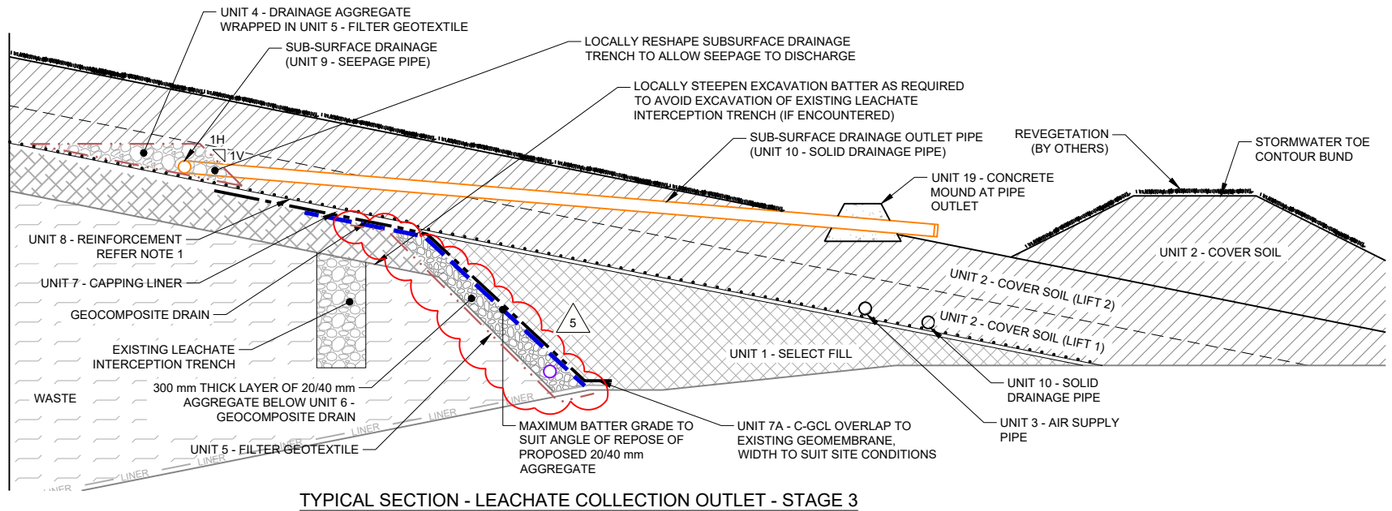
PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

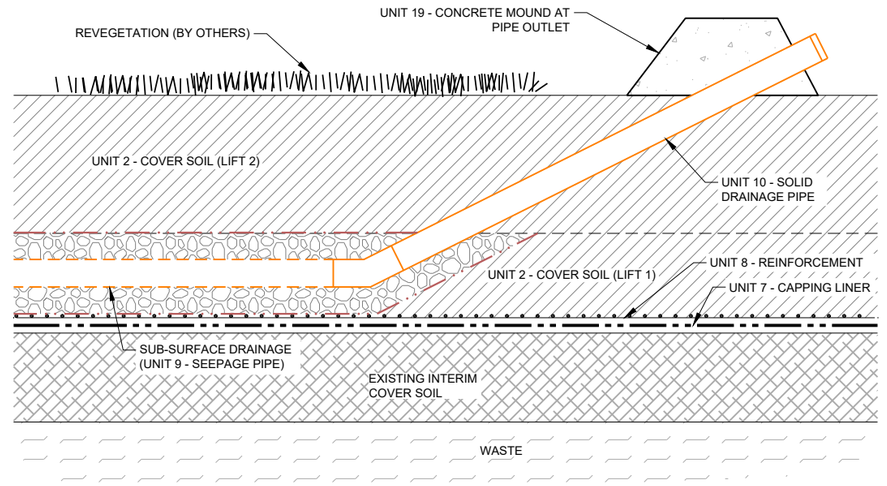
TITLE
LANDFILL SITE SECTIONS

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	10 of 20	010



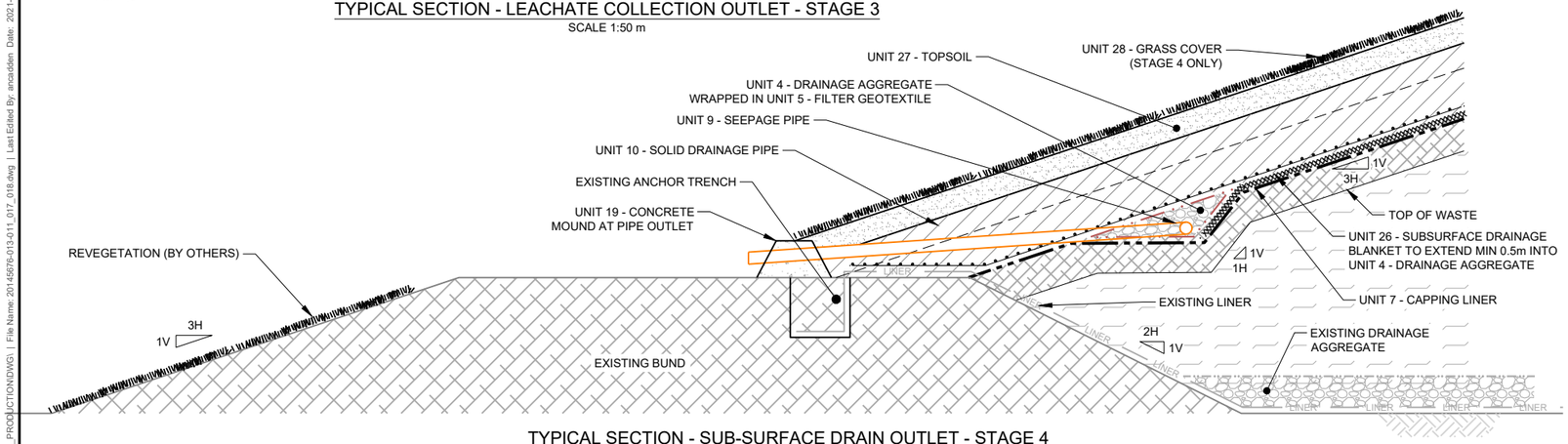
TYPICAL SECTION - LEACHATE COLLECTION OUTLET - STAGE 3

SCALE 1:50 m



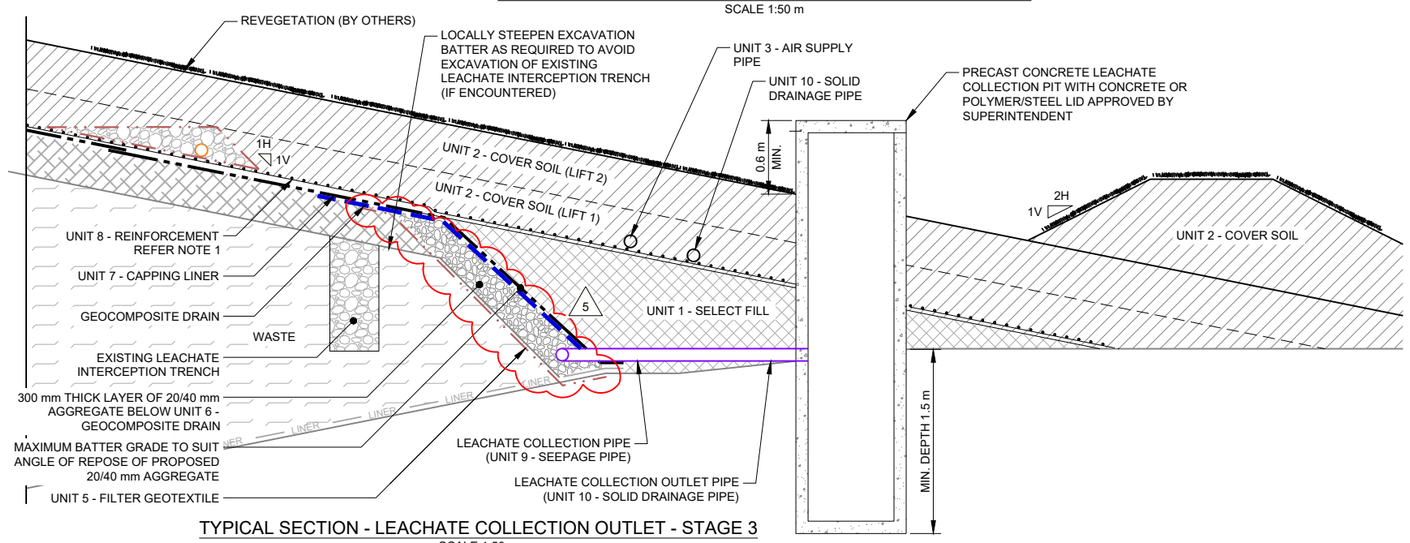
TYPICAL DETAIL - SUB-SURFACE DRAIN FLUSH POINT

SCALE 1:20 m



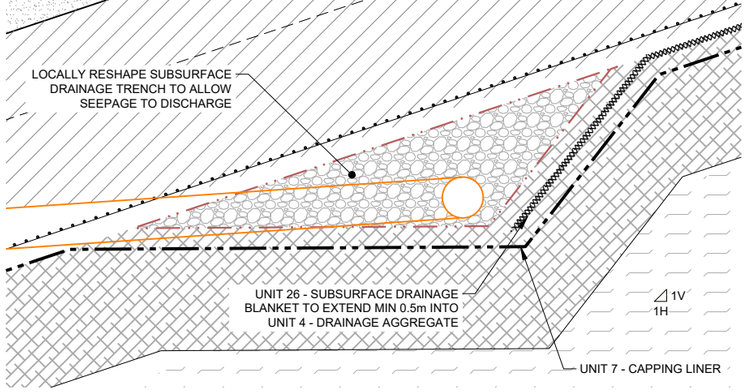
TYPICAL SECTION - SUB-SURFACE DRAIN OUTLET - STAGE 4

SCALE 1:50 m



TYPICAL SECTION - LEACHATE COLLECTION OUTLET - STAGE 3

SCALE 1:50 m



TYPICAL DETAIL - SUB-SURFACE DRAIN COLLECTION TRENCH - STAGE 4 TOE

SCALE 1:15 m

ISSUED FOR

CONSTRUCTION

0 1 2
1:50 METRES

0 0.5 1
1:20 METRES

0 0.25 0.5
1:15 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
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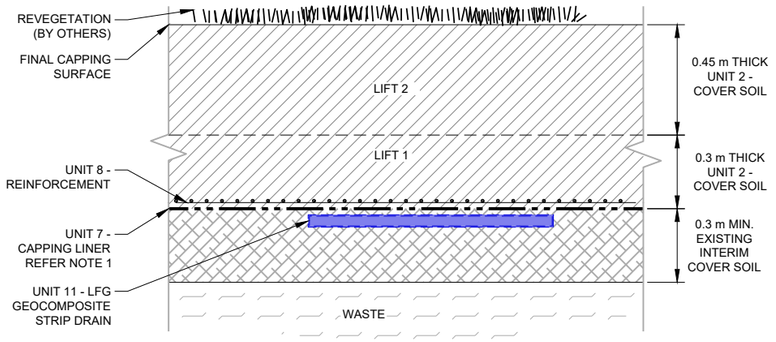
PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

TITLE
SUB-SURFACE WATER MANAGEMENT - SECTIONS AND DETAILS

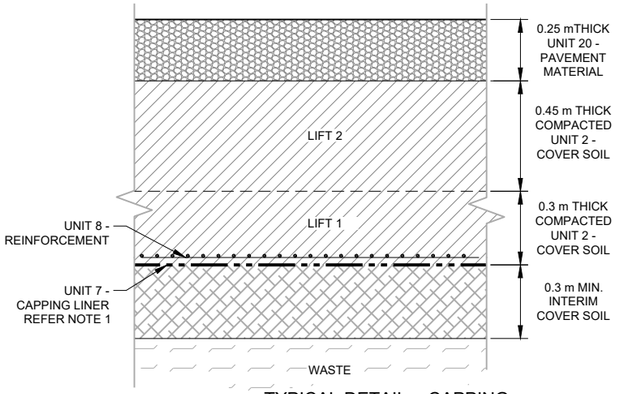
PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	11 of 20	011

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

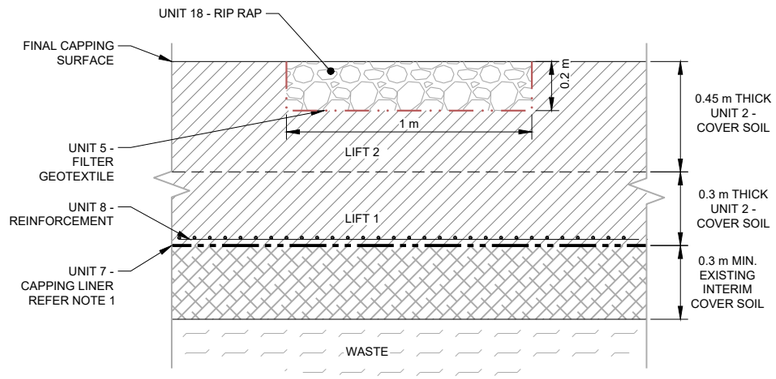
25 mm 0



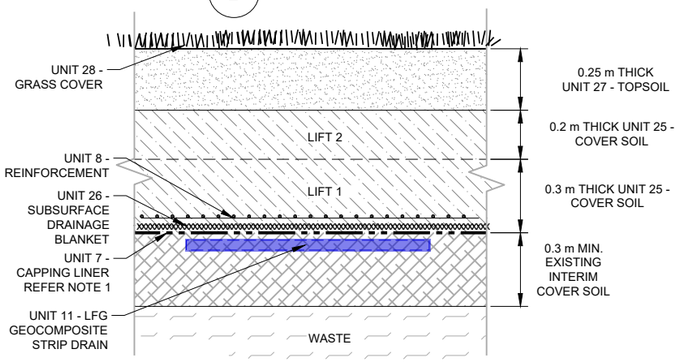
SCALE 1:25 m (1) TYPICAL DETAIL - CAPPING PROFILE TYPE A



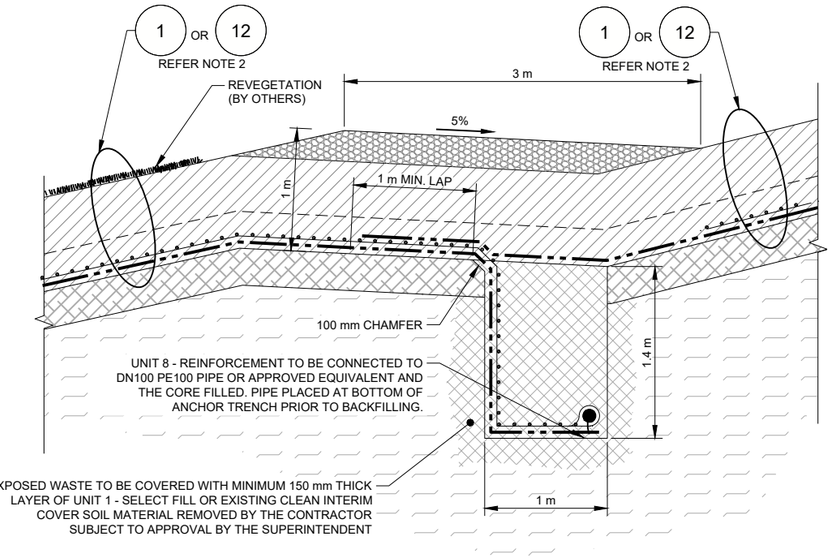
SCALE 1:25 m (2) TYPICAL DETAIL - CAPPING PROFILE ON BENCHES AND RAMP



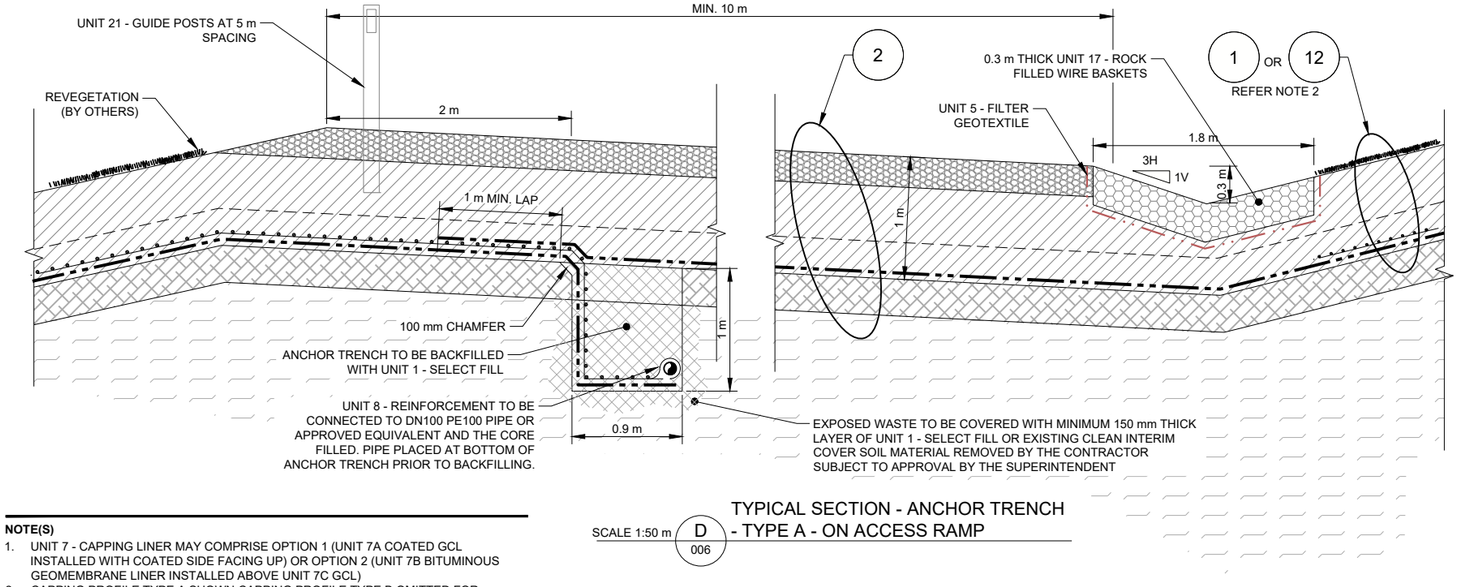
SCALE 1:25 m (3) TYPICAL DETAIL - CAPPING PROFILE UNDER IRRIGATION SYSTEM WHEEL TRACK



SCALE 1:25 m (12) TYPICAL DETAIL - CAPPING PROFILE TYPE B (STAGE 4 NORTHERN AND WESTERN BATTER)



SCALE 1:50 m (E 006) TYPICAL SECTION - ANCHOR TRENCH - TYPE B AND C - ON BENCH



SCALE 1:50 m (D 006) TYPICAL SECTION - ANCHOR TRENCH - TYPE A - ON ACCESS RAMP

NOTE(S)

1. UNIT 7 - CAPPING LINER MAY COMPRISE OPTION 1 (UNIT 7A COATED GCL INSTALLED WITH COATED SIDE FACING UP) OR OPTION 2 (UNIT 7B BITUMINOUS GEOMEMBRANE LINER INSTALLED ABOVE UNIT 7C GCL)
2. CAPPING PROFILE TYPE A SHOWN CAPPING PROFILE TYPE B OMITTED FOR CLARITY. REFER DRAWING 005 FOR LOCATIONS/EXTENTS OF CAPPING PROFILES

ISSUED FOR

CONSTRUCTION

0 0.5 1
1:25 METRES

0 1 2
1:50 METRES

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3	2021-06-11	ISSUED FOR CONSTRUCTION	BGK	BGK	SW	FWG	JSB
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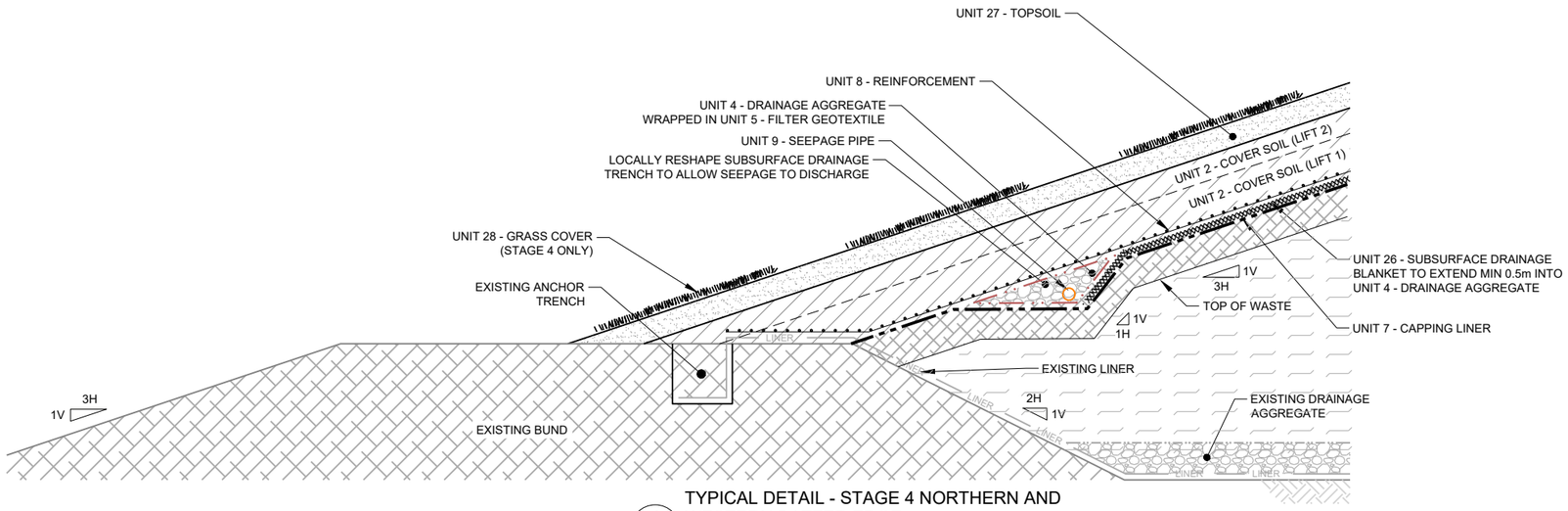
PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

TITLE
ANCHOR TRENCH AND LINER CONNECTION SECTIONS AND DETAILS - (SHEET 1 OF 2)

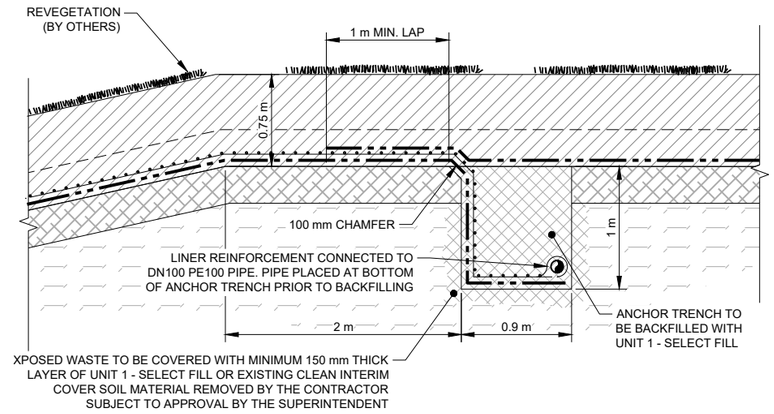
PROJECT NO.	CONTROL	REV.	12 of 20	DRAWING
20145676	013	5		012

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0



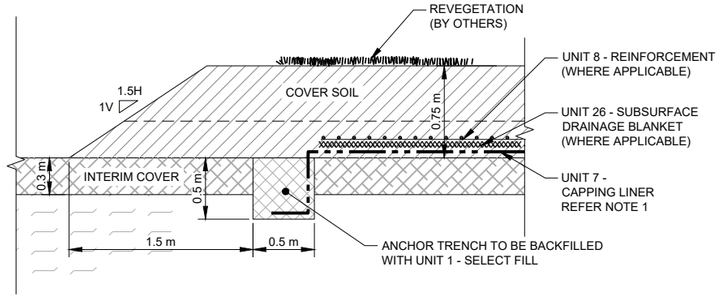
TYPICAL DETAIL - STAGE 4 NORTHERN AND WESTERN BATTER EDGE

SCALE 1:50 m — 4 / 012



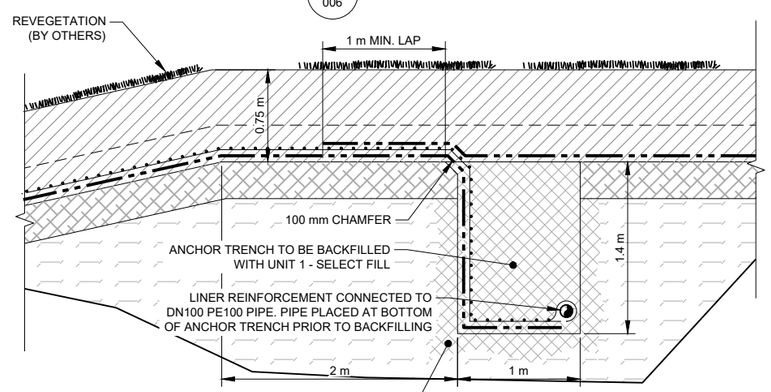
TYPICAL SECTION - ANCHOR TRENCH - TYPE A - AT CREST

SCALE 1:50 m — G / 006



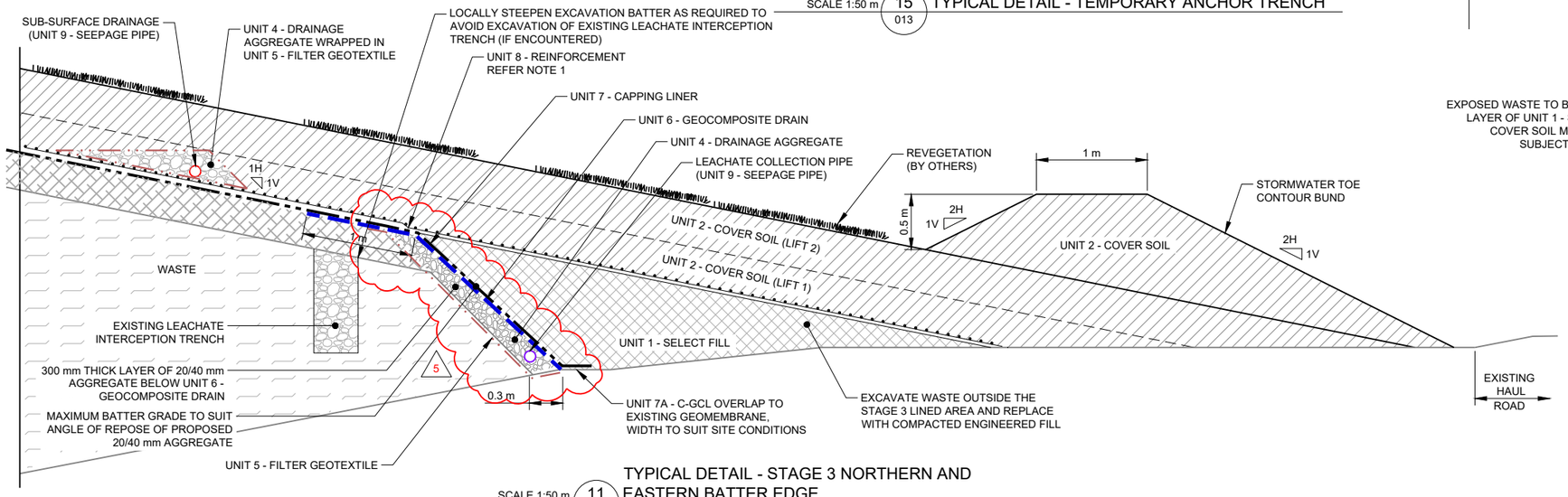
TYPICAL DETAIL - TEMPORARY ANCHOR TRENCH

SCALE 1:50 m — 15 / 013



TYPICAL SECTION - ANCHOR TRENCH - TYPE B AND C - AT CREST

SCALE 1:50 m — H / 006



TYPICAL DETAIL - STAGE 3 NORTHERN AND EASTERN BATTER EDGE

SCALE 1:50 m — 11 / 012

ISSUED FOR

CONSTRUCTION

0 1 2

1:50 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
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1	2020-12-22	ISSUED FOR TENDER	SW	SMW	FWG	JSB	
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PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

TITLE
ANCHOR TRENCH AND LINER CONNECTION SECTIONS AND DETAILS - (SHEET 2 OF 2)

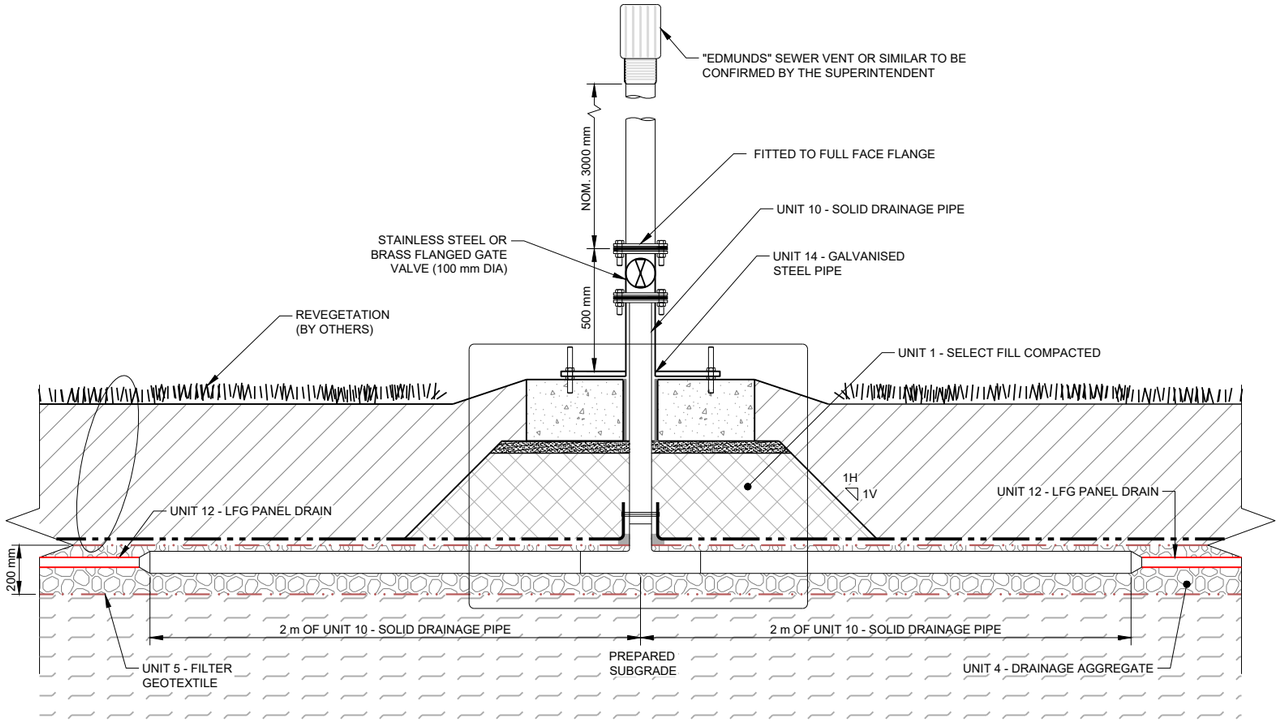
PROJECT NO.	CONTROL	REV.	13 of 20	DRAWING
20145676	013	5		013

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

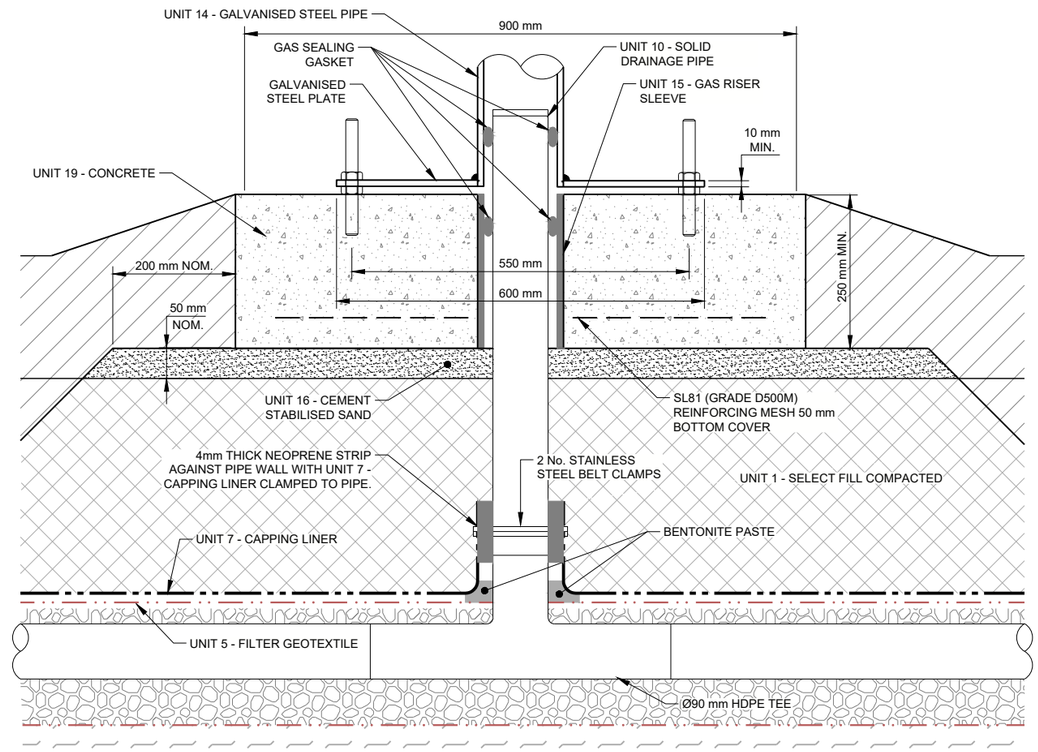
25 mm

0

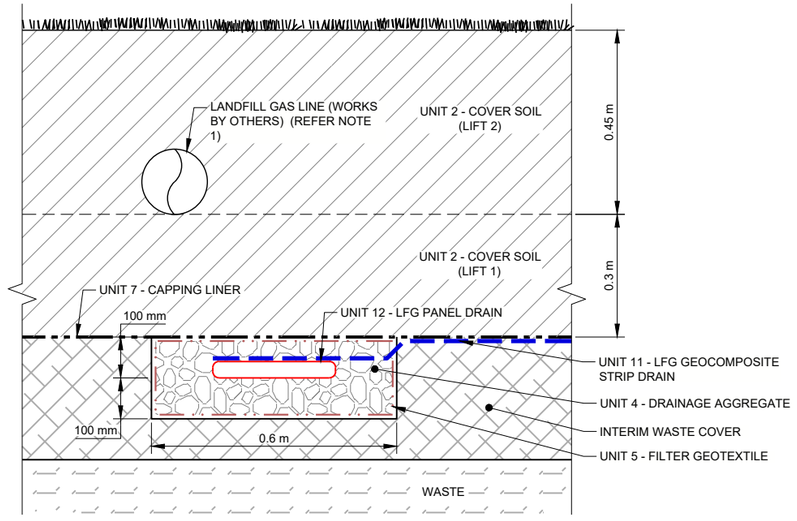
Path: \\golder.gds\gen\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\98_PROJECTS\20145676 - Stage 3-4 Capping\Concept\Design\013-Stage3-4_Capping\Detailed\Design\02_PRODUCTION\DWGS\ | File Name: 20145676-013-012_013.dwg | Last Edited By: anodden Date: 2021-09-06 Time:12:03:03 PM | Printed By: AnCadden Date: 2021-09-06 Time:12:08:35 PM



SCALE 1:25 m (9 / 014) TYPICAL DETAIL - GAS RISER PENETRATION AND UNIT 24 - PASSIVE GAS VENT



SCALE 1:10 m (10) TYPICAL DETAIL - GAS RISER PENETRATION DETAIL



TYPICAL DETAIL - PASSIVE GAS PANEL DRAIN
SCALE 1:15 m

NOTE(S)

1. EXISTING LANDFILL GAS LINES TO BE DECOMMISSIONED (WORKS BY OTHERS) AND REINSTALLED (BY OTHERS) AFTER PLACEMENT OF UNIT 2 - COVER SOIL (LIFT 1).

ISSUED FOR
CONSTRUCTION

0 0.25 0.5
1:15 METRES

0 0.25 0.5
1:10 METRES

0 0.5 1
1:25 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
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0	2020-12-10	ISSUE FOR CLIENT REVIEW	SW	SMW	FWG	JSB	

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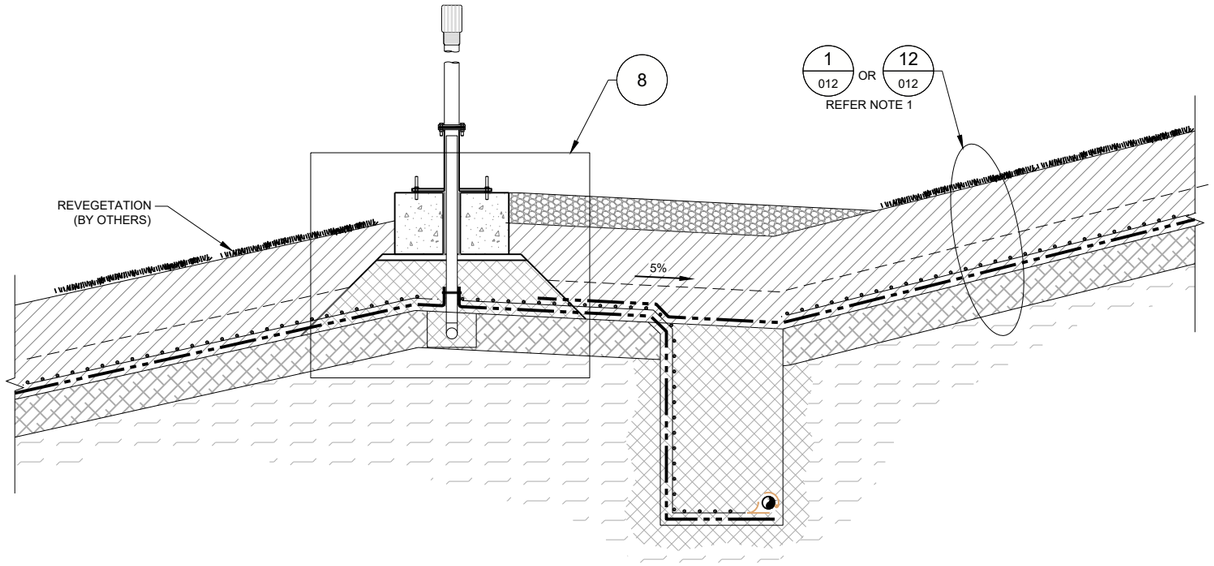
PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

TITLE
PASSIVE GAS SECTIONS AND DETAIL - SHEET 1 OF 2

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	14 of 20	014

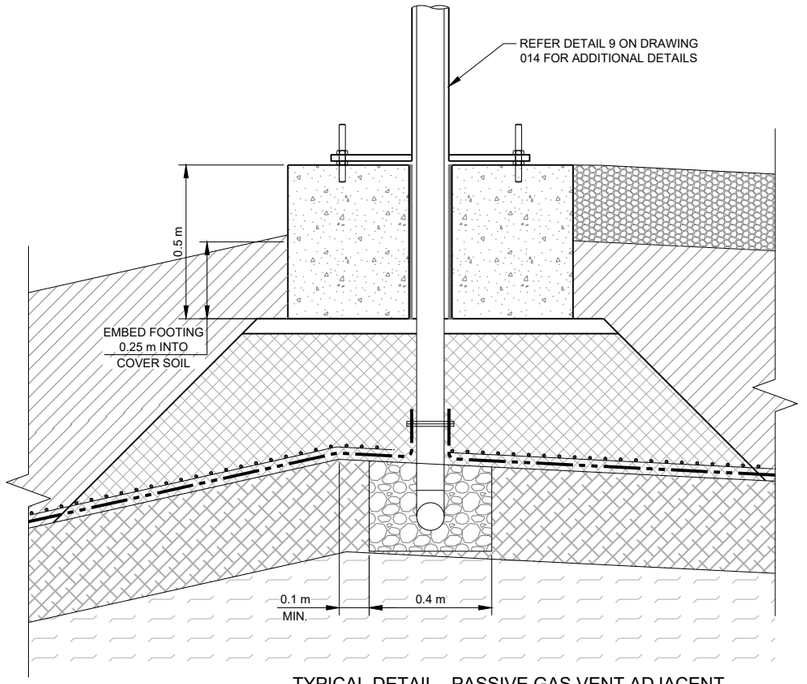
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0



TYPICAL SECTION - UNIT 24 - PASSIVE GAS VENT ADJACENT TO MID-SLOPE BENCH

SCALE 1:50 m

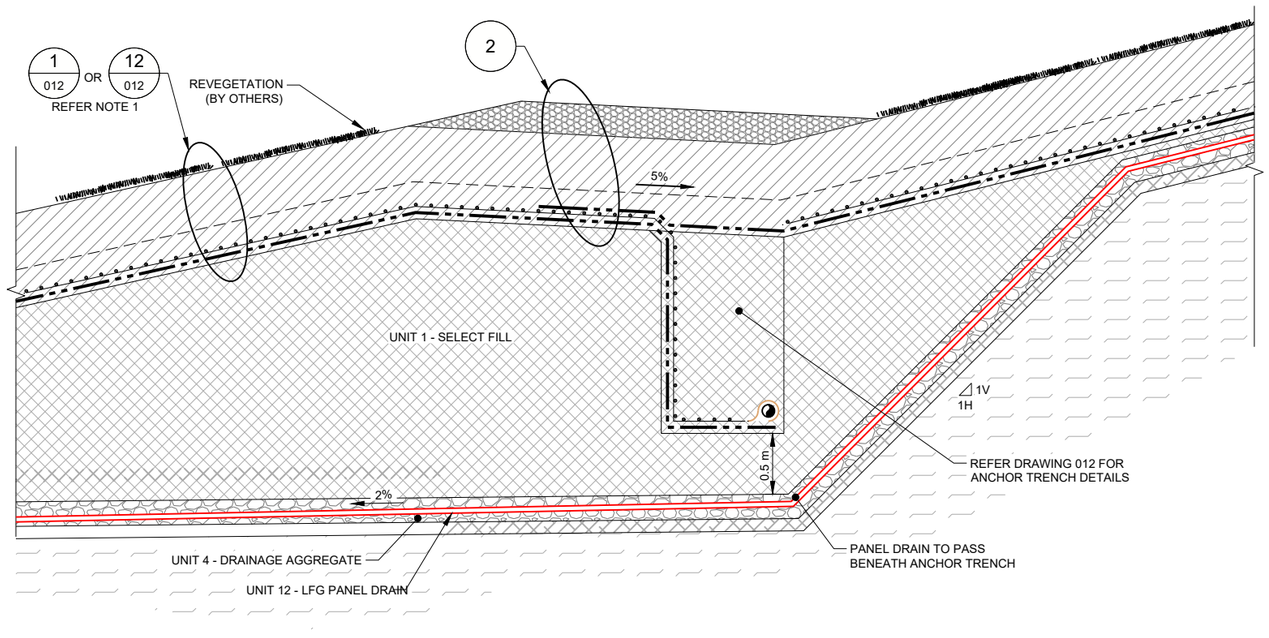
O
015



TYPICAL DETAIL - PASSIVE GAS VENT ADJACENT TO MID-SLOPE BENCH

SCALE 1:20 m

8



TYPICAL SECTION - PANEL DRAIN CROSSING AT ANCHOR TRENCH

SCALE 1:50 m

NOTE(S)

1. CAPPING PROFILE TYPE A SHOWN CAPPING PROFILE TYPE B OMITTED FOR CLARITY. REFER DRAWING 005 FOR LOCATIONS/EXTENTS OF CAPPING PROFILES.

ISSUED FOR

CONSTRUCTION

0 0.5 1
1:20 METRES

0 1 2
1:50 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
5	2021-09-06	RE-ISSUE	SW	ADGC	JSB	JSB	
4	2021-08-25	ISSUED FOR CONSTRUCTION	SW	BGK	JSB	JSB	
3	2021-06-11	ISSUED FOR CONSTRUCTION	BGK	BGK	SW	FWG	JSB
2	2021-03-30	ISSUED FOR TENDER	SW	BGK	FWG	JSB	
1	2020-12-22	ISSUED FOR TENDER	SW	SMW	FWG	JSB	
0	2020-12-10	ISSUE FOR CLIENT REVIEW	SW	SMW	FWG	JSB	

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PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

TITLE
PASSIVE GAS SECTIONS AND DETAIL - SHEET 2 OF 2

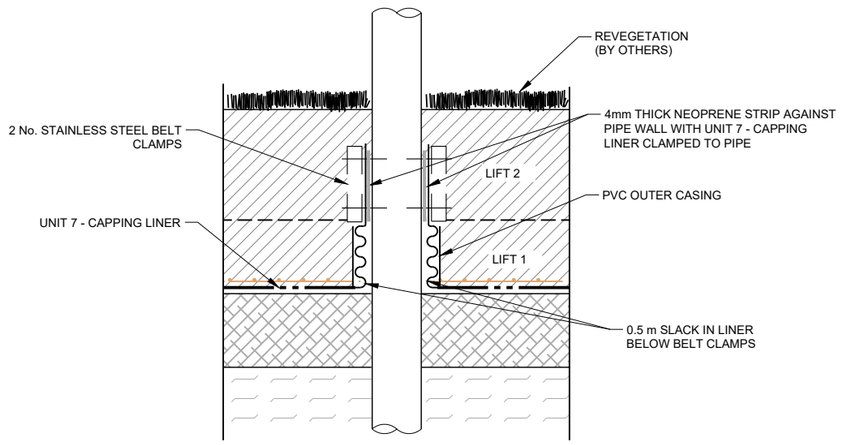
PROJECT NO.	CONTROL	REV.	DRAWING
20145676	013	5	015

15 of 20

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

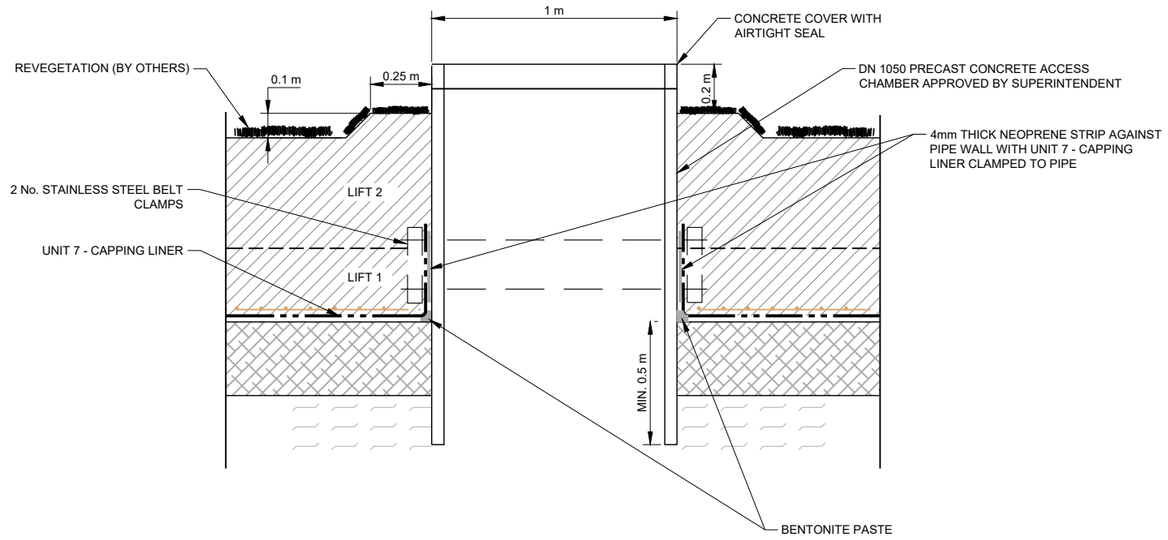
25 mm

0



TYPICAL DETAIL - PENETRATION FOR EXISTING GAS WELLS AND LEACHATE SUMPS

SCALE 1:25 m



TYPICAL DETAIL - PENETRATION FOR FUTURE GAS WELL INSTALLATION

SCALE 1:25 m

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
5	2021-09-06	RE-ISSUE	SW	ADGC	JSB	JSB	
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3	2021-06-11	ISSUED FOR CONSTRUCTION	BGK	BGK	SW	FWG	JSB
2	2021-03-30	ISSUED FOR TENDER	SW	BGK	FWG	JSB	
1	2020-12-22	ISSUED FOR TENDER	SW	SMW	FWG	JSB	
0	2020-12-10	ISSUE FOR CLIENT REVIEW	SW	SMW	FWG	JSB	

ISSUED FOR

CONSTRUCTION

0 0.5 1

1:25 METRES

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PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

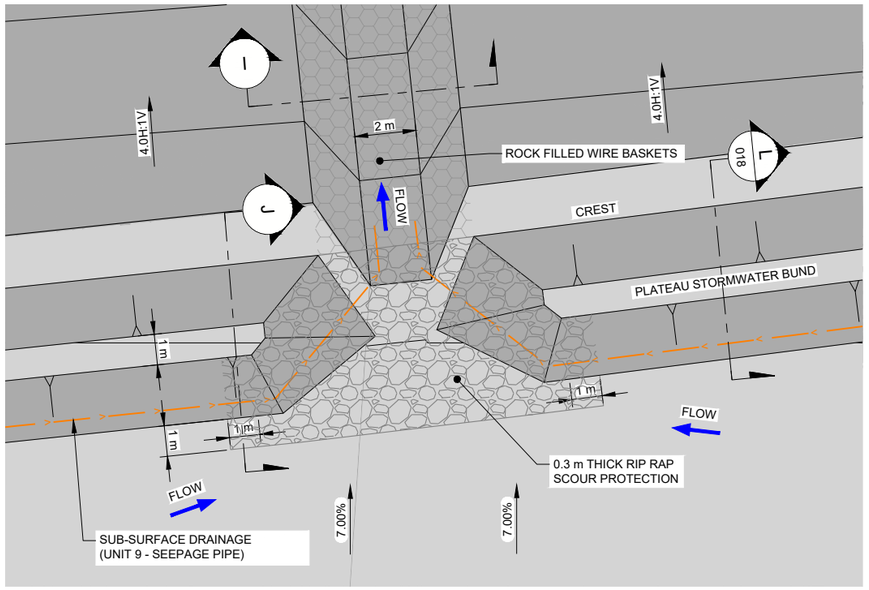
TITLE
CAPPING SYSTEM PENETRATION DETAILS

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	16 of 20	016

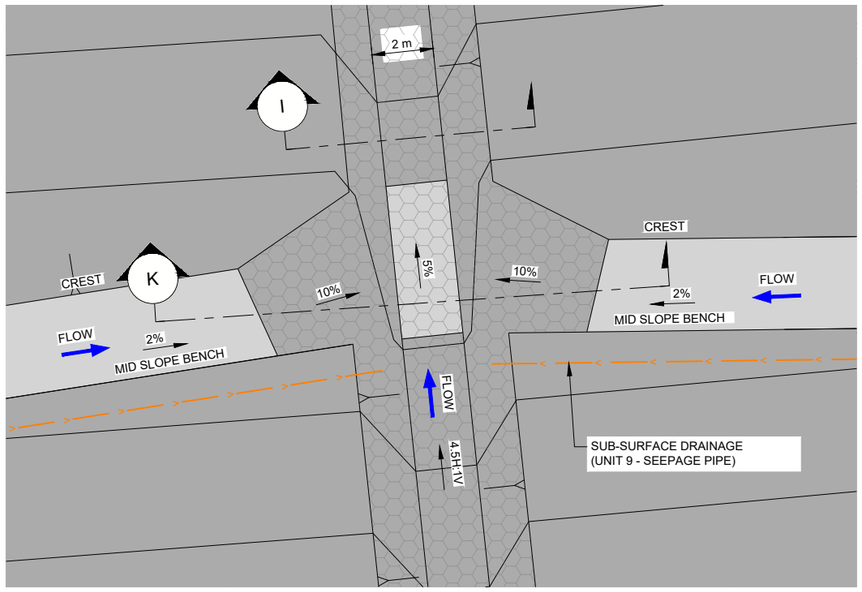
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

25 mm

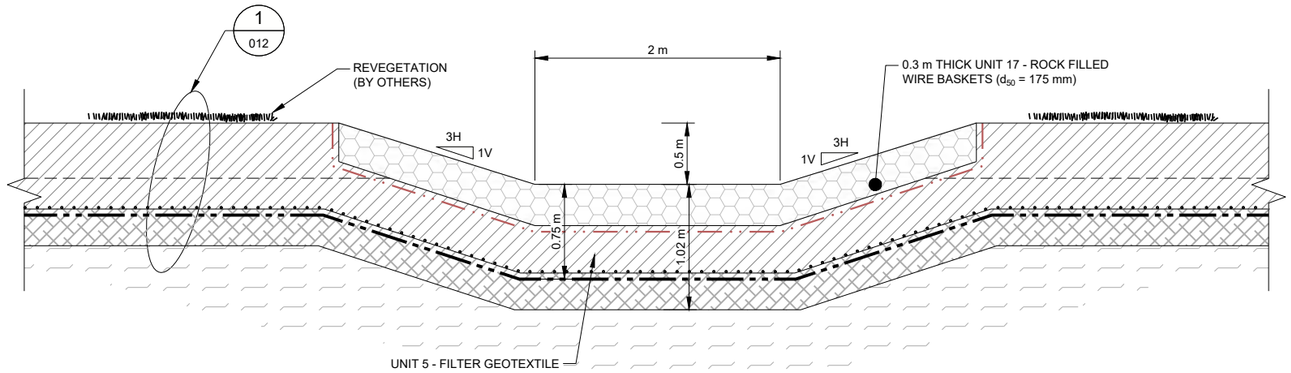
0



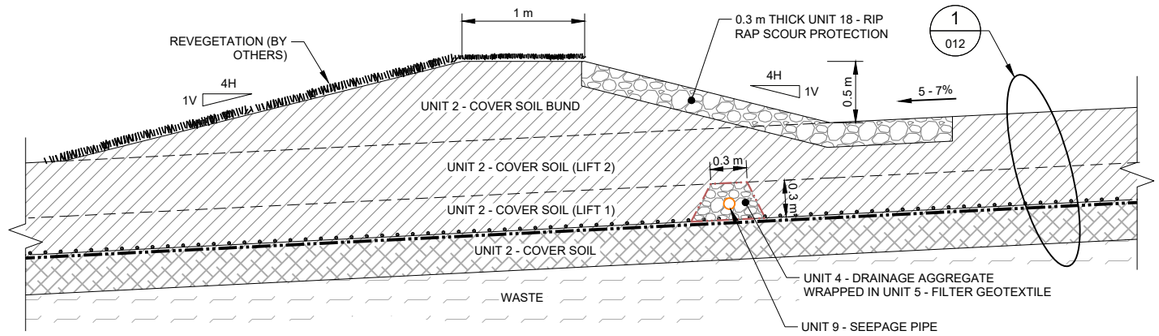
SCALE 1:200 m 5/009 TYPICAL DETAIL - DIVERSION BUND AND CHUTE INTERFACE ON PLATEAU



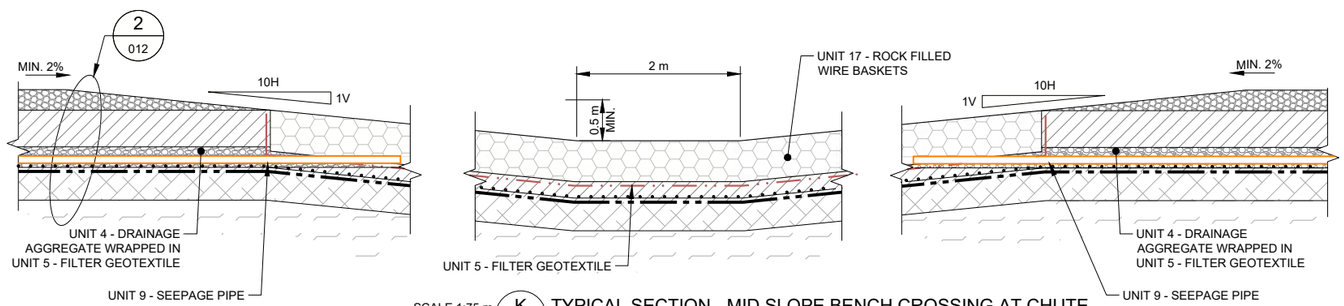
SCALE 1:200 m 6/009 TYPICAL DETAIL - MID SLOPE BENCH AND CHUTE INTERFACE



SCALE 1:50 m I/017 TYPICAL SECTION - STORMWATER CHUTE



SCALE 1:50 m J TYPICAL SECTION - PLATEAU STORMWATER BUND AT CHUTE INTERFACE



SCALE 1:75 m K/017 TYPICAL SECTION - MID SLOPE BENCH CROSSING AT CHUTE

ISSUED FOR

CONSTRUCTION

0 5 10
1:200 METRES

0 1.25 2.5
1:75 METRES

0 1 2
1:50 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
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2	2021-03-30	ISSUED FOR TENDER	SW	BGK	FWG	JSB	
1	2020-12-22	ISSUED FOR TENDER	SW	SMW	FWG	JSB	
0	2020-12-10	ISSUE FOR CLIENT REVIEW	SW	SMW	FWG	JSB	

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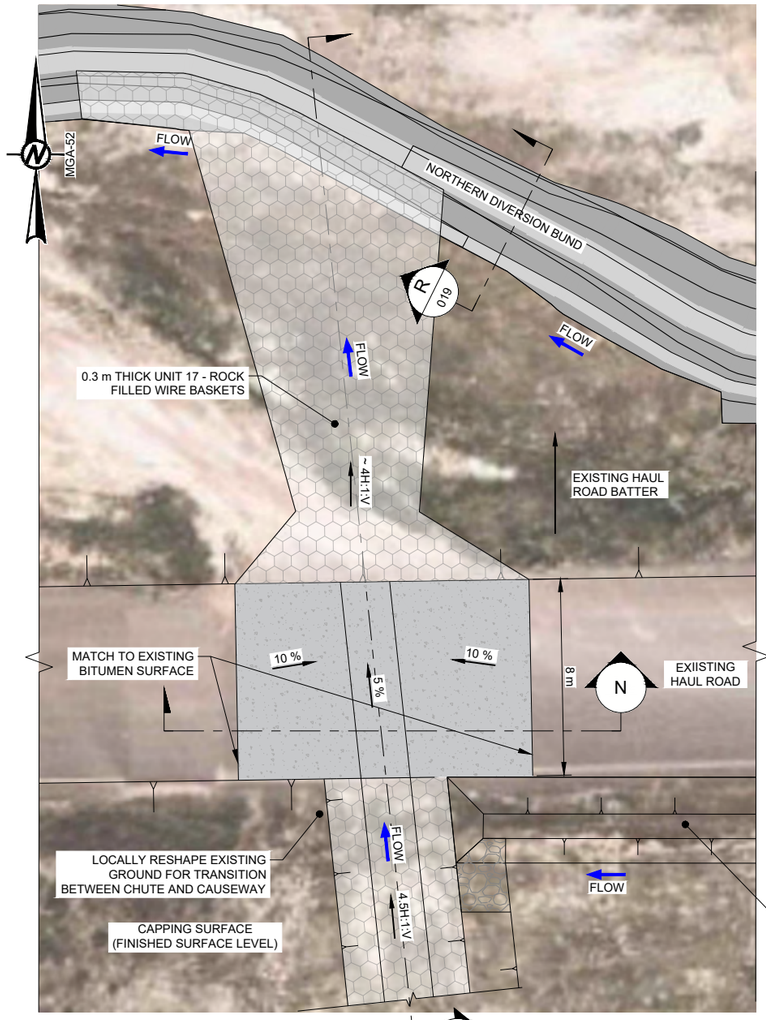
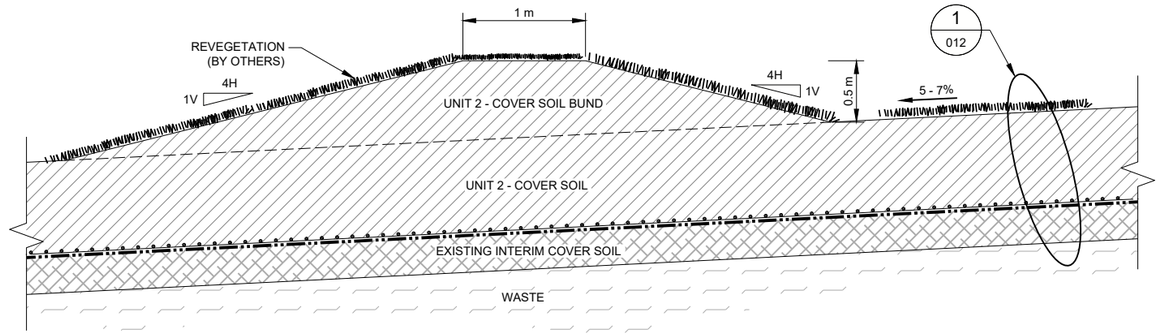
PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

TITLE
STORMWATER CHUTE INLET - SECTIONS AND DETAILS

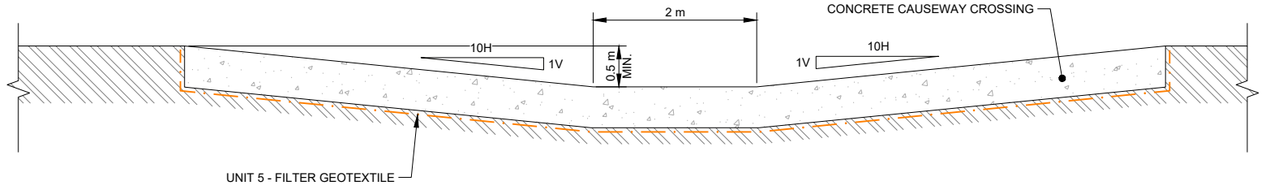
PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	17 of 20	017



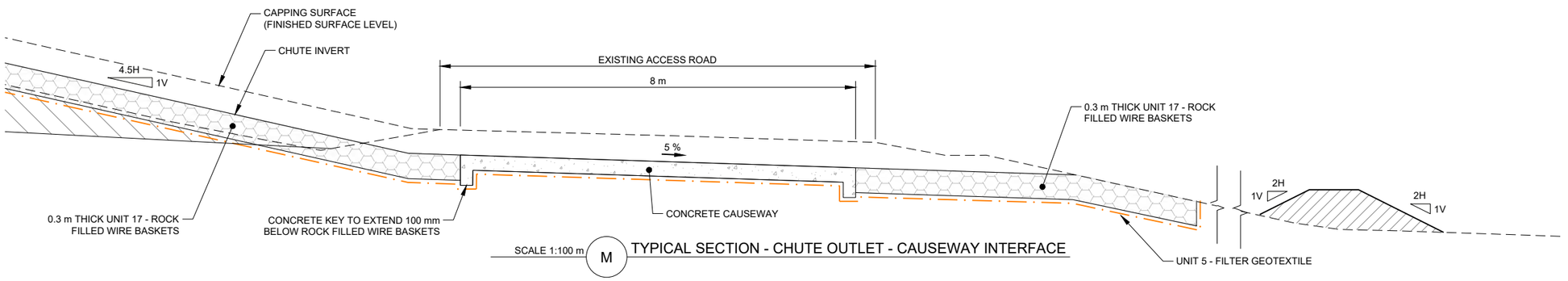
SCALE 1:250 m — 7 / 018 — CAUSEWAY LAYOUT PLAN



SCALE H_SCALE — L / 009 — TYPICAL SECTION - PLATEAU STORMWATER BUND



SCALE 1:75 m — N — TYPICAL SECTION - HAUL ROAD CAUSEWAY



SCALE 1:100 m — M — TYPICAL SECTION - CHUTE OUTLET - CAUSEWAY INTERFACE

ISSUED FOR

CONSTRUCTION

0 1.25 2.5
1:75 METRES

0 2.5 5
1:100 METRES

0 5 10
1:250 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
5	2021-09-06	RE-ISSUE	SW	ADGC	JSB	JSB	
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3	2021-06-11	ISSUED FOR CONSTRUCTION	BGK	BGK	SW	FWG	JSB
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0	2020-12-10	ISSUE FOR CLIENT REVIEW	SW	SMW	FWG	JSB	

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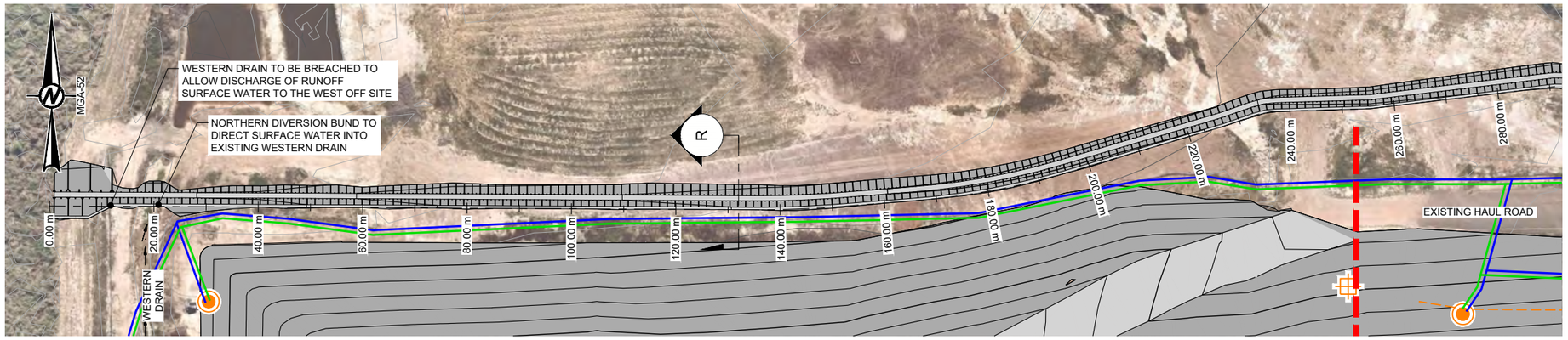
PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

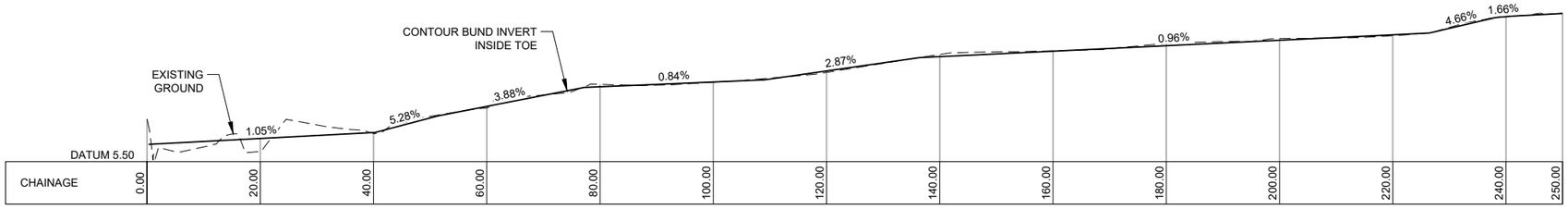
TITLE
STORMWATER CHUTE OUTLET - SECTIONS AND DETAILS

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	18 of 20	018



LAYOUT PLAN - NORTHERN DIVERSION BUND - CH 0 - CH 250

SCALE 1:1,000 m

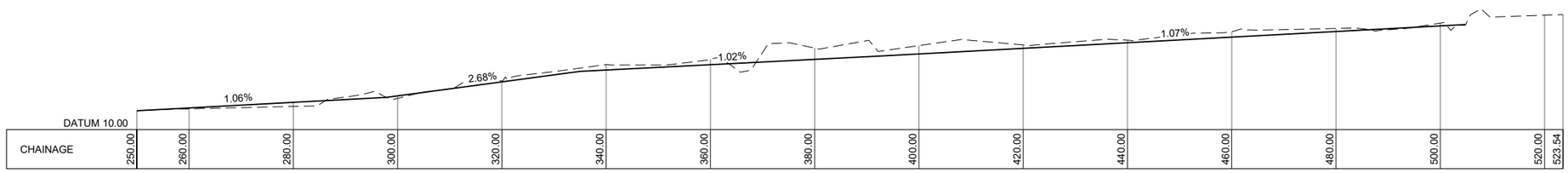


LONGITUDINAL SECTION - NORTHERN DIVERSION BUND - CH 0 - CH 250

SCALE 1:1,000 m

LAYOUT PLAN - NORTHERN DIVERSION BUND - CH 250 - CH 523

SCALE 1:1,000 m

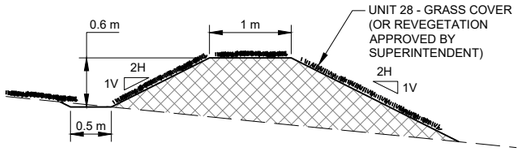


LONGITUDINAL SECTION - NORTHERN DIVERSION BUND - CH 250 - CH 523

SCALE 1:1,000 m

LEGEND

- EXISTING GROUND CONTOURS (1 m INTERVALS)
- DESIGN CONTOURS (1 m INTERVALS)
- TEST PIT LOCATION
- EXISTING LEACHATE SUMP



TYPICAL SECTION - NORTHERN DIVERSION BUND

SCALE 1:75 m

R

ISSUED FOR

CONSTRUCTION

0 1.25 2.5

1:75 METRES

0 25 50

1:1,000 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
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0	2020-12-10	ISSUE FOR CLIENT REVIEW	SW	SMW	FWG	JSB	

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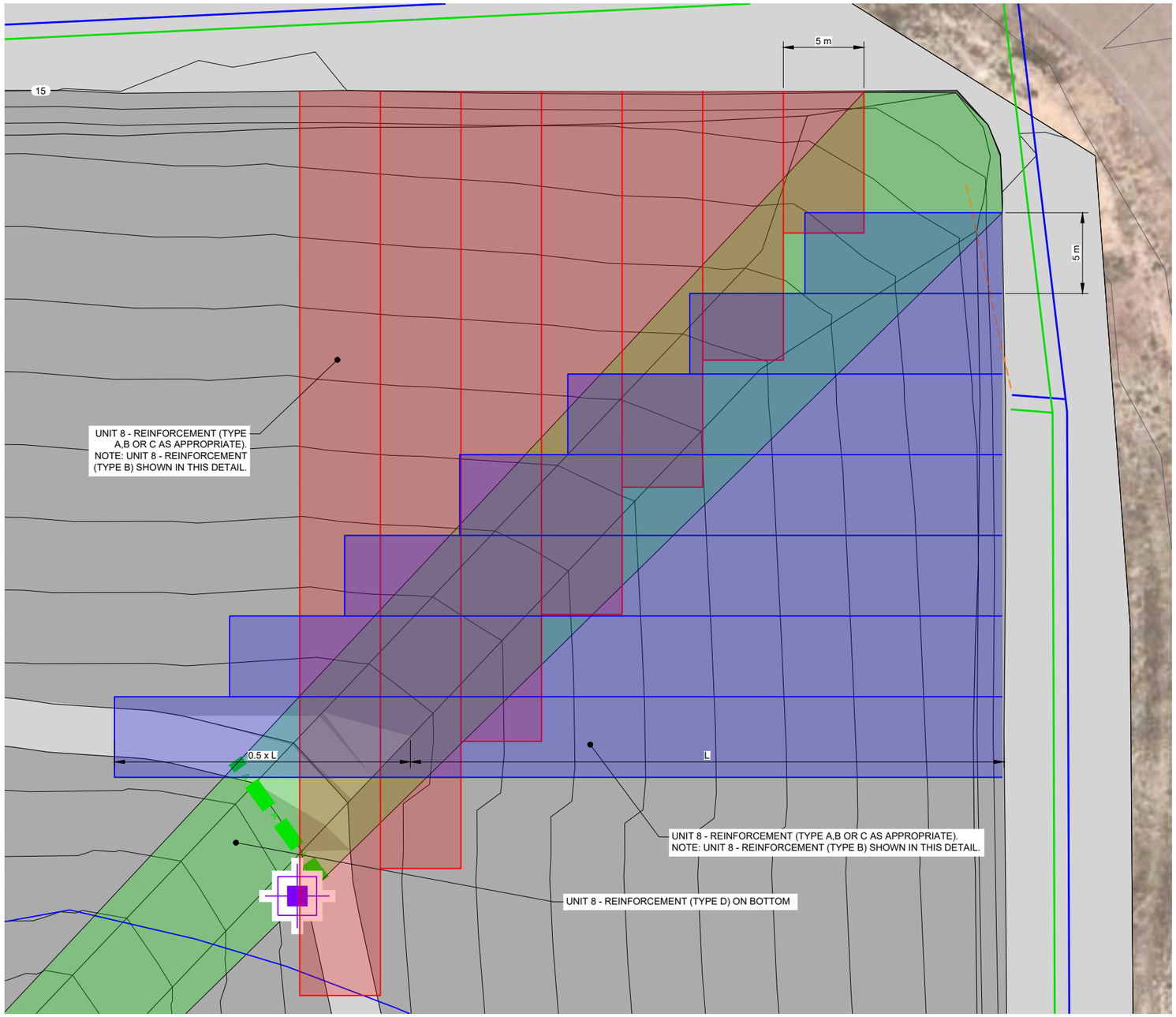
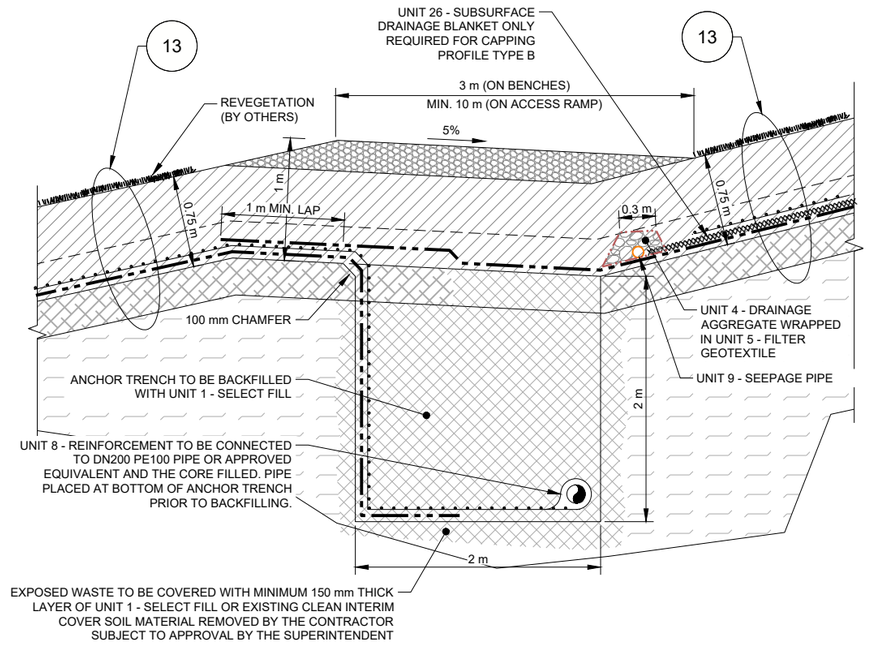
PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

TITLE
NORTHERN DIVERSION BUND - LAYOUT PLAN AND LONGITUDINAL SECTION

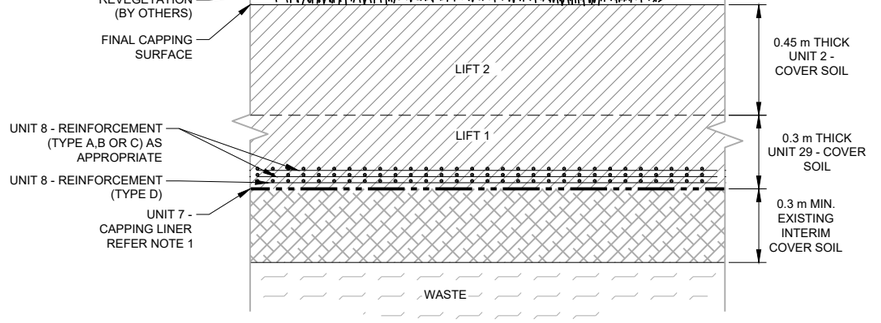
PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	19 of 20	019



SCALE 1:300 m (14 / 006) TYPICAL DETAIL - REINFORCEMENT ARRANGEMENT PLAN AT CORNER RIDGES



SCALE 1:50 M (F / 006) TYPICAL SECTION - ANCHOR TRENCH - TYPE D - ON BENCH



SCALE SCALE (13 / 020) TYPICAL DETAIL - CAPPING PROFILE IN CORNERS

NOTE(S)

1. REFER SECTION 9.2.2 OF TECHNICAL SPECIFICATION FOR SPECIAL INSTALLATION REQUIREMENTS FOR UNIT 8 - REINFORCEMENT IN CORNERS.

0 0.5 1 — 1:25 METRES

0 1 2 — 1:50 METRES

0 5 10 — 1:300 METRES

ISSUED FOR

CONSTRUCTION

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
5	2021-09-06	RE-ISSUE	SW	ADGC	JSB	JSB	
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3	2021-06-11	ISSUED FOR CONSTRUCTION	BGK	BGK	SW	FWG	JSB
2	2021-03-30	ISSUED FOR TENDER	SW	BGK	FWG	JSB	
1		NOT ISSUED					
0		NOT ISSUED					

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PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

TITLE
REINFORCEMENT AT CORNERS - TYPICAL SECTIONS AND DETAILS

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	5	20 of 20	020

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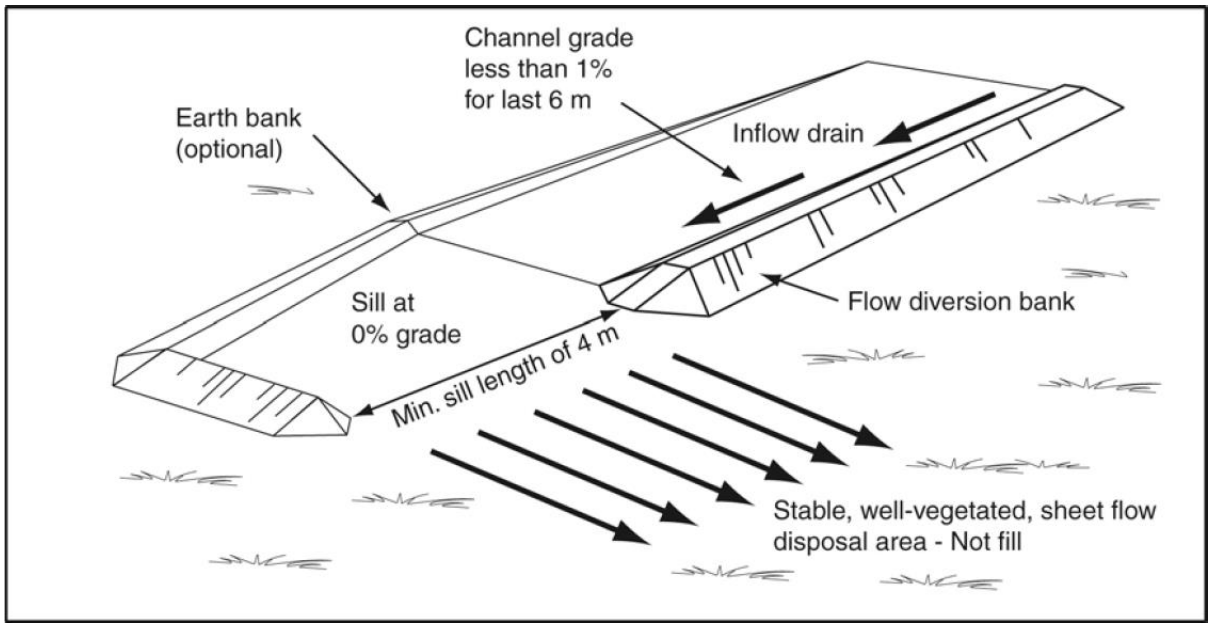
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

0 25 mm

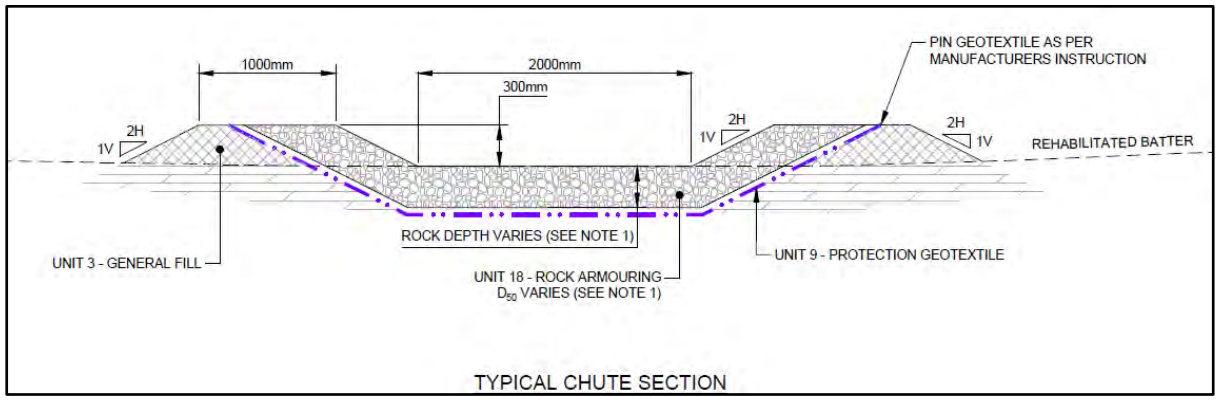
APPENDIX E

Stormwater Treatment Train Typical Infrastructure Examples

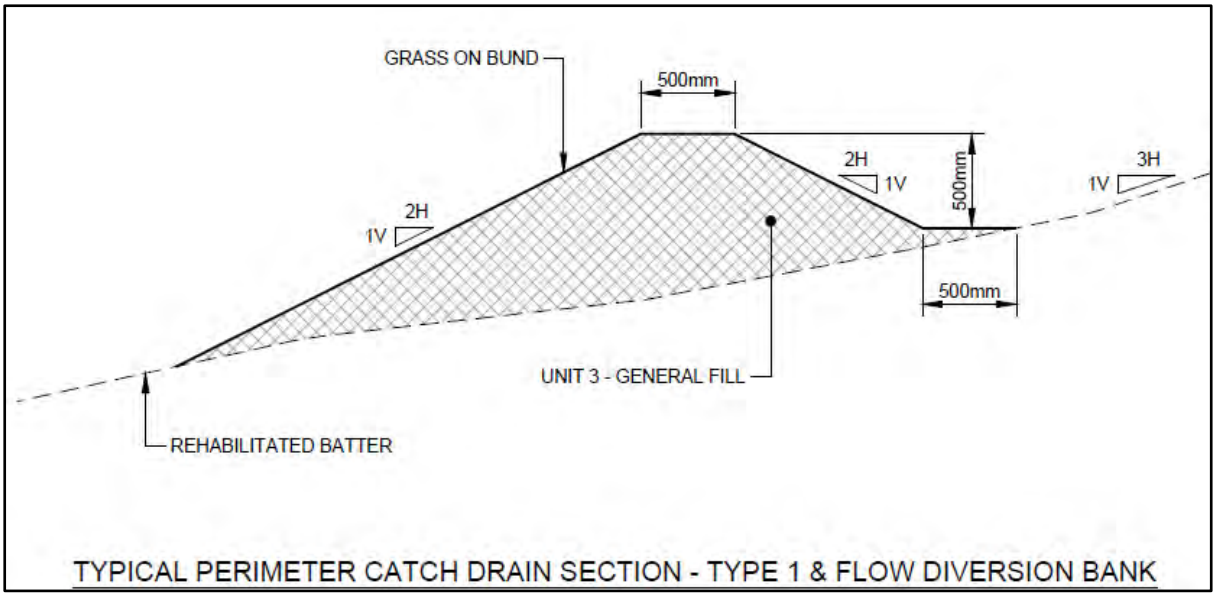
Typical Level Spreader



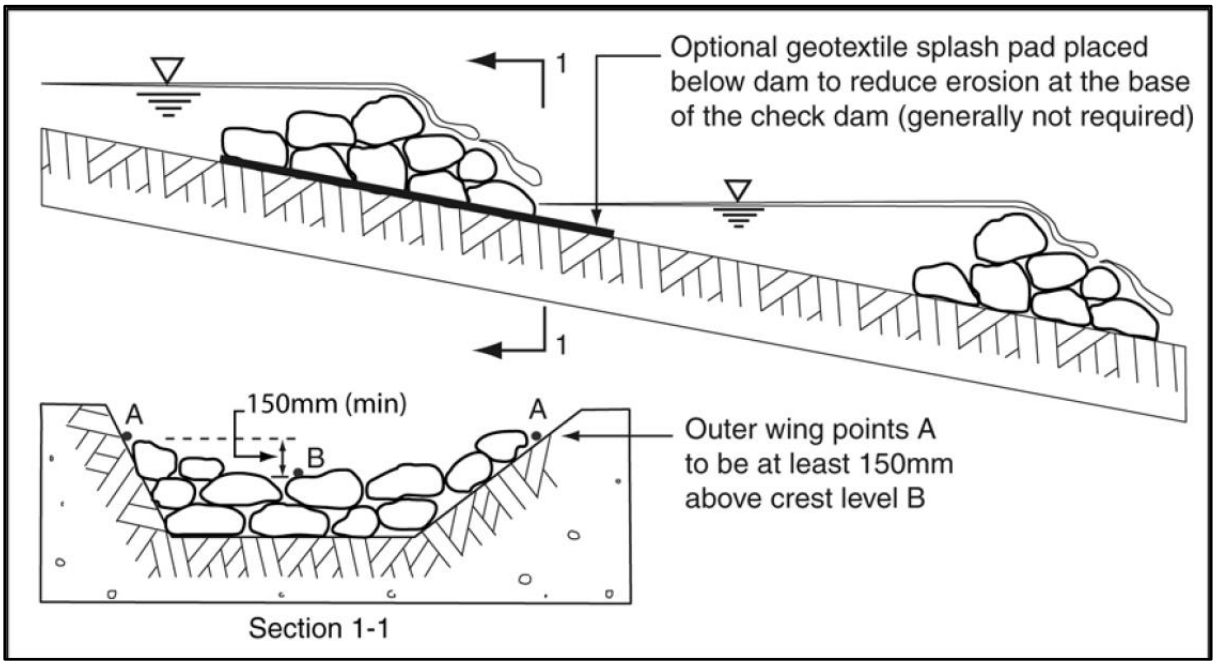
Typical Rock Chute (Bunded)



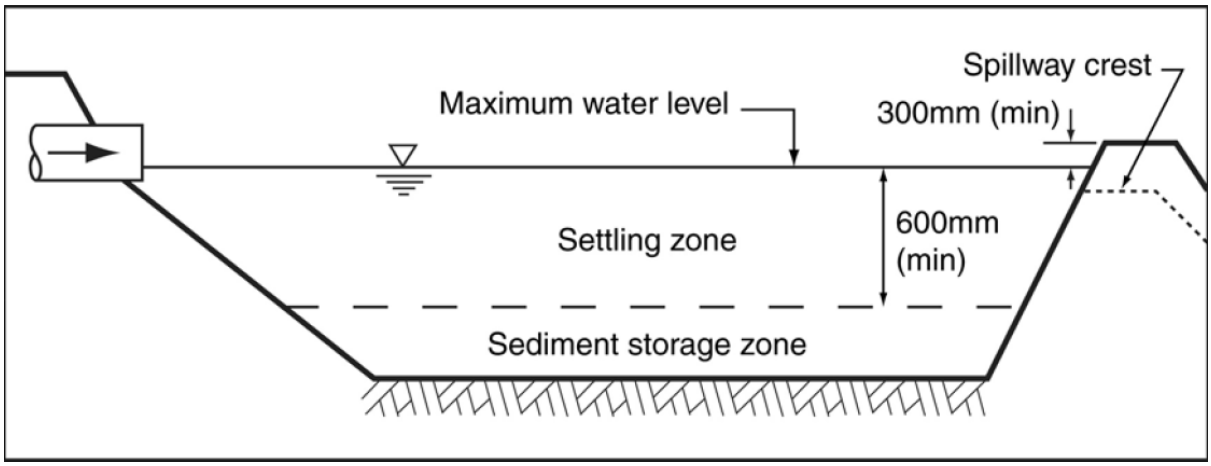
Typical Contour Bank (on batter)



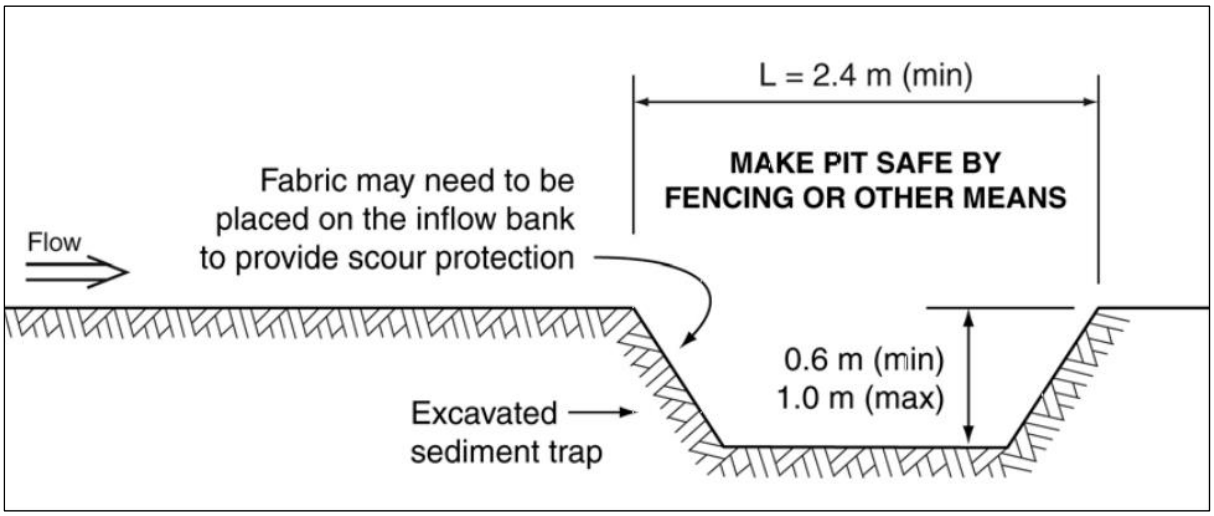
Typical Rock Check Dams



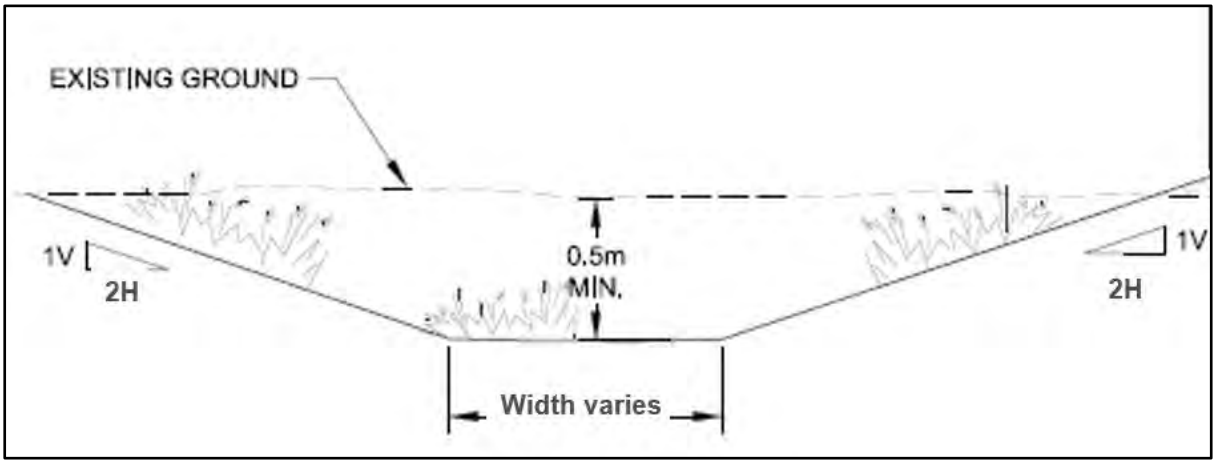
Typical Sediment Basin



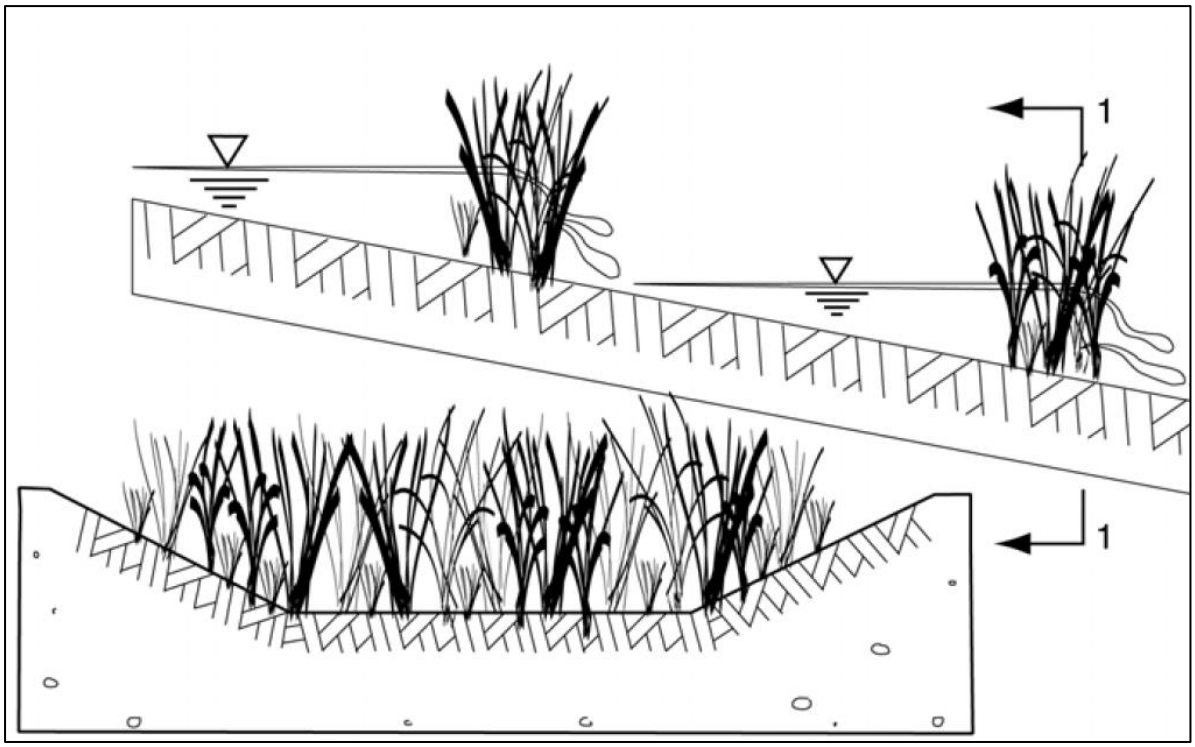
Typical Excavated Sediment Trap



Typical Catch Drain (Grassed)



Typical Stiff Grass Barrier



APPENDIX F

Important Information

The document ("Report") to which this page is attached and which this page forms a part of, has been issued by Golder Associates Pty Ltd ("Golder") subject to the important limitations and other qualifications set out below.

This Report constitutes or is part of services ("Services") provided by Golder to its client ("Client") under and subject to a contract between Golder and its Client ("Contract"). The contents of this page are not intended to and do not alter Golder's obligations (including any limits on those obligations) to its Client under the Contract.

This Report is provided for use solely by Golder's Client and persons acting on the Client's behalf, such as its professional advisers. Golder is responsible only to its Client for this Report. Golder has no responsibility to any other person who relies or makes decisions based upon this Report or who makes any other use of this Report. Golder accepts no responsibility for any loss or damage suffered by any person other than its Client as a result of any reliance upon any part of this Report, decisions made based upon this Report or any other use of it.

This Report has been prepared in the context of the circumstances and purposes referred to in, or derived from, the Contract and Golder accepts no responsibility for use of the Report, in whole or in part, in any other context or circumstance or for any other purpose.

The scope of Golder's Services and the period of time they relate to are determined by the Contract and are subject to restrictions and limitations set out in the Contract. If a service or other work is not expressly referred to in this Report, do not assume that it has been provided or performed. If a matter is not addressed in this Report, do not assume that any determination has been made by Golder in regards to it.

At any location relevant to the Services conditions may exist which were not detected by Golder, in particular due to the specific scope of the investigation Golder has been engaged to undertake. Conditions can only be verified at the exact location of any tests undertaken. Variations in conditions may occur between tested locations and there may be conditions which have not been revealed by the investigation and which have not therefore been taken into account in this Report.

Golder accepts no responsibility for and makes no representation as to the accuracy or completeness of the information provided to it by or on behalf of the Client or sourced from any third party. Golder has assumed that such information is correct unless otherwise stated and no responsibility is accepted by Golder for incomplete or inaccurate data supplied by its Client or any other person for whom Golder is not responsible. Golder has not taken account of matters that may have existed when the Report was prepared but which were only later disclosed to Golder.

Having regard to the matters referred to in the previous paragraphs on this page in particular, carrying out the Services has allowed Golder to form no more than an opinion as to the actual conditions at any relevant location. That opinion is necessarily constrained by the extent of the information collected by Golder or otherwise made available to Golder. Further, the passage of time may affect the accuracy, applicability or usefulness of the opinions, assessments or other information in this Report. This Report is based upon the information and other circumstances that existed and were known to Golder when the Services were performed and this Report was prepared. Golder has not considered the effect of any possible future developments including physical changes to any relevant location or changes to any laws or regulations relevant to such location.

Where permitted by the Contract, Golder may have retained subconsultants affiliated with Golder to provide some or all of the Services. However, it is Golder which remains solely responsible for the Services and there is no legal recourse against any of Golder's affiliated companies or the employees, officers or directors of any of them.

By date, or revision, the Report supersedes any prior report or other document issued by Golder dealing with any matter that is addressed in the Report.

Any uncertainty as to the extent to which this Report can be used or relied upon in any respect should be referred to Golder for clarification

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Appendix E2 Leachate Strategy

GOLDER
MEMBER OF WSP

REPORT

Integrated Leachate Management Program

Shoal Bay Waste Management Facility

Submitted to:

City of Darwin
GPO Box 84
Darwin NT 0801

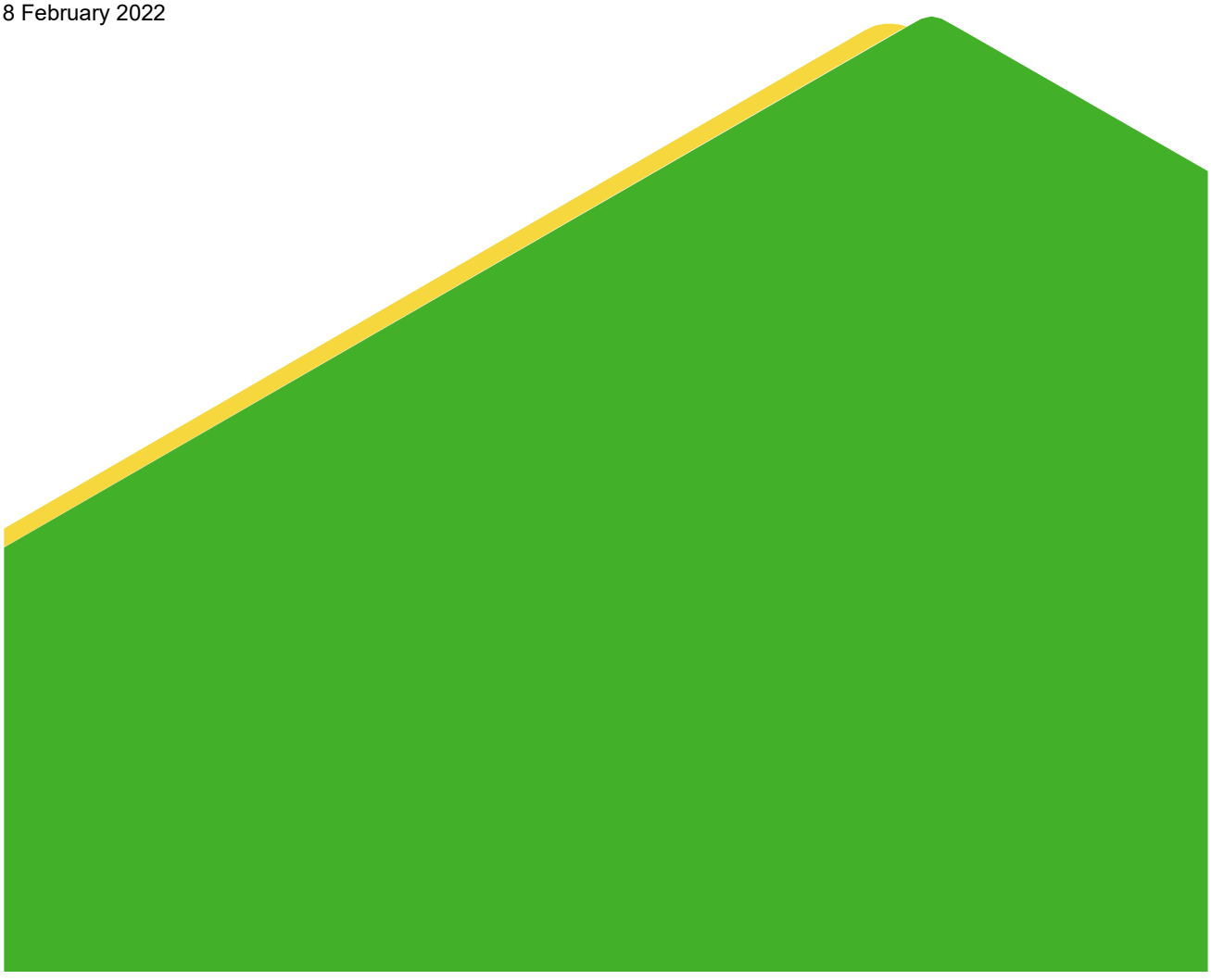
Submitted by:

Golder Associates Pty Ltd
147 Coronation Drive, Milton, Queensland 4064, Australia

+61 7 3721 5400

20140796-006-R-Rev2

8 February 2022



Distribution List

Organisation	Client Contact	Version	Date Issued	Method of Delivery
City of Darwin	N/A	Revision 0	28 October 2021	Email
City of Darwin	N/A	Revision 1	27 January 2022	Email
City of Darwin	N/A	Revision 2	8 February 2022	Email

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APPENDICES

1.0 INTRODUCTION

Golder Associates Pty Ltd (Golder) was commissioned by City of Darwin (Council) to prepare an Integrated Leachate Monitoring, Inspection and Maintenance Program (the Program) for the Shoal Bay Waste Management Facility (SBWMF). The Program specifically addresses the following conditions of the SBWMF Environmental Protection Licence (EPL188):

- Condition 88: The licensee must develop an Integrated Leachate Monitoring, Inspection and Maintenance program for the site, reviewed by an independent environmental auditor. The program is to include, but not limited to;

  88.1 leachate collection systems and all leachate sources received by the system.

  88.2 method of conveyance of leachate from all source points to the leachate management system.

  88.3 leachate leakage detection system.

  88.4 the subgrade drainage testing and their locations.

  88.5 the type of leachate pump and operation of pumping systems.

  88.6 data collection infrastructure and recording methodology.

  88.7 a program for the inspection of drainage, pumps, blockages, flows and equipment.

- Condition 89: The licensee must submit the integrated Leachate Monitoring, Inspection and Maintenance program reviewed by an independent environmental auditor to the NT EPA by 30 October 2021.

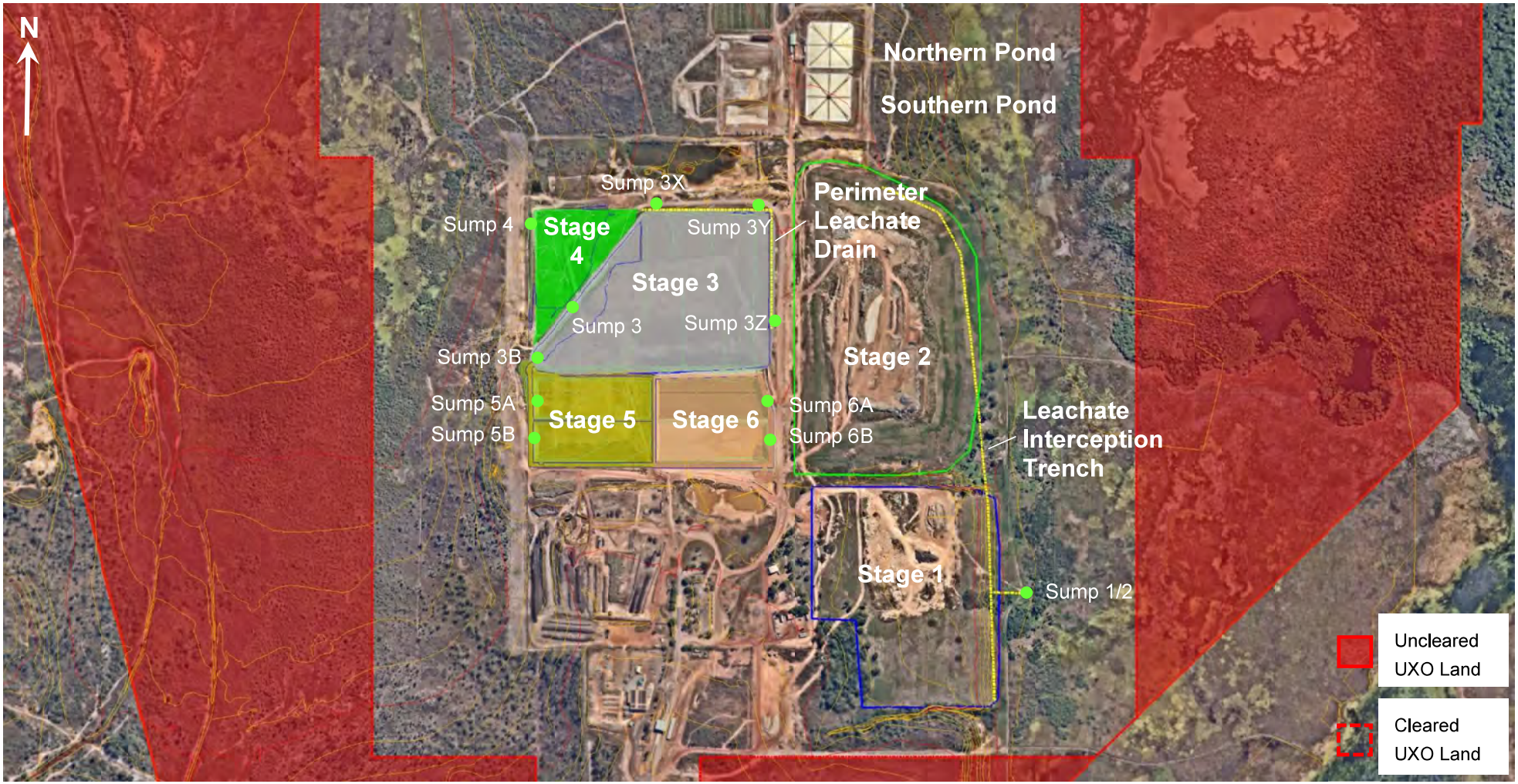
Information for this Program has been largely obtained from existing design, operation and monitoring documents applicable to the SBWMF, including:

- Water Balance Model, Leachate and Stormwater Management Strategies – Shoal Bay Landfill, Darwin (Golder Associates, 2021). This document includes design documentation for the general waste disposal cells (Stage 3 to Stage 6)
- Environmental Management Plan – Shoal Bay Waste Management Facility (City of Darwin, 2020).
- Water Quality Monitoring Plan – Shoal Bay Waste Management Facility (EcOz Environmental Consultants, 2020)

2.0 OVERVIEW OF LANDFILL LEACHATE SOURCES AND VOLUMES

Council has constructed six stages of general waste disposal cells at the SBWMF, as shown on Figure 1. These are summarised in Table 1.

Figure 1: SBWMF Constructed General Waste Landfill Cells and Leachate Collection Pump Locations



Sources: Nearmap Image, June 2021, Council LIDAR Survey Data, Council/Defence Lease Plan, Council Stage 4/Stage 5 As-Constructed Survey, 2012 & 2016, Golder Design, 2019

Table 1: SBWMF General Waste Cell Summary

Stages	Area	Description	Liner System	Leachate Collection	Current Capping
Stage 1	12.2 ha	Non-engineered former general waste landfill. Currently comprises vacant hardstand used for soil stockpiles.	None	Perimeter interception drain	Non-engineered soil barrier
Stage 2	18.1 ha	Non-engineered former general waste landfill. Currently used as inert waste disposal area	None	Perimeter interception drain	Non-engineered soil barrier
Stage 3	10.6 ha	Basic engineered general waste landfill. Best practice final capping currently being constructed.	Geo-membrane	Basic pipe drains. Assessed as non-functional	Interim soil barrier
Stage 4	3.1 ha	Good practice engineered general waste cell. Best practice final capping currently being constructed.	Composite liner system	Full gravel blanket and drainage pipes	Interim soil barrier
Stage 5	4.1 ha	Best practice engineered general waste cell. Currently general waste disposal landfill.	Composite liner system	Full gravel blanket and drainage pipes	Daily/Interim capping
Stage 6	3.9 ha	Best practice engineered general waste cell. Currently general waste disposal landfill.	Composite liner system	Full gravel blanket and drainage pipes	Daily/Interim capping

Future general waste disposal stages are planned for the SBWMF; however, at the time of preparing this Program, these stages do not generate or store leachate.

Estimated leachate collection volumes (refer Golder Associates, 2021) for each landfill stage are summarised in Table 2 and Table 3 below.

Table 2: Estimated Leachate Collection Volumes 2022

Stages	Landfill Operation Conditions	Estimated Leachate Volume (ML/annum)
Stage 1 & 2	Non-operational/Inert waste Landfill	50th percentile rainfall: 4 90th percentile rainfall: 8
Stage 3 & 4	35% final capping/65% interim capping	50th percentile rainfall: 22.5 90th percentile rainfall: 29
Stage 5A & 5B	General operation	
Stage 6A	Not used / early operation	
Stage 6B	General operation	

Table 3: Estimated Leachate Collection Volumes 2023-2027

Stages	Landfill Operation Conditions	Estimated Leachate Volume (ML/annum)
Stage 1 & 2	Non-operational/inert waste Landfill	50th percentile rainfall: 4 90th percentile rainfall: 8
Stage 3 & 4	65% final capping/35% interim capping	50th percentile rainfall: 16 90th percentile rainfall: 21
Stage 5A & 5B Stage 6A & 6B	General operation	

Please note the collection volumes nominated in Table 2 and Table 3 exclude the dewatering of an existing leachate mound located within the Stage 3 general waste landfill that has a non-functional leachate collection system. This dewatering will be managed under a standalone dewatering plan, to be detailed by Council at a later date.

3.0 LEACHATE COLLECTION SYSTEM

3.1 Overview

An overview of the leachate collection infrastructure is detailed in the sections below. A collection system network diagram for the engineered general waste landfill stages is presented in Figure 2. Table 4 provides a summary of the collection infrastructure for each general waste landfill stage.

Table 4: Landfill Stages and Leachate Collection Systems

Stage	Leachate Collection System	Collection Sump	Condition (as of October 2021)
Stage 1	Toe Pipe and Trench	Sump 1/2	Operational
Stage 2	Toe Pipe and Trench	Sump 1/2	Operational
Stage 3	Pipes and gravel strips @ 50 m spacing	Sump 3	Non-Functional
	Pipe and gravel blanket	Sump 3B	Operational
	Toe pipe/aggregate	Sump 3X/3Y/3Z	Operational
Stage 4	Gravel blanket & pipes	Sump 4	Operational
Stage 5	Gravel blanket & pipes	Sump 5A	Operational
	Gravel blanket & pipes	Sump 5B	Operational
Stage 6	Gravel blanket & pipes	Sump 6A	Constructed/Not in Use
	Gravel blanket & pipes	Sump 6B	Operational

Figure 2: Leachate Collection Systems - SBWMF Engineered General Waste Landfill Stages

3.2 Engineered Landfill Stages Collection Infrastructure

Collector lines, which feed to a network of sumps with pneumatic pumps have been installed in the engineered landfill stages (Stage 3, 4, 5 and 6) at the site. The collection system for Stages 4, 5 and 6 were constructed with a composite liner system and leachate gravel drainage blanket and pipe network. These systems were fully operational as of October 2021. It is noted that the collection system at the base of Stage 3 has failed; however, a perimeter drain system has been installed along the northern and eastern toe line to capture leachate from this area. This system drains to three dedicated collection sumps (3X, 3Y, 3Z), with dedicated pneumatic pumps. All leachate pumps operate autonomously, with regular monitoring and maintenance conducted (see Section 7.0).

3.3 Non-Engineered Landfill Stages Collection Infrastructure

Leachate generated in Stages 1 and 2 is collected via a toe interception trench, which feeds to a single sump (Sump 1/2). As-constructed details of the leachate interception system are not available. Leachate collected in Sump 1/2 is pumped, via an automated electric pump, to a surface irrigation system operated within the Stage 1 footprint, summarised in Section 4.3.

3.4 Leachate Storage Infrastructure

Leachate from the four engineered general waste stages (Stage 3 to Stage 6) is pumped to two engineered covered leachate storage ponds. Each pond has approximately 14 ML of storage capacity (approximately 28 ML total storage). The ponds were constructed with geosynthetic liners to minimise leakage and are covered to prevent rainfall capture. The covers are designed to allow stormwater runoff to be collected atop the cover, mitigating the risk of damage associated with cyclone events and bushfires. The leachate ponds are secured by internal perimeter fencing, designed to exclude unauthorised access.

4.0 LEACHATE MANAGEMENT SYSTEMS

4.1 Conveyance Pipe Networks

Leachate that is collected from Stages 1 and 2, collects in Sump 1/2. From here, it is pumped via electric pump and rising main pipe to an irrigation system (refer to Section 4.3) located within the Stage 1 landfill footprint.

Leachate collected from general waste Stages 3, 4, 5 and 6 is pumped via an above ground rising main pipe network (refer Figure 2) to the Leachate Storage Ponds (refer to Section 3.4) for management.

4.2 Leachate Treatment System – Proposed for Mid-2022

The leachate management infrastructure is being upgraded at the time of the preparation of this Management Program. As of mid-2022, advanced leachate treatment infrastructure will be installed at the site. Leachate will be pumped from the leachate storage ponds to the leachate treatment system. The system is designed to treat the leachate to remove contaminants, rending its quality suitable for discharge within the site. The leachate treatment system includes the following processes:

1) Foam fractionation and extraction process for PFAS removal.
2) Biological nutrient removal – Sequence Batch Reactor (SBR) combined with Moving Bed Biological Reactor (MBBR).
3) Dissolved air floatation (DAF) for solids removal.
4) Constructed wetlands.

5) Storage and irrigation of treated leachate over a vetiver grass to be incorporated into the final capping system currently being constructed within Stage 3 and Stage 4.

The treatment system is designed to manage flows of up to 140 kL/day; however, the system is scalable to manage fluctuating leachate volumes and concentrations.

4.3 Current Leachate Irrigation Systems (October 2021)

4.3.1 Stage 1 and Stage 2

Leachate is pumped directly from Sump 1/2 to a surface irrigation system, which applies and evaporates the leachate across a designated irrigation area within the plateau area of Stage 1. This system is only operated as required during the dry season.

4.3.2 Stage 3, 4, 5 and 6

Leachate from Stages 3, 4, 5 and 6 is pumped to the two leachate storage ponds. Leachate is pumped (pneumatic pumps) from the storage ponds to a localised section of the plateau of Stage 3 and 4 for application and evaporation across a designated irrigation area.

4.4 Leachate Evaporation

Council has installed two temporary Benevap enhanced leachate evaporation systems to assist with the disposal of leachate until the construction of a permanent leachate treatment system in 2022. The energy for these temporary systems is currently supplied using diesel.

4.5 Current and Proposed Leachate Disposal Volumes

The current (until mid-2022) and proposed (mid-2022 onwards) leachate treatment and irrigation volumes are summarised in Table 5 below (refer Golder 2021).

Table 5: Current and Proposed Leachate Disposal/Treatment Infrastructure

Disposal / Treatment System	Operational Period	Treatment Capacity (kL/day)	Irrigation/Evaporation/ Reuse Capacity (kL/day)
Surface Irrigation	Current to mid-2022	0	60
Enhanced Evaporation (Benevap)	Current to mid-2022	0	40
Permanent Leachate Treatment System	2022- onwards	140	140

An overview of the leachate treatment system is presented in Figure 3 below.

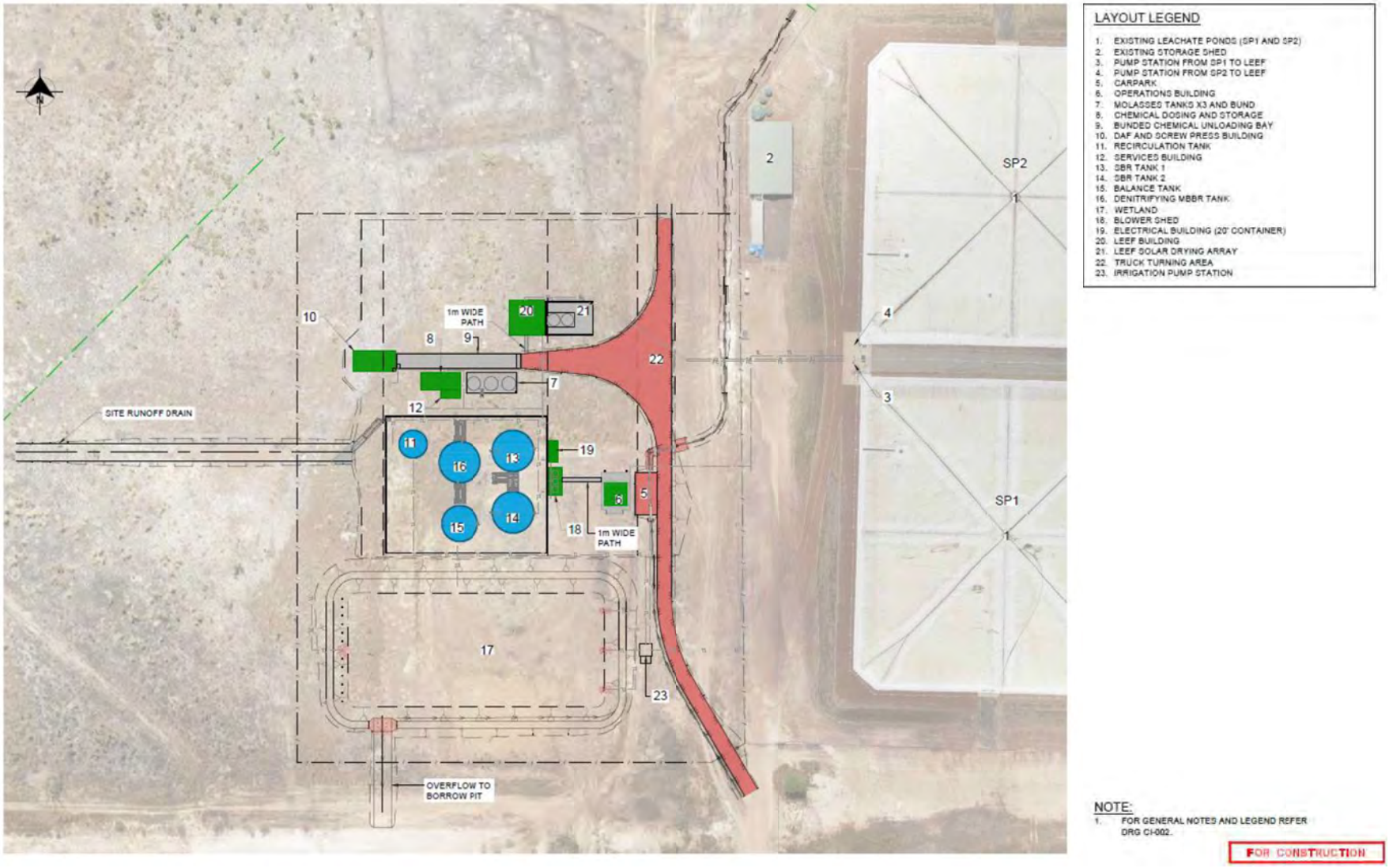


Figure 3: Leachate Treatment System Overview

5.0 LEACHATE LEAKAGE MONITORING

5.1 Groundwater Monitoring Well Network

A network of 44 groundwater monitoring wells has been installed within the SBWMF that is designed to identify the migration of contaminants from the various general waste landfill stages into underlying groundwaters.

This network acts as a leak detection system for the leachate management systems at the site, including the landfill cell linings and the leachate storage facilities. The monitoring network also includes leachate sampling points withing the landfill cells, supporting the comparison of the leachate contaminant profile with potential contamination trends observed in the groundwater.

A Water Quality Monitoring Plan (WQMP) has been developed for the facility (EcOz Environmental Consultants, 2020). This document is appended to the Environmental Management Plan (City of Darwin, 2020). The WQMP requires that groundwater and leachate samples are collected quarterly, in January, April, July and October each year. Collected samples are analysed for:

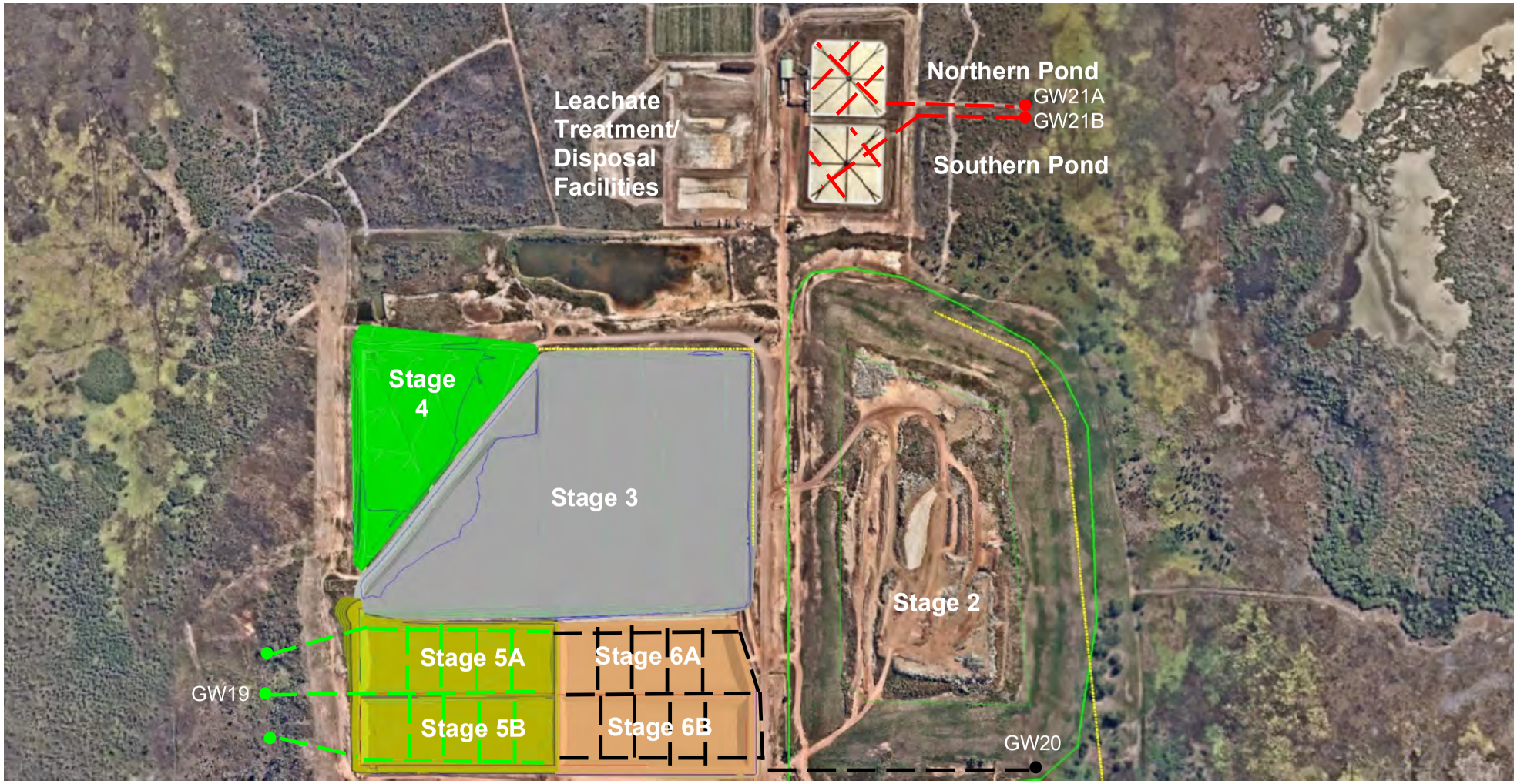
- Ammonium
- Total dissolved solids
- Chemical oxygen demand
- Total organic carbon
- Major ions (Na, K, Ca, Mg, alkalinity, chloride, SO4)
- Nutrients (ammonia as N, nitrate, nitrite, total nitrogen, total phosphorus)
- Dissolved metals (chromium, copper, nickel, lead and zinc)
- Petroleum hydrocarbons (TRH)
- Benzene, toluene, ethylbenzene, xylene, naphthalene (BTEXN)
- Per- and poly-fluoroalkyl substances (PFAS)

The location of each of the monitoring points is detailed in Table 2-1 of the WQMP and each location is mapped in Figure 2-1 of the WQMP. This figure has been included in Appendix B.

5.2 Subgrade Drainage Monitoring Network

Groundwater subgrade drainage infrastructure has been installed beneath the liner systems of the Stage 5 and Stage 6 general waste landfill cells and the two covered leachate storage ponds. The purpose of these subgrade drainage systems it to maintain a minimum 2 m vertical distance between the base of the respective liner systems and underlying shallow perched groundwater that rises near to ground level during wet season conditions. The subgrade drainage systems comprise gravel filled trenches fitted with perforated pipelines that gravity drain to surface outlets located above 1% AEP flood levels within the adjacent tidal wetlands. The installed subgrade drainage networks are shown on Figure 3,

Figure 4: SBWMF Subgrade drainage networks and monitoring locations



Sources: Nearmap Image, June 2021, Council Stage 4/Stage 5 As-Constructed Survey, 2012 & 2016, Golder Design, 2019

Discharges from the subsurface drainage systems are used as part of the leachate leakage detection monitoring system as summarised in Table 6. The location of the monitoring infrastructure is outlined in Figure 4.

Table 6: Subsurface Drainage Groundwater Discharge Monitoring Locations

Drainage Systems	Stage 5	Stage 6	Northern Pond	Southern Pond
Monitoring Locations	GW19	GW20	GW21A	GW21B

Samples are collected quarterly (when drainage system is discharging groundwater) directly from the outfall points. Samples collected from each of the outfalls is analysed for the following:

- Ammonium
- Total dissolved solids
- Chemical oxygen demand
- Total organic carbon
- Major ions (Na, K, Ca, Mg, alkalinity, chloride, SO4)
- Nutrients (ammonia as N, nitrate, nitrite, total nitrogen, total phosphorus)
- Dissolved metals (chromium, copper, nickel, lead and zinc)
- Petroleum hydrocarbons (TRH)
- Benzene, toluene, ethylbenzene, xylene, naphthalene (BTEXN)
- Per- and poly-fluoroalkyl substances (PFAS)

6.0 LEACHATE PUMPING SYSTEMS

Pumping systems operated within the SBWMF to collect and transfer leachate from the waste disposal stages to management infrastructure is summarised in Table 7.

Table 7: Summary of Leachate Pumping Systems and Operation

Stages	Leachate Sumps	Pumping System	Energy Source	Operation
Stage 1	Sump 1/2	Electric	Mains Power	Automatic Water Level Trigger
Stage 2				
Stage 3	Sump 3B	Pneumatic	Automatic compressor systems connected to mains power	Automatic Water Level Trigger
Stage 4	Sump 4			Automatic Water Level Trigger
Stage 5	Sump 5A/5B			Automatic Water Level Trigger
Stage 6	Sump 6A/6B			Automatic Water Level Trigger
Leachate Ponds	Sump NP/SP			Automatic Water Level Trigger

7.0 INSPECTION AND MAINTENANCE PROGRAMS

Operations at the Facility are managed and conducted by Veolia in accordance with a Site Based Management Plan (SBMP) for the SBWMF. This SBMP contains operational and environmental control plans, which identify hazards, objectives for the management of a hazard, performance indicators, monitoring requirements, reporting requirements and control strategies for the hazard. The SBMP contains an operational and environmental control plan for leachate management, with key elements summarised in Table 8 below.

Table 8: Operational and Environmental Control Plan - Leachate Management (Veolia, 2020)

Element	Actions	Responsible Person	Timing
Objective	To manage the potential impacts associated with the production and storage of leachate.		
Management Strategy	To maintain appropriate leachate collection structures and devices to manage the production and release of leachate.		
Performance Indicators	■ Leachate from the landfill is to remain on site; and ■ All surface leachate to be collected and contained on the site.		
Monitoring	Site manager, supervisor, and operational personnel to assess the condition of leachate systems and structures on a weekly basis, results to be recorded.	OM, SS, OP, SS	Weekly
Reporting	Report any incident to the Operations Manager/Supervisor. Any incidents to be recorded in RIVO. Weekly leachate infrastructure monitoring to be recorded in Landfill Weekly Checklist.	OM, OP, SS	As required Weekly
Control Strategies	To manage the potential impacts of leachate the following strategies may be implemented:		
	■ Maintain appropriate leachate collection and storage structures to prevent the release of leachate.	OM, SS, SM	As required
	■ Cover all completed landfill areas with a suitable cover material to minimise the ingress of water.	SS, OM	Ongoing
	■ Ensure that leachate pumps are correctly installed and operating in leachate sumps to pump leachate into storage tanks for recirculation back into landfill working face or through leachate recirculation lines.	SS, OM	As required
	■ Minimise the level of leachate above the landfill floor by pumping leachate from the sump directly onto the landfill leachate recirculation system.	SS, OP	As required
	■ Redirect stormwater away from the landfill face to prevent the contamination of stormwater.	OP, EO, WO	Ongoing
	■ Ensure all waste meets the landfills waste acceptance criteria.	SS	Ongoing

SS – Site Supervisor OP – Operational Personnel

RIVO – Veolia's Incident and Compliance Management System

8.0 DATA COLLECTION INFRASTRUCTURE AND RECORDING METHODOLOGY

The methodology and processes for the collection and recording of leachate data is documented in Council's Environmental Management Plan for the SBWMF. Key elements of data management comprise:

- Council is required by the Information Act to ensure that complete and accurate records of the business of Council are created and managed for as long as required to support business, accountability, and legislative requirements until their disposal in accordance with an authorised retention and disposal schedule. This requirement is outlined in Council Record and Information Management Policy (Policy No 057), which applies to all Council staff and to records of all business activities performed by or on behalf of Council.
- All environmental documentation, plans, procedures, reports, data and records will be uploaded onto the Council electronic document and records management system. Records of quantities and source of leachate managed at the SBWMF will be maintained through Council electronic systems.
- All records will be held for at least 10-years and will be accessible to the regulatory authorities as required.
- Leachate management data recorded by the Landfill Operations Contractor (Veolia) and Council is summarised in Table 9.

Table 9: Leachate Management Data Collection Summary

Locations	Data Source	Methodology	Frequency
Stage 1	Sump 1/2	Water flow meter – manual reading	Daily
Stage 2			
Stage 3	Sump 3B/3X/3Y/3Z	Pneumatic pump cycles – automated readings	Daily
Stage 4	Sump 4	Pneumatic pump cycles – automated readings	Daily
Stage 5	Sump 5A/5B	Pneumatic pump cycles – automated readings	Daily
Stage 6	Sump 6A/6B	Pneumatic pump cycles – automated readings	Daily
Leachate Ponds	Inflow volumes	Water flow meter – manual reading	Daily
	Storage volumes	Survey of floating cover elevation	Monthly
Benevap Systems	Evaporation system 1	Water flow meter – manual reading	Daily
	Evaporation system 2	Water flow meter – manual reading	Daily
Irrigation Systems	Stage 1/Stage 2	Water flow meter – manual reading	Daily
	Stage 3/Stage 4	Water flow meter – manual reading	Daily
Treatment System	Leachate Pond Extraction	Under construction. To be confirmed.	Daily
	Treated Leachate Storage		Daily
	Treated Leachate Irrigation		Daily

8.1 Future Leachate Irrigation Monitoring

Prior to the commencement of leachate irrigation, an irrigation monitoring program must be developed. This program should include the monitoring of irrigation water (leachate) quality, as well as monitoring of vegetation condition and runoff mitigation infrastructure. Reference to this monitoring program should be added to this Program as part of a future revision (see Section 9.0).

9.0 REVISION OF THIS PROGRAM

This Program should be reviewed on an annual basis, or as new systems come online. Additions, such as treatment and irrigation infrastructure, should be incorporated into the Program immediately upon commissioning.

10.0 IMPORTANT INFORMATION

Your attention is drawn to the document titled - “Important Information Relating to this Report”, which is included in Appendix A of this report. The statements presented in that document are intended to inform a reader of the report about its proper use. There are important limitations as to who can use the report and how it can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Important Information document does not alter the obligations Golder Associates has under the contract between it and its client.

Signature Page

Golder Associates Pty Ltd

Luke Jacovides
Senior Environmental Scientist

James Begg
Principal Engineer, Waste Management

LJ/AH/JSB/sk

A.B.N. 64 006 107 857

https://golderassociates.sharepoint.com/sites/124524/shared documents/deliverables/006 - integrated leachate management program/rev2/20140796-006-r-rev2 - shoal bay landfill leachate management program.docx

APPENDIX A

Important Information

The document ("Report") to which this page is attached and which this page forms a part of, has been issued by Golder Associates Pty Ltd ("Golder") subject to the important limitations and other qualifications set out below.

This Report constitutes or is part of services ("Services") provided by Golder to its client ("Client") under and subject to a contract between Golder and its Client ("Contract"). The contents of this page are not intended to and do not alter Golder's obligations (including any limits on those obligations) to its Client under the Contract.

This Report is provided for use solely by Golder's Client and persons acting on the Client's behalf, such as its professional advisers. Golder is responsible only to its Client for this Report. Golder has no responsibility to any other person who relies or makes decisions based upon this Report or who makes any other use of this Report. Golder accepts no responsibility for any loss or damage suffered by any person other than its Client as a result of any reliance upon any part of this Report, decisions made based upon this Report or any other use of it.

This Report has been prepared in the context of the circumstances and purposes referred to in, or derived from, the Contract and Golder accepts no responsibility for use of the Report, in whole or in part, in any other context or circumstance or for any other purpose.

The scope of Golder's Services and the period of time they relate to are determined by the Contract and are subject to restrictions and limitations set out in the Contract. If a service or other work is not expressly referred to in this Report, do not assume that it has been provided or performed. If a matter is not addressed in this Report, do not assume that any determination has been made by Golder in regards to it.

At any location relevant to the Services conditions may exist which were not detected by Golder, in particular due to the specific scope of the investigation Golder has been engaged to undertake. Conditions can only be verified at the exact location of any tests undertaken. Variations in conditions may occur between tested locations and there may be conditions which have not been revealed by the investigation and which have not therefore been taken into account in this Report.

Golder accepts no responsibility for and makes no representation as to the accuracy or completeness of the information provided to it by or on behalf of the Client or sourced from any third party. Golder has assumed that such information is correct unless otherwise stated and no responsibility is accepted by Golder for incomplete or inaccurate data supplied by its Client or any other person for whom Golder is not responsible. Golder has not taken account of matters that may have existed when the Report was prepared but which were only later disclosed to Golder.

Having regard to the matters referred to in the previous paragraphs on this page in particular, carrying out the Services has allowed Golder to form no more than an opinion as to the actual conditions at any relevant location. That opinion is necessarily constrained by the extent of the information collected by Golder or otherwise made available to Golder. Further, the passage of time may affect the accuracy, applicability or usefulness of the opinions, assessments or other information in this Report. This Report is based upon the information and other circumstances that existed and were known to Golder when the Services were performed and this Report was prepared. Golder has not considered the effect of any possible future developments including physical changes to any relevant location or changes to any laws or regulations relevant to such location.

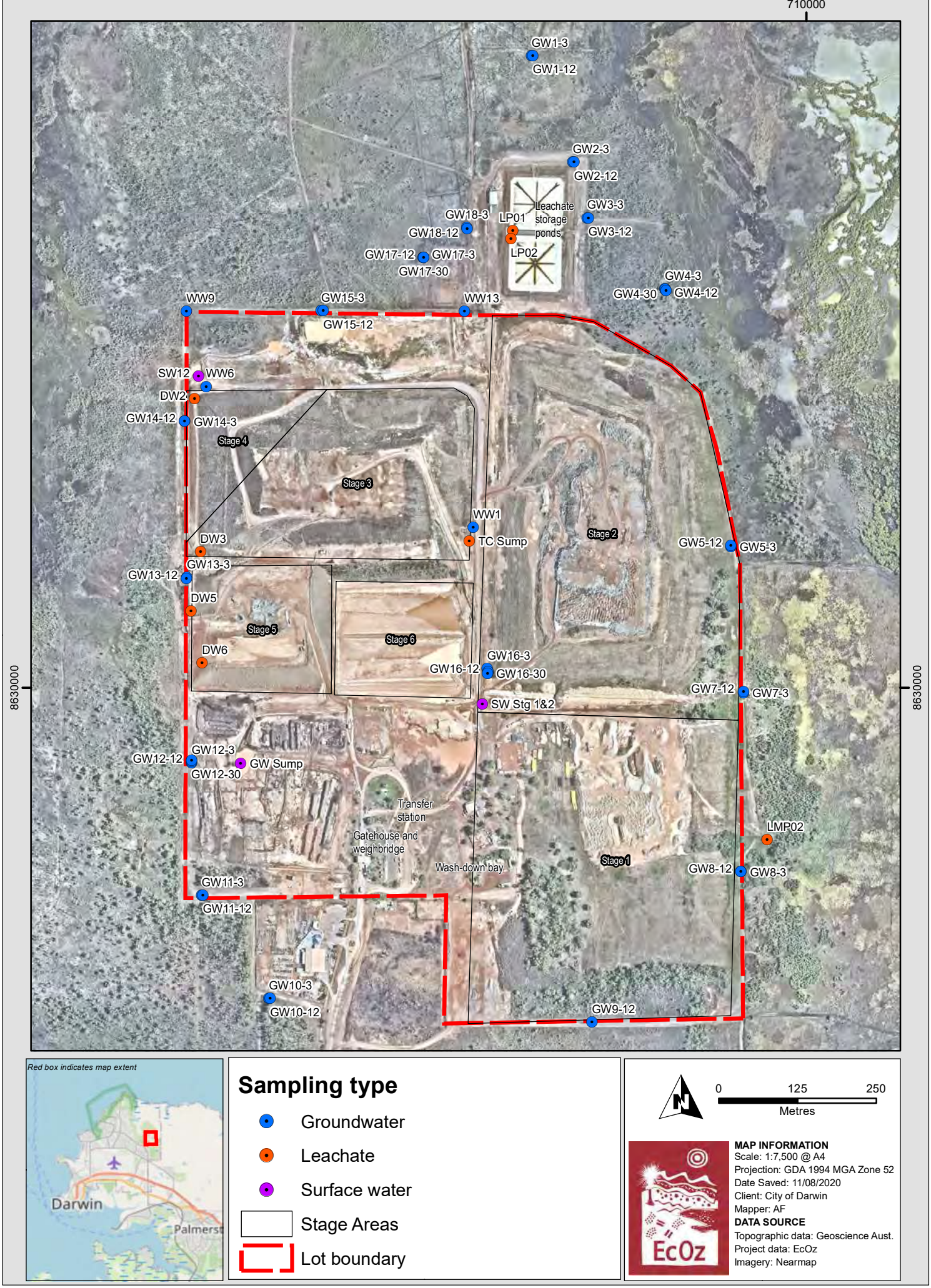
Where permitted by the Contract, Golder may have retained subconsultants affiliated with Golder to provide some or all of the Services. However, it is Golder which remains solely responsible for the Services and there is no legal recourse against any of Golder's affiliated companies or the employees, officers or directors of any of them.

By date, or revision, the Report supersedes any prior report or other document issued by Golder dealing with any matter that is addressed in the Report.

Any uncertainty as to the extent to which this Report can be used or relied upon in any respect should be referred to Golder for clarification

APPENDIX B

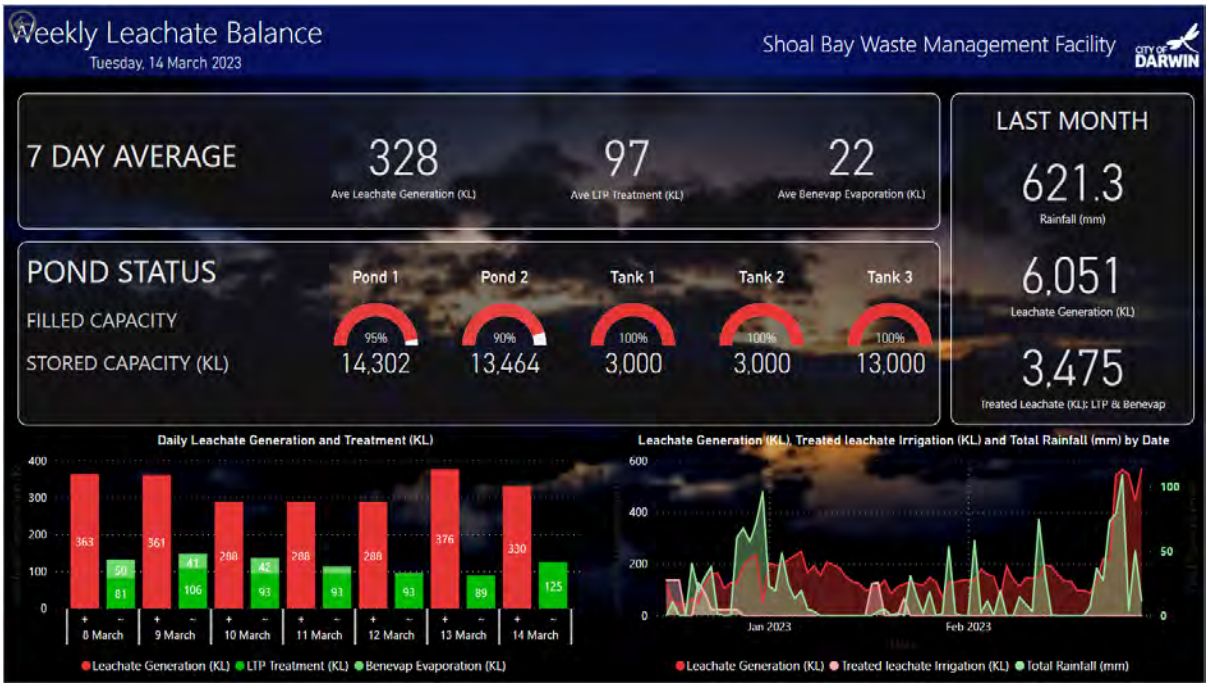
Monitoring Points: Figure 2-1 from the WQMP

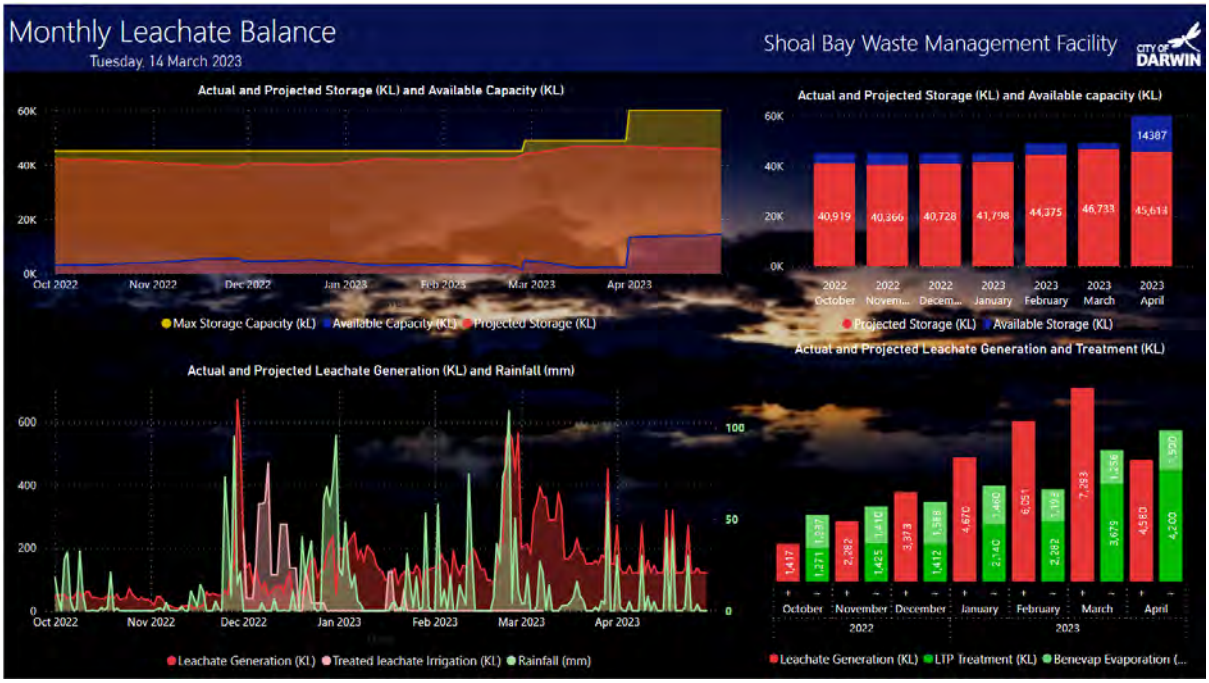


Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\WQMP Figure 2-1. SBWMF layout and monitorig site locations.mxd

Figure 2-1 Map of SBWMF layout and monitoring site locations

golder.com


Weekly Leachate Balance
Tuesday, 14 March 2023
Shoal Bay Waste Management Facility
CITY OF DARWIN
7 DAY AVERAGE
328
Ave Leachate Generation (KL)
97
Ave LTP Treatment (KL)
22
Ave Benevap Evaporation (KL)
LAST MONTH
621.3
Rainfall (mm)
6,051
Leachate Generation (KL)
3,475
Treated Leachate (KL): LTP & Benevap
POND STATUS
FILLED CAPACITY
STORED CAPACITY (KL)
Pond 1
95%
14,302
Pond 2
90%
13,464
Tank 1
100%
3,000
Tank 2
100%
3,000
Tank 3
100%
13,000
Daily Leachate Generation and Treatment (KL)
8 March
9 March
10 March
11 March
12 March
13 March
14 March
Leachate Generation (KL)
LTP Treatment (KL)
Benevap Evaporation (KL)
Leachate Generation (KL), Treated leachate Irrigation (KL) and Total Rainfall (mm) by Date
Jan 2023
Feb 2023
Leachate Generation (KL)
Treated leachate Irrigation (KL)
Total Rainfall (mm)


Monthly Leachate Balance
Tuesday, 14 March 2023
Shoal Bay Waste Management Facility
CITY OF DARWIN
Actual and Projected Storage (KL) and Available Capacity (KL)
Max Storage Capacity (KL)
Available Capacity (KL)
Projected Storage (KL)
Actual and Projected Storage (KL) and Available capacity (KL)
Projected Storage (KL)
Available Storage (KL)
Actual and Projected Leachate Generation (KL) and Rainfall (mm)
Leachate Generation (KL)
Treated leachate Irrigation (KL)
Rainfall (mm)
Actual and Projected Leachate Generation and Treatment (KL)
Leachate Generation (KL)
LTP Treatment (KL)
Benevap Evaporation (...

GOLDER
MEMBER OF WSP

REPORT

Integrated Leachate Management Program

Shoal Bay Waste Management Facility

Submitted to:

City of Darwin
GPO Box 84
Darwin NT 0801

Submitted by:

Golder Associates Pty Ltd
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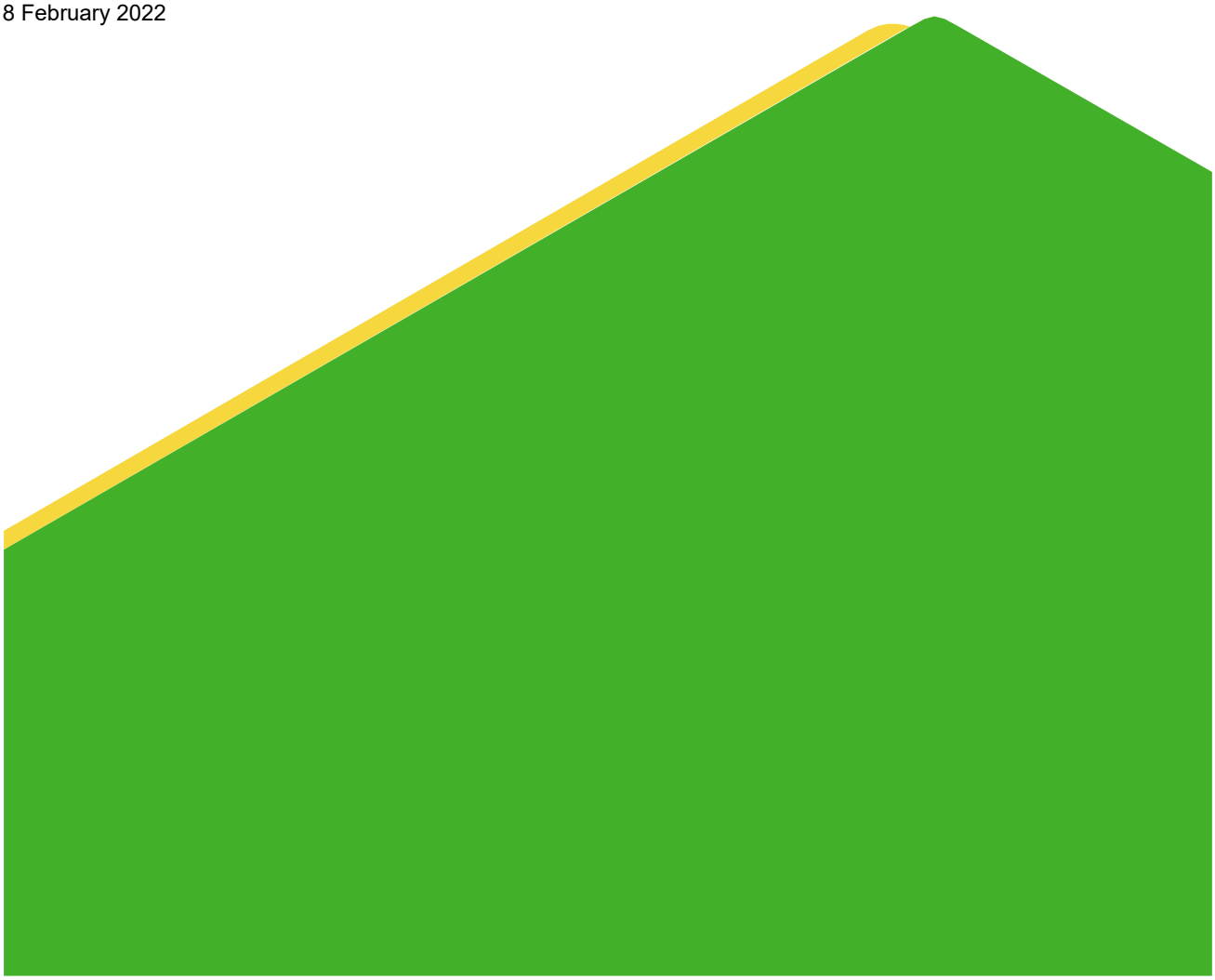
20140796-006-R-Rev2

8 February 2022



Distribution List

Organisation	Client Contact	Version	Date Issued	Method of Delivery
City of Darwin	N/A	Revision 0	28 October 2021	Email
City of Darwin	N/A	Revision 1	27 January 2022	Email
City of Darwin	N/A	Revision 2	8 February 2022	Email

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APPENDICES

1.0 INTRODUCTION

Golder Associates Pty Ltd (Golder) was commissioned by City of Darwin (Council) to prepare an Integrated Leachate Monitoring, Inspection and Maintenance Program (the Program) for the Shoal Bay Waste Management Facility (SBWMF). The Program specifically addresses the following conditions of the SBWMF Environmental Protection Licence (EPL188):

- Condition 88: The licensee must develop an Integrated Leachate Monitoring, Inspection and Maintenance program for the site, reviewed by an independent environmental auditor. The program is to include, but not limited to;

  88.1 leachate collection systems and all leachate sources received by the system.

  88.2 method of conveyance of leachate from all source points to the leachate management system.

  88.3 leachate leakage detection system.

  88.4 the subgrade drainage testing and their locations.

  88.5 the type of leachate pump and operation of pumping systems.

  88.6 data collection infrastructure and recording methodology.

  88.7 a program for the inspection of drainage, pumps, blockages, flows and equipment.

- Condition 89: The licensee must submit the integrated Leachate Monitoring, Inspection and Maintenance program reviewed by an independent environmental auditor to the NT EPA by 30 October 2021.

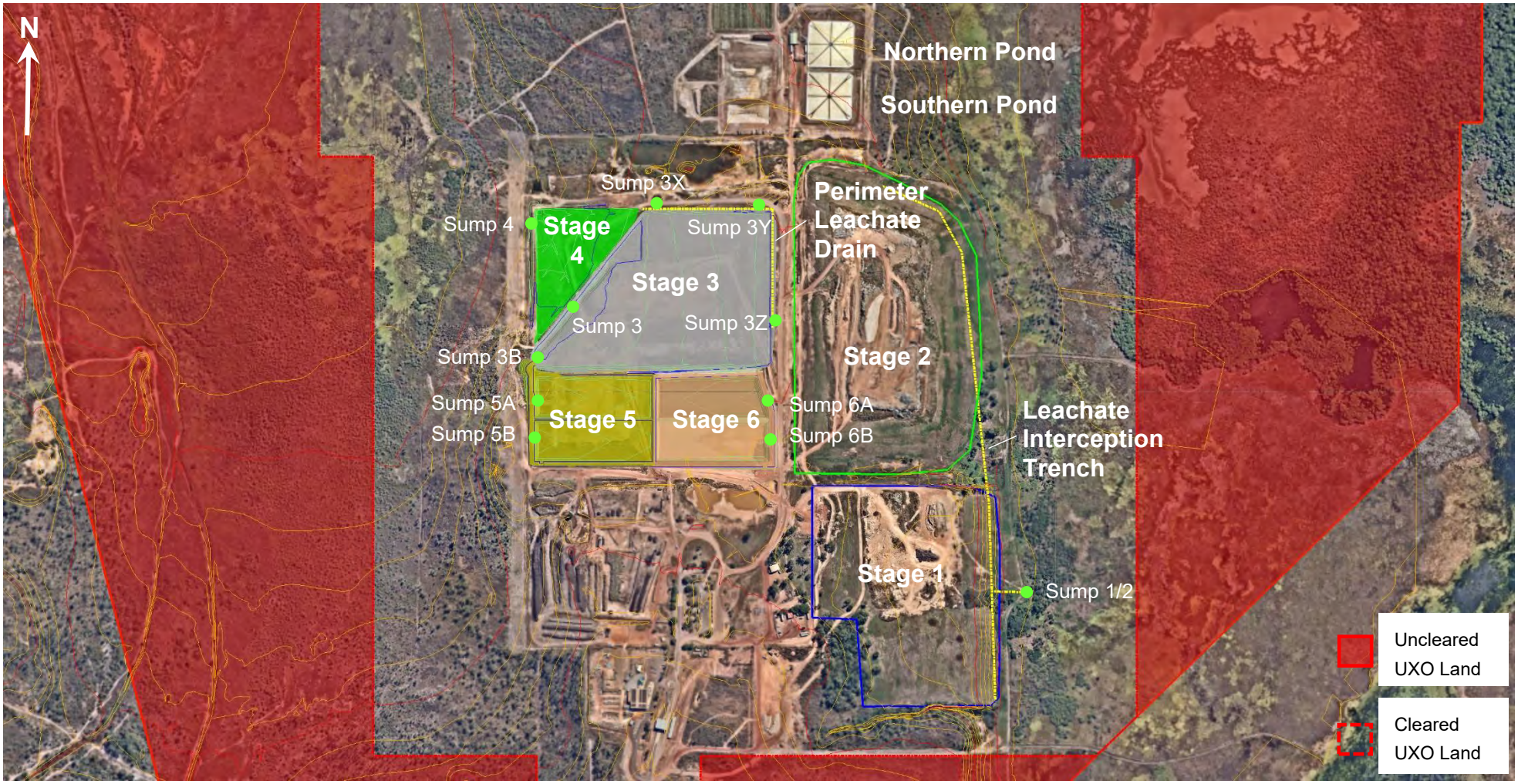
Information for this Program has been largely obtained from existing design, operation and monitoring documents applicable to the SBWMF, including:

- Water Balance Model, Leachate and Stormwater Management Strategies – Shoal Bay Landfill, Darwin (Golder Associates, 2021). This document includes design documentation for the general waste disposal cells (Stage 3 to Stage 6)
- Environmental Management Plan – Shoal Bay Waste Management Facility (City of Darwin, 2020).
- Water Quality Monitoring Plan – Shoal Bay Waste Management Facility (EcOz Environmental Consultants, 2020)

2.0 OVERVIEW OF LANDFILL LEACHATE SOURCES AND VOLUMES

Council has constructed six stages of general waste disposal cells at the SBWMF, as shown on Figure 1. These are summarised in Table 1.

Figure 1: SBWMF Constructed General Waste Landfill Cells and Leachate Collection Pump Locations



Sources: Nearmap Image, June 2021, Council LIDAR Survey Data, Council/Defence Lease Plan, Council Stage 4/Stage 5 As-Constructed Survey, 2012 & 2016, Golder Design, 2019

Table 1: SBWMF General Waste Cell Summary

Stages	Area	Description	Liner System	Leachate Collection	Current Capping
Stage 1	12.2 ha	Non-engineered former general waste landfill. Currently comprises vacant hardstand used for soil stockpiles.	None	Perimeter interception drain	Non-engineered soil barrier
Stage 2	18.1 ha	Non-engineered former general waste landfill. Currently used as inert waste disposal area	None	Perimeter interception drain	Non-engineered soil barrier
Stage 3	10.6 ha	Basic engineered general waste landfill. Best practice final capping currently being constructed.	Geo-membrane	Basic pipe drains. Assessed as non-functional	Interim soil barrier
Stage 4	3.1 ha	Good practice engineered general waste cell. Best practice final capping currently being constructed.	Composite liner system	Full gravel blanket and drainage pipes	Interim soil barrier
Stage 5	4.1 ha	Best practice engineered general waste cell. Currently general waste disposal landfill.	Composite liner system	Full gravel blanket and drainage pipes	Daily/Interim capping
Stage 6	3.9 ha	Best practice engineered general waste cell. Currently general waste disposal landfill.	Composite liner system	Full gravel blanket and drainage pipes	Daily/Interim capping

Future general waste disposal stages are planned for the SBWMF; however, at the time of preparing this Program, these stages do not generate or store leachate.

Estimated leachate collection volumes (refer Golder Associates, 2021) for each landfill stage are summarised in Table 2 and Table 3 below.

Table 2: Estimated Leachate Collection Volumes 2022

Stages	Landfill Operation Conditions	Estimated Leachate Volume (ML/annum)
Stage 1 & 2	Non-operational/Inert waste Landfill	50th percentile rainfall: 4 90th percentile rainfall: 8
Stage 3 & 4	35% final capping/65% interim capping	50th percentile rainfall: 22.5 90th percentile rainfall: 29
Stage 5A & 5B	General operation	
Stage 6A	Not used / early operation	
Stage 6B	General operation	

Table 3: Estimated Leachate Collection Volumes 2023-2027

Stages	Landfill Operation Conditions	Estimated Leachate Volume (ML/annum)
Stage 1 & 2	Non-operational/inert waste Landfill	50th percentile rainfall: 4 90th percentile rainfall: 8
Stage 3 & 4	65% final capping/35% interim capping	50th percentile rainfall: 16 90th percentile rainfall: 21
Stage 5A & 5B Stage 6A & 6B	General operation	

Please note the collection volumes nominated in Table 2 and Table 3 exclude the dewatering of an existing leachate mound located within the Stage 3 general waste landfill that has a non-functional leachate collection system. This dewatering will be managed under a standalone dewatering plan, to be detailed by Council at a later date.

3.0 LEACHATE COLLECTION SYSTEM

3.1 Overview

An overview of the leachate collection infrastructure is detailed in the sections below. A collection system network diagram for the engineered general waste landfill stages is presented in Figure 2. Table 4 provides a summary of the collection infrastructure for each general waste landfill stage.

Table 4: Landfill Stages and Leachate Collection Systems

Stage	Leachate Collection System	Collection Sump	Condition (as of October 2021)
Stage 1	Toe Pipe and Trench	Sump 1/2	Operational
Stage 2	Toe Pipe and Trench	Sump 1/2	Operational
Stage 3	Pipes and gravel strips @ 50 m spacing	Sump 3	Non-Functional
	Pipe and gravel blanket	Sump 3B	Operational
	Toe pipe/aggregate	Sump 3X/3Y/3Z	Operational
Stage 4	Gravel blanket & pipes	Sump 4	Operational
Stage 5	Gravel blanket & pipes	Sump 5A	Operational
	Gravel blanket & pipes	Sump 5B	Operational
Stage 6	Gravel blanket & pipes	Sump 6A	Constructed/Not in Use
	Gravel blanket & pipes	Sump 6B	Operational

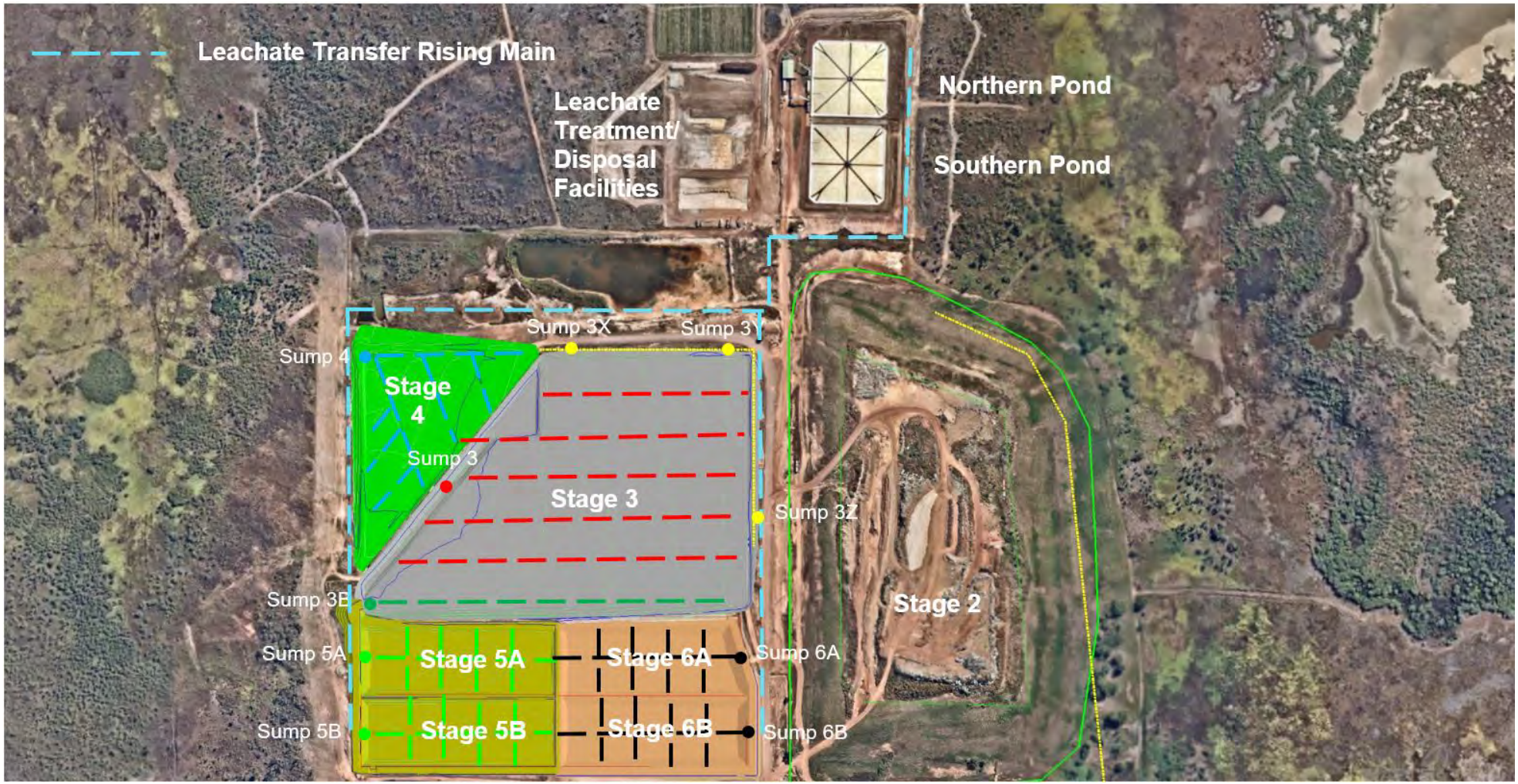


Figure 2: Leachate Collection Systems - SBWMF Engineered General Waste Landfill Stages

3.2 Engineered Landfill Stages Collection Infrastructure

Collector lines, which feed to a network of sumps with pneumatic pumps have been installed in the engineered landfill stages (Stage 3, 4, 5 and 6) at the site. The collection system for Stages 4, 5 and 6 were constructed with a composite liner system and leachate gravel drainage blanket and pipe network. These systems were fully operational as of October 2021. It is noted that the collection system at the base of Stage 3 has failed; however, a perimeter drain system has been installed along the northern and eastern toe line to capture leachate from this area. This system drains to three dedicated collection sumps (3X, 3Y, 3Z), with dedicated pneumatic pumps. All leachate pumps operate autonomously, with regular monitoring and maintenance conducted (see Section 7.0).

3.3 Non-Engineered Landfill Stages Collection Infrastructure

Leachate generated in Stages 1 and 2 is collected via a toe interception trench, which feeds to a single sump (Sump 1/2). As-constructed details of the leachate interception system are not available. Leachate collected in Sump 1/2 is pumped, via an automated electric pump, to a surface irrigation system operated within the Stage 1 footprint, summarised in Section 4.3.

3.4 Leachate Storage Infrastructure

Leachate from the four engineered general waste stages (Stage 3 to Stage 6) is pumped to two engineered covered leachate storage ponds. Each pond has approximately 14 ML of storage capacity (approximately 28 ML total storage). The ponds were constructed with geosynthetic liners to minimise leakage and are covered to prevent rainfall capture. The covers are designed to allow stormwater runoff to be collected atop the cover, mitigating the risk of damage associated with cyclone events and bushfires. The leachate ponds are secured by internal perimeter fencing, designed to exclude unauthorised access.

4.0 LEACHATE MANAGEMENT SYSTEMS

4.1 Conveyance Pipe Networks

Leachate that is collected from Stages 1 and 2, collects in Sump 1/2. From here, it is pumped via electric pump and rising main pipe to an irrigation system (refer to Section 4.3) located within the Stage 1 landfill footprint.

Leachate collected from general waste Stages 3, 4, 5 and 6 is pumped via an above ground rising main pipe network (refer Figure 2) to the Leachate Storage Ponds (refer to Section 3.4) for management.

4.2 Leachate Treatment System – Proposed for Mid-2022

The leachate management infrastructure is being upgraded at the time of the preparation of this Management Program. As of mid-2022, advanced leachate treatment infrastructure will be installed at the site. Leachate will be pumped from the leachate storage ponds to the leachate treatment system. The system is designed to treat the leachate to remove contaminants, rending its quality suitable for discharge within the site. The leachate treatment system includes the following processes:

1) Foam fractionation and extraction process for PFAS removal.
2) Biological nutrient removal – Sequence Batch Reactor (SBR) combined with Moving Bed Biological Reactor (MBBR).
3) Dissolved air floatation (DAF) for solids removal.
4) Constructed wetlands.

5) Storage and irrigation of treated leachate over a vetiver grass to be incorporated into the final capping system currently being constructed within Stage 3 and Stage 4.

The treatment system is designed to manage flows of up to 140 kL/day; however, the system is scalable to manage fluctuating leachate volumes and concentrations.

4.3 Current Leachate Irrigation Systems (October 2021)

4.3.1 Stage 1 and Stage 2

Leachate is pumped directly from Sump 1/2 to a surface irrigation system, which applies and evaporates the leachate across a designated irrigation area within the plateau area of Stage 1. This system is only operated as required during the dry season.

4.3.2 Stage 3, 4, 5 and 6

Leachate from Stages 3, 4, 5 and 6 is pumped to the two leachate storage ponds. Leachate is pumped (pneumatic pumps) from the storage ponds to a localised section of the plateau of Stage 3 and 4 for application and evaporation across a designated irrigation area.

4.4 Leachate Evaporation

Council has installed two temporary Benevap enhanced leachate evaporation systems to assist with the disposal of leachate until the construction of a permanent leachate treatment system in 2022. The energy for these temporary systems is currently supplied using diesel.

4.5 Current and Proposed Leachate Disposal Volumes

The current (until mid-2022) and proposed (mid-2022 onwards) leachate treatment and irrigation volumes are summarised in Table 5 below (refer Golder 2021).

Table 5: Current and Proposed Leachate Disposal/Treatment Infrastructure

Disposal / Treatment System	Operational Period	Treatment Capacity (kL/day)	Irrigation/Evaporation/ Reuse Capacity (kL/day)
Surface Irrigation	Current to mid-2022	0	60
Enhanced Evaporation (Benevap)	Current to mid-2022	0	40
Permanent Leachate Treatment System	2022- onwards	140	140

An overview of the leachate treatment system is presented in Figure 3 below.

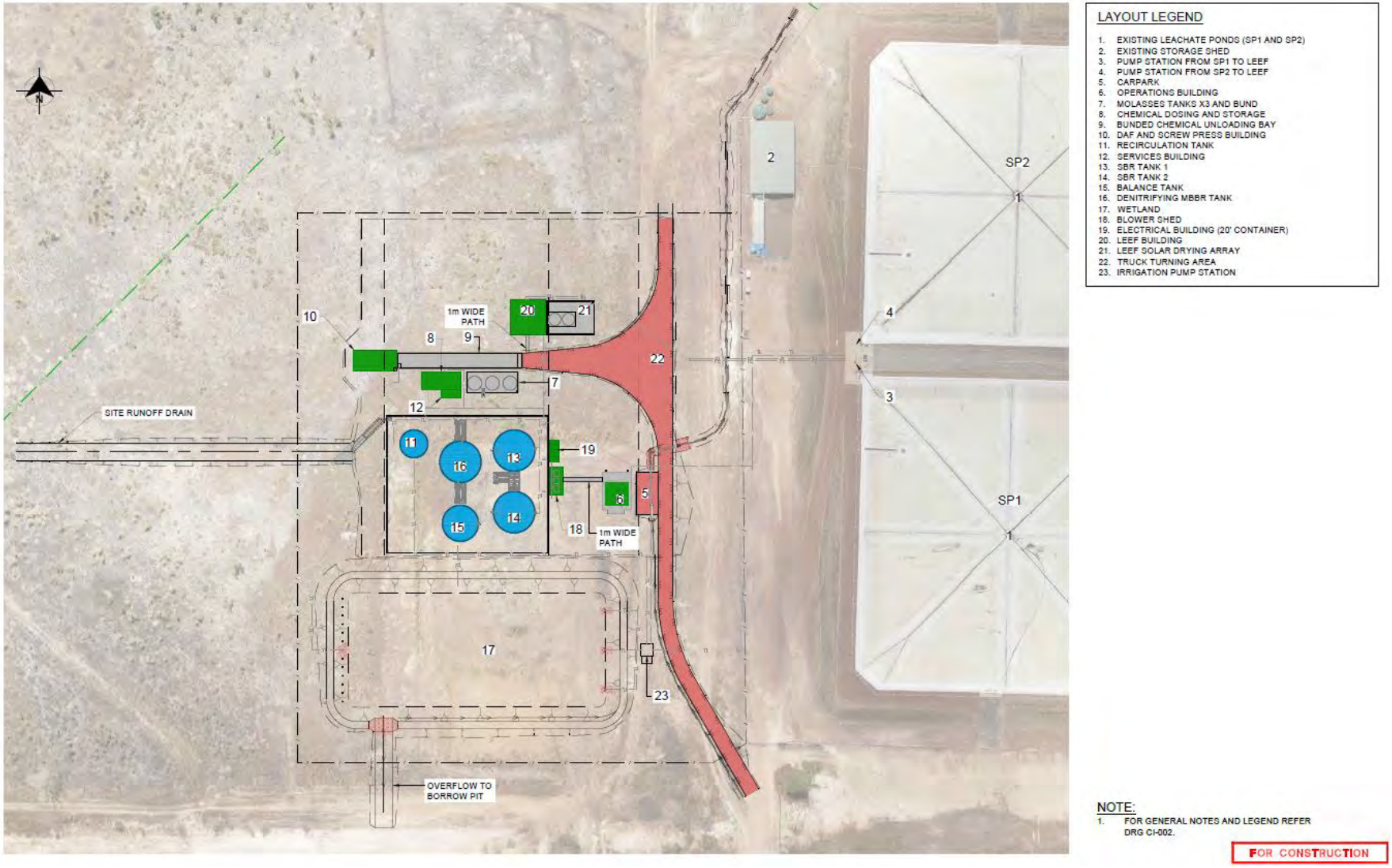


Figure 3: Leachate Treatment System Overview

5.0 LEACHATE LEAKAGE MONITORING

5.1 Groundwater Monitoring Well Network

A network of 44 groundwater monitoring wells has been installed within the SBWMF that is designed to identify the migration of contaminants from the various general waste landfill stages into underlying groundwaters.

This network acts as a leak detection system for the leachate management systems at the site, including the landfill cell linings and the leachate storage facilities. The monitoring network also includes leachate sampling points withing the landfill cells, supporting the comparison of the leachate contaminant profile with potential contamination trends observed in the groundwater.

A Water Quality Monitoring Plan (WQMP) has been developed for the facility (EcOz Environmental Consultants, 2020). This document is appended to the Environmental Management Plan (City of Darwin, 2020). The WQMP requires that groundwater and leachate samples are collected quarterly, in January, April, July and October each year. Collected samples are analysed for:

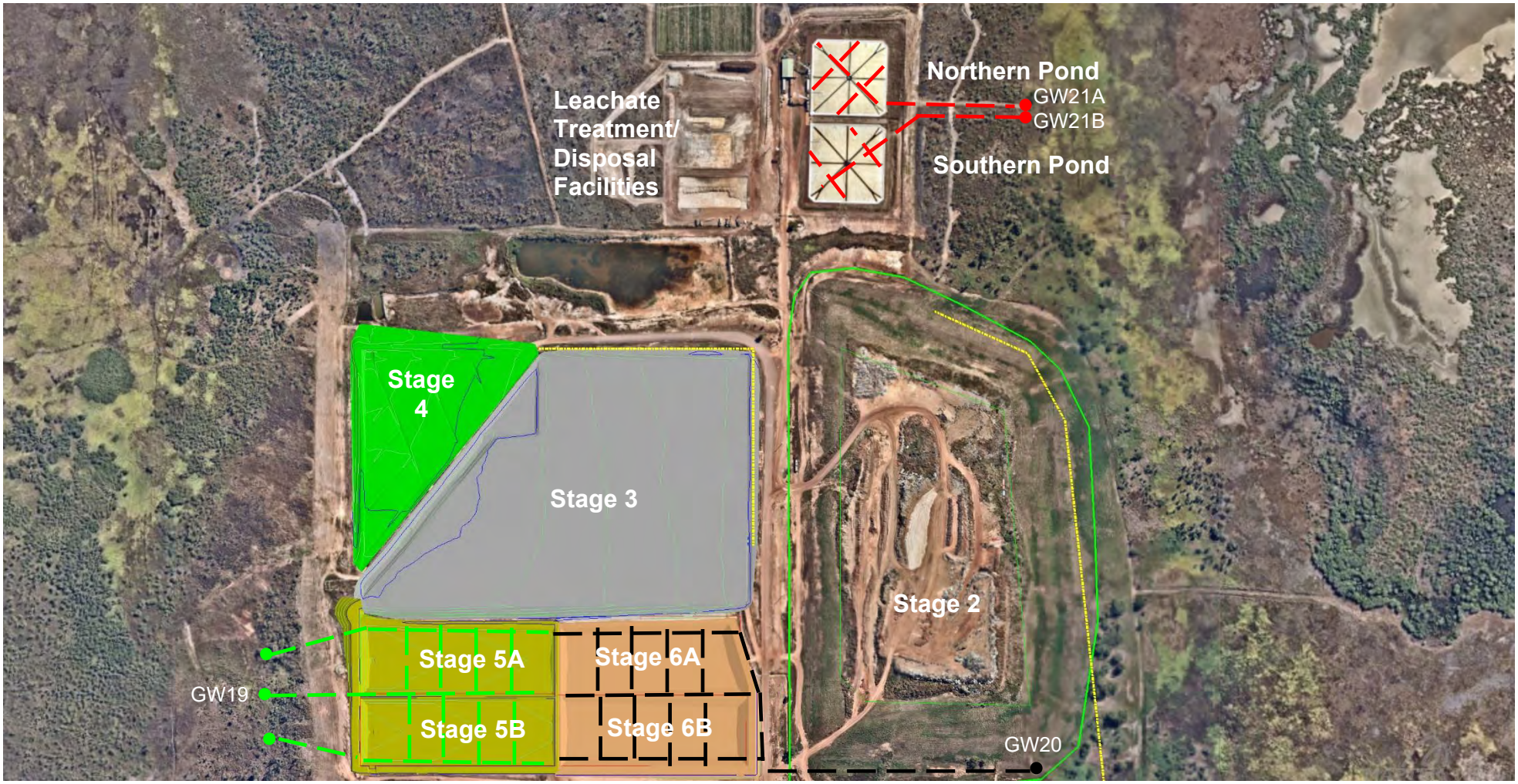
- Ammonium
- Total dissolved solids
- Chemical oxygen demand
- Total organic carbon
- Major ions (Na, K, Ca, Mg, alkalinity, chloride, SO4)
- Nutrients (ammonia as N, nitrate, nitrite, total nitrogen, total phosphorus)
- Dissolved metals (chromium, copper, nickel, lead and zinc)
- Petroleum hydrocarbons (TRH)
- Benzene, toluene, ethylbenzene, xylene, naphthalene (BTEXN)
- Per- and poly-fluoroalkyl substances (PFAS)

The location of each of the monitoring points is detailed in Table 2-1 of the WQMP and each location is mapped in Figure 2-1 of the WQMP. This figure has been included in Appendix B.

5.2 Subgrade Drainage Monitoring Network

Groundwater subgrade drainage infrastructure has been installed beneath the liner systems of the Stage 5 and Stage 6 general waste landfill cells and the two covered leachate storage ponds. The purpose of these subgrade drainage systems it to maintain a minimum 2 m vertical distance between the base of the respective liner systems and underlying shallow perched groundwater that rises near to ground level during wet season conditions. The subgrade drainage systems comprise gravel filled trenches fitted with perforated pipelines that gravity drain to surface outlets located above 1% AEP flood levels within the adjacent tidal wetlands. The installed subgrade drainage networks are shown on Figure 3,

Figure 4: SBWMF Subgrade drainage networks and monitoring locations



Sources: Nearmap Image, June 2021, Council Stage 4/Stage 5 As-Constructed Survey, 2012 & 2016, Golder Design, 2019

Discharges from the subsurface drainage systems are used as part of the leachate leakage detection monitoring system as summarised in Table 6. The location of the monitoring infrastructure is outlined in Figure 4.

Table 6: Subsurface Drainage Groundwater Discharge Monitoring Locations

Drainage Systems	Stage 5	Stage 6	Northern Pond	Southern Pond
Monitoring Locations	GW19	GW20	GW21A	GW21B

Samples are collected quarterly (when drainage system is discharging groundwater) directly from the outfall points. Samples collected from each of the outfalls is analysed for the following:

- Ammonium
- Total dissolved solids
- Chemical oxygen demand
- Total organic carbon
- Major ions (Na, K, Ca, Mg, alkalinity, chloride, SO4)
- Nutrients (ammonia as N, nitrate, nitrite, total nitrogen, total phosphorus)
- Dissolved metals (chromium, copper, nickel, lead and zinc)
- Petroleum hydrocarbons (TRH)
- Benzene, toluene, ethylbenzene, xylene, naphthalene (BTEXN)
- Per- and poly-fluoroalkyl substances (PFAS)

6.0 LEACHATE PUMPING SYSTEMS

Pumping systems operated within the SBWMF to collect and transfer leachate from the waste disposal stages to management infrastructure is summarised in Table 7.

Table 7: Summary of Leachate Pumping Systems and Operation

Stages	Leachate Sumps	Pumping System	Energy Source	Operation
Stage 1	Sump 1/2	Electric	Mains Power	Automatic Water Level Trigger
Stage 2				
Stage 3	Sump 3B	Pneumatic	Automatic compressor systems connected to mains power	Automatic Water Level Trigger
Stage 4	Sump 4			Automatic Water Level Trigger
Stage 5	Sump 5A/5B			Automatic Water Level Trigger
Stage 6	Sump 6A/6B			Automatic Water Level Trigger
Leachate Ponds	Sump NP/SP			Automatic Water Level Trigger

7.0 INSPECTION AND MAINTENANCE PROGRAMS

Operations at the Facility are managed and conducted by Veolia in accordance with a Site Based Management Plan (SBMP) for the SBWMF. This SBMP contains operational and environmental control plans, which identify hazards, objectives for the management of a hazard, performance indicators, monitoring requirements, reporting requirements and control strategies for the hazard. The SBMP contains an operational and environmental control plan for leachate management, with key elements summarised in Table 8 below.

Table 8: Operational and Environmental Control Plan - Leachate Management (Veolia, 2020)

Element	Actions	Responsible Person	Timing
Objective	To manage the potential impacts associated with the production and storage of leachate.		
Management Strategy	To maintain appropriate leachate collection structures and devices to manage the production and release of leachate.		
Performance Indicators	■ Leachate from the landfill is to remain on site; and ■ All surface leachate to be collected and contained on the site.		
Monitoring	Site manager, supervisor, and operational personnel to assess the condition of leachate systems and structures on a weekly basis, results to be recorded.	OM, SS, OP, SS	Weekly
Reporting	Report any incident to the Operations Manager/Supervisor. Any incidents to be recorded in RIVO. Weekly leachate infrastructure monitoring to be recorded in Landfill Weekly Checklist.	OM, OP, SS	As required Weekly
Control Strategies	To manage the potential impacts of leachate the following strategies may be implemented:		
	■ Maintain appropriate leachate collection and storage structures to prevent the release of leachate.	OM, SS, SM	As required
	■ Cover all completed landfill areas with a suitable cover material to minimise the ingress of water.	SS, OM	Ongoing
	■ Ensure that leachate pumps are correctly installed and operating in leachate sumps to pump leachate into storage tanks for recirculation back into landfill working face or through leachate recirculation lines.	SS, OM	As required
	■ Minimise the level of leachate above the landfill floor by pumping leachate from the sump directly onto the landfill leachate recirculation system.	SS, OP	As required
	■ Redirect stormwater away from the landfill face to prevent the contamination of stormwater.	OP, EO, WO	Ongoing
	■ Ensure all waste meets the landfills waste acceptance criteria.	SS	Ongoing

SS – Site Supervisor OP – Operational Personnel

RIVO – Veolia's Incident and Compliance Management System

8.0 DATA COLLECTION INFRASTRUCTURE AND RECORDING METHODOLOGY

The methodology and processes for the collection and recording of leachate data is documented in Council's Environmental Management Plan for the SBWMF. Key elements of data management comprise:

- Council is required by the Information Act to ensure that complete and accurate records of the business of Council are created and managed for as long as required to support business, accountability, and legislative requirements until their disposal in accordance with an authorised retention and disposal schedule. This requirement is outlined in Council Record and Information Management Policy (Policy No 057), which applies to all Council staff and to records of all business activities performed by or on behalf of Council.
- All environmental documentation, plans, procedures, reports, data and records will be uploaded onto the Council electronic document and records management system. Records of quantities and source of leachate managed at the SBWMF will be maintained through Council electronic systems.
- All records will be held for at least 10-years and will be accessible to the regulatory authorities as required.
- Leachate management data recorded by the Landfill Operations Contractor (Veolia) and Council is summarised in Table 9.

Table 9: Leachate Management Data Collection Summary

Locations	Data Source	Methodology	Frequency
Stage 1	Sump 1/2	Water flow meter – manual reading	Daily
Stage 2			
Stage 3	Sump 3B/3X/3Y/3Z	Pneumatic pump cycles – automated readings	Daily
Stage 4	Sump 4	Pneumatic pump cycles – automated readings	Daily
Stage 5	Sump 5A/5B	Pneumatic pump cycles – automated readings	Daily
Stage 6	Sump 6A/6B	Pneumatic pump cycles – automated readings	Daily
Leachate Ponds	Inflow volumes	Water flow meter – manual reading	Daily
	Storage volumes	Survey of floating cover elevation	Monthly
Benevap Systems	Evaporation system 1	Water flow meter – manual reading	Daily
	Evaporation system 2	Water flow meter – manual reading	Daily
Irrigation Systems	Stage 1/Stage 2	Water flow meter – manual reading	Daily
	Stage 3/Stage 4	Water flow meter – manual reading	Daily
Treatment System	Leachate Pond Extraction	Under construction. To be confirmed.	Daily
	Treated Leachate Storage		Daily
	Treated Leachate Irrigation		Daily

8.1 Future Leachate Irrigation Monitoring

Prior to the commencement of leachate irrigation, an irrigation monitoring program must be developed. This program should include the monitoring of irrigation water (leachate) quality, as well as monitoring of vegetation condition and runoff mitigation infrastructure. Reference to this monitoring program should be added to this Program as part of a future revision (see Section 9.0).

9.0 REVISION OF THIS PROGRAM

This Program should be reviewed on an annual basis, or as new systems come online. Additions, such as treatment and irrigation infrastructure, should be incorporated into the Program immediately upon commissioning.

10.0 IMPORTANT INFORMATION

Your attention is drawn to the document titled - “Important Information Relating to this Report”, which is included in Appendix A of this report. The statements presented in that document are intended to inform a reader of the report about its proper use. There are important limitations as to who can use the report and how it can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Important Information document does not alter the obligations Golder Associates has under the contract between it and its client.

Signature Page

Golder Associates Pty Ltd

Luke Jacovides
Senior Environmental Scientist

James Begg
Principal Engineer, Waste Management

LJ/AH/JSB/sk

A.B.N. 64 006 107 857

https://golderassociates.sharepoint.com/sites/124524/shared documents/deliverables/006 - integrated leachate management program/rev2/20140796-006-r-rev2 - shoal bay landfill leachate management program.docx

APPENDIX A

Important Information

The document ("Report") to which this page is attached and which this page forms a part of, has been issued by Golder Associates Pty Ltd ("Golder") subject to the important limitations and other qualifications set out below.

This Report constitutes or is part of services ("Services") provided by Golder to its client ("Client") under and subject to a contract between Golder and its Client ("Contract"). The contents of this page are not intended to and do not alter Golder's obligations (including any limits on those obligations) to its Client under the Contract.

This Report is provided for use solely by Golder's Client and persons acting on the Client's behalf, such as its professional advisers. Golder is responsible only to its Client for this Report. Golder has no responsibility to any other person who relies or makes decisions based upon this Report or who makes any other use of this Report. Golder accepts no responsibility for any loss or damage suffered by any person other than its Client as a result of any reliance upon any part of this Report, decisions made based upon this Report or any other use of it.

This Report has been prepared in the context of the circumstances and purposes referred to in, or derived from, the Contract and Golder accepts no responsibility for use of the Report, in whole or in part, in any other context or circumstance or for any other purpose.

The scope of Golder's Services and the period of time they relate to are determined by the Contract and are subject to restrictions and limitations set out in the Contract. If a service or other work is not expressly referred to in this Report, do not assume that it has been provided or performed. If a matter is not addressed in this Report, do not assume that any determination has been made by Golder in regards to it.

At any location relevant to the Services conditions may exist which were not detected by Golder, in particular due to the specific scope of the investigation Golder has been engaged to undertake. Conditions can only be verified at the exact location of any tests undertaken. Variations in conditions may occur between tested locations and there may be conditions which have not been revealed by the investigation and which have not therefore been taken into account in this Report.

Golder accepts no responsibility for and makes no representation as to the accuracy or completeness of the information provided to it by or on behalf of the Client or sourced from any third party. Golder has assumed that such information is correct unless otherwise stated and no responsibility is accepted by Golder for incomplete or inaccurate data supplied by its Client or any other person for whom Golder is not responsible. Golder has not taken account of matters that may have existed when the Report was prepared but which were only later disclosed to Golder.

Having regard to the matters referred to in the previous paragraphs on this page in particular, carrying out the Services has allowed Golder to form no more than an opinion as to the actual conditions at any relevant location. That opinion is necessarily constrained by the extent of the information collected by Golder or otherwise made available to Golder. Further, the passage of time may affect the accuracy, applicability or usefulness of the opinions, assessments or other information in this Report. This Report is based upon the information and other circumstances that existed and were known to Golder when the Services were performed and this Report was prepared. Golder has not considered the effect of any possible future developments including physical changes to any relevant location or changes to any laws or regulations relevant to such location.

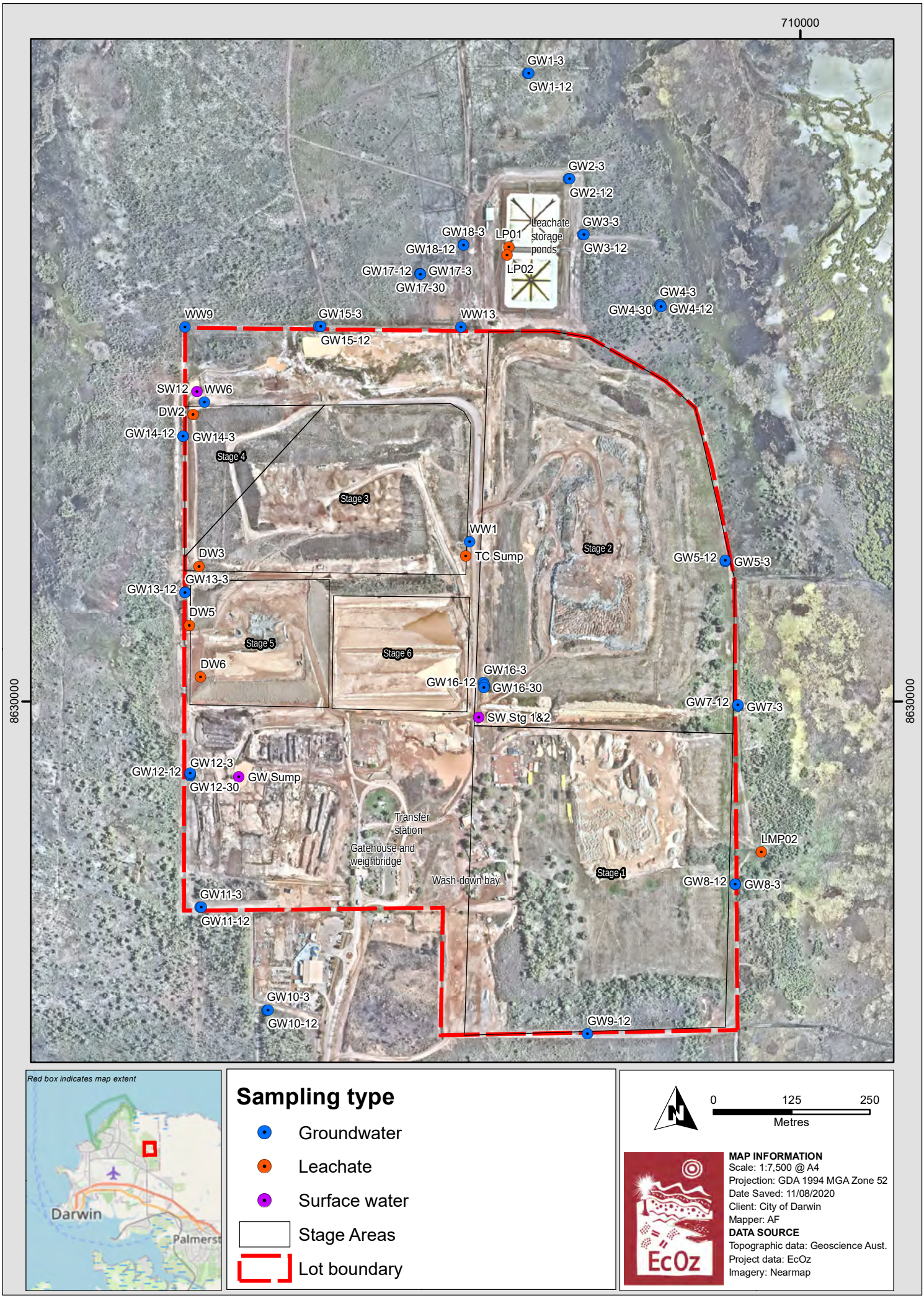
Where permitted by the Contract, Golder may have retained subconsultants affiliated with Golder to provide some or all of the Services. However, it is Golder which remains solely responsible for the Services and there is no legal recourse against any of Golder's affiliated companies or the employees, officers or directors of any of them.

By date, or revision, the Report supersedes any prior report or other document issued by Golder dealing with any matter that is addressed in the Report.

Any uncertainty as to the extent to which this Report can be used or relied upon in any respect should be referred to Golder for clarification

APPENDIX B

Monitoring Points: Figure 2-1 from the WQMP



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\WQMP Figure 2-1. SBWMF layout and monitorig site locations.mxd

Figure 2-1. Map of SBWMF layout and monitoring site locations

golder.com

Appendix E3 Leachate Irrigation Plan

Shoal Bay Leachate Treatment Facility

the WATER & CARBON group

Irrigation Management Plan

Prepared for the City of Darwin

February, 2022

Project Title	**SHOAL BAY WASTE LEACHATE TREATMENT AND DISPOSAL FACILITY**
Project Location	Holmes, NT.
Main Contractor details	The Water and Carbon Group Pty Ltd
Main Contractor ABN/ACN	ABN: 17 125 935 855
Site Manager	Simon Toomey 0403 699 983
Client	City of Darwin
Planned commencement dates and project schedule	Construction Start 2020 – Commissioning 2022.

Report Disclaimer

This report has been prepared by The Water and Carbon Group Pty Ltd upon instructions and information supplied by City of Darwin.

The Water and Carbon Group should be consulted to ascertain the suitability of the information contained herein. The Water and Carbon Group accepts no responsibility for the application of the contents of this report by a third party who has not verified the use of this report for their purposes with the Water and Carbon Group.

VERS.	ISSUE	ISSUED TO	PREPARED	REVIEWED	APPROVED	DATE
Rev 0	Initial	City of Darwin	Robert McKenzie	Cliff Duckworth David Leinster	Jean-Marc Laurillard	24-02-22

Abbreviations and Definitions

Summary	Details
ANZECC	Australian and New Zealand Environment and Conservation Council
CEMP	Construction Environmental Management Plan
CoD	City of Darwin
DoD	Department of Defence
EC	Electrical Conductivity
ECe	Electrical Conductivity of a Water-Saturated Soil Paste
EPL	Environmental Protection License
ESP	Exchangeable Sodium Percentage
IMP	Irrigation Management Plan
LMF	Leachate Management Facility
LPWA	Low Power Wide Area
NT EPA	Northern Territory Environmental Protection Authority
PFOA	Perfluorooctanoic Acid
PFOS	Perfluorooctane sulfonic acid
SBWMF	Shoal Bay Waste Management Facility
SCCP	Stakeholder Consultation and Communication Plan
SMP	Safety Management Plan
TMP	Traffic Management Plan
TN	Total Nitrogen
WCG	The Water and Carbon Group

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1. Introduction

This document constitutes the Irrigation Management Plan (IMP) for the Shoal Bay Waste Management Facility's (SBWMF) Irrigation area. The Water and Carbon Group is engaged by the City of Darwin (CoD) to Design, Build and Operate the leachate treatment and disposal facility at the Shoal Bay Waste Management Facility.

This Irrigation Management Plan has been developed to outline the management activities which form the operation of the irrigation area. It comprises a presentation of the project background and objectives, and describes the operation, maintenance and environmental management activities and control measures that will be implemented to avoid or minimise environmental impacts arising from the irrigation area.

1.1. Purpose of Irrigation Management Plan

The purpose of this Irrigation Management Plan is to detail how the treated leachate irrigation scheme is to be managed to ensure that it is carried out in an environmentally sustainable manner. The IMP has been prepared as a requirement of the NT EPA licence Conditions (refer to Section 1.3) and with reference to the following key documents:

1. NSW Environmental Guidelines: Use of Effluent via Irrigation, NSW Department of Environment and Conservation (2004); and
2. National Water Quality Management Strategy - Guidelines for Sewerage Systems - Use of Reclaimed Water (ARMCANZ, ANZECC, NHMRC 2000);

In addition to the IMP, a number of supporting documents have been prepared and are referenced throughout. These documents include:

1. Shoal Bay Leachate Disposal Area Detailed Design Drawings
2. Shoal Bay Leachate Disposal Area MEDLI model and report
3. Landfill Cell Capping Design

This IMP outlines the management practices required for the sustainable operation of the irrigation scheme, continued improvement, and review of irrigation operations and to achieve a best practice approach to water resource management. Management strategies aim to

1. Minimise environmental harm to the site,
2. Preserve site vegetation and soil conditions,
3. Minimise off-site movement of irrigation water via surface flow or soil interflow, and
4. To ensure that the capacity of the land to assimilate nutrients is not exceeded.

This document aims to provide treated leachate irrigation operational strategies for periods of dry and wet weather.

1.2. Scope of Irrigation Management Plan

The aim of the Shoal Bay Leachate Disposal Area Irrigation Management Plan is to irrigate an estimated 50ML/yr of treated leachate to the 6.5ha irrigation area planted with Vetiver (*Chrysopogon zizanioides).*

Vetiver is a fast growing, sterile perennial, tufted grass with a dense, deep, and strong root structure. The stem networks of Vetiver grass create dense hedges that dissipate energy, increase water infiltration and retention, plus stabilise, and protect soil. These unique attributes are further bolstered by Vetiver's ability to increase soil microbial activity, maximising the grasses' ability to break down, absorb and store pollutants.

This IMP details irrigation management and monitoring of the vetiver irrigation area so that the following objectives are met:

1. Vetiver grows vigorously and maximises water and nutrient uptake,
2. The capacity of the irrigation area to assimilate nutrients is not exceeded,
3. Treated leachate is evenly distributed on the irrigation area,
4. There is no surface ponding of treated leachate,
5. Soil moisture levels are managed to avoid soil saturation during the dry season and therefore surface runoff,
6. Soil erosion and deterioration in soil structure is avoided,
7. Salts are managed as not to affect plant health and growth,
8. Provide procedures for health and safety for operators,
9. Optimal maintenance of centre pivot and monitoring probes to ensure long-term reliability, and
10. Effective management of spray drift, pests, fire and weeds to avoid negative impacts on the irrigation scheme.

1.3. NT EPA Licence Clauses for Irrigation Area

This Irrigation, Operations and Maintenance Program must be in accordance with the Use of Effluent by Irrigation Guideline by the Department of Environment and Conservation (NSW) 2004 to:

- 40.1 manage the impact of treated leachate on soil structure for the specific soil type;
- 40.2 the quality of runoff leaving the irrigation area from the use of saline irrigation water; and
- 40.3 repair and maintenance of surfaces such as vegetation, draining and cover soil top up.

The operator must ensure that any irrigation, repair, or maintenance specified are undertaken in accordance with the Irrigation, Operations and Maintenance Program.

2. System Overview

WCG has been engaged by City of Darwin (CoD) to deliver the leachate treatment solution for the SBWMF since 2016. Over the past five years, and through a rigorous tender process, WCG has developed and tested a leachate and PFAS treatment solution to meet the unique needs of the Shoal Bay Waste Management Facility. The system will progressively treat the legacy leachate accumulated within the landfill cells and the leachate storage ponds, as well as ongoing production of leachate over the coming years. This unique project delivers outstanding environmental outcomes for Darwin by significantly reducing the risks for future uncontrolled releases of leachate and associated contaminants, with a system designed to minimise waste production and energy usage.

The SBWMF is located approximately 12km northeast of Darwin city within Lot 3952, Town of Sanderson as shown in Figure 1. The property on which sits the SBWMF is owned by the Commonwealth Department of Defence (DoD) and leased to CoD. Under the terms and conditions of the lease, the property is designated as a Waste Management Project Area in which CoD is authorised to conduct waste management and ancillary activities.

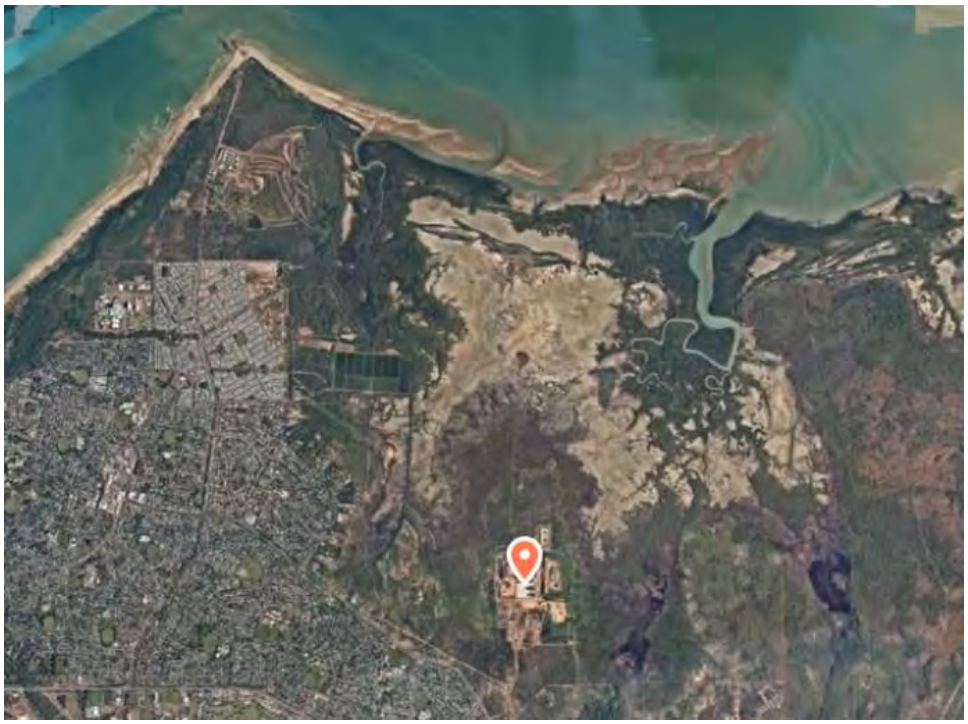


Figure 1: Location of Shoal Bay Waste Management Facility (NearMaps 2020)

The operational area of the SBWMF is located within the southern part of the property and 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 to the SBWMF is the suburb of Karama, about 0.7km to the southwest with a bushland buffer in between.

2.1. Leachate Treatment

The raw leachate collected in the Raw Leachate Storage Pond SP1 will be treated to a high quality to enable irrigation to land and any excess of the treated leachate will be stored in the Treated Leachate Storage Pond SP2 for future use. The treatment process consists of the following major process stages:

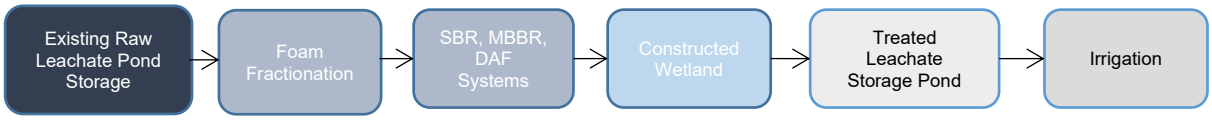


Figure 2: Shoal Bay Landfill Leachate Treatment Process

1. A raw leachate storage pond
2. Foam fractionation and extraction process for PFAS removal
3. Sequencing Batch Reactor (SBR) and Moving Bed Biofilm Reactor (MBBR) process – aerobic tanks, anoxic tank and Dissolved Air Flotation (DAF)
4. Constructed wetland
5. Treated leachate storage pond
6. Irrigation vetiver grass operation

The treatment system has been sized to treat flows up to 140kL/d and designed to operate from 25kL/d (minimum) to 140kL/d (maximum) to treat the nominated water quality influent listed in Table 1 and Table 2 with the main contaminant of concern Total Nitrogen (TN) being treated from 2000mg/L to <170mg/L prior to irrigation.

Table 1: Summary of Raw Leachate Data from Shoal Bay Landfill (2017 - 2018)

		Leachate well data (2014 - 2018): DW1, DW2, DW3, TC Sump		Leachate Pond data (2016-2018): LP1, LP2		Selected Design Values	Tolerance	
Parameter	Units	Average	Median	Average	Median		+%	-%
Dissolved Oxygen	mg/L					2	N/A	N/A
Biochemical Oxygen Demand	mg/L	259	190.0	128	91	200	20	50
Chemical Oxygen Demand	mg/L	4411	4230	3622	3930	4400*	20	50
TOC	mg/L	1508	1350	1441	1220	1500	10	50
Chloride	mg/L	2530	2600	1894	1860	2500	10	20
Conductivity (at 25°C)	µS/cm	21057	21080	17099	17325	20000	10	20
Total Dissolved Solids	mg/L	3245	11.8	2133	11.2	8000	10	20
Total Dissolved Solids (sum of ions)	mg/L					14000**	10	20
Ammonia (as N)	mg/L	1605	1583	1302	1260	1600	25***	50
Nitrate & Nitrite (as N)	mg/L	11	6.6	54	5.0	25	20	100
Nitrate (as N)	mg/L	26.4	2.0	45.2	2.0	20	20	100
Nitrite (as N)	mg/L	3	2.0	26	2.1	5	20	100
Total Kjeldahl Nitrogen (as N)	mg/L	1861	1821	11	11	2000	25***	50
Total Nitrogen (as N)	mg/L	1902	1825	1591	1516	2000	25***	50
pH	-	7.8	7.8	8.0	8.0	7.8	10	10
Phosphate ortho (as P)	mg/L	10.0	9.2	9	10	10	20	10
Phosphate total (as P)	mg/L	14	13.6	11	11.3	12	10	10
Sulphate (as S)	mg/L	65	10.0	99	10.0	100	20	20
Alkali Metals								
Calcium	mg/L	48	42	42	43	50	50	20
Magnesium	mg/L	51	50.6	47	46	50	50	20
Potassium	mg/L	794	760	751	453	800	20	20
Sodium	mg/L	1973	2000.0	1731	1295	1750	20	20
Alkalinity (speciated)								
Bicarbonate Alkalinity (as $CaCO_3$)	mg/L	7722	7131	6928	6452	8800	50	10
Carbonate Alkalinity (as $CaCO_3$)	mg/L	70	45.0	118	62.0	150	50	10
Hydroxide Alkalinity (as $CaCO_3$)	mg/L	2.0	0.5	1.9	0.5	5	50	10
Total Alkalinity (as $CaCO_3$)	mg/L	7870	7400	5344	5171	8955	50	10
Alkalinity to Ammonia-N Ratio						5.6	20	0
Heavy Metals								
Boron	mg/L	4.4	4.2	4.0	4.0	4.5	10	100
Iron	mg/L	9	8.6	7.6	5.2	8	20	100
Mn	mg/L	1.8	0.1	0.1	6.0	0.25	20	100
Fe (II)	mg/L	5.7	4.1	4.0	3.0	6	20	100
Fe (III)	mg/L	2.0	1.1	3.5	3.8	4	20	100
Cd	mg/L	0.0	0.0	0.0	2.9	0.002	10	100
Cr (III)	mg/L	0.5	0.5	0.6	0.3	0.6	10	100
Cr (VI)	mg/L	0.4	0.3	0.4	0.5	0.4	10	100
Cu	mg/L	0.1	0.1	0.0	0.1	0.1	10	100
Ni	mg/L	0.2	0.2	0.2	0.1	0.2	10	100
Pb	mg/L	0.0	0.0	0.0	0.1	0.025	10	100
Zn	mg/L	0.6	0.6	0.7	0.2	0.8	10	100
Total Recoverable Hydrocarbons - 1999 NEPM Fractions								
TRH C10-36 (Total)	mg/L	12	8.6	13.7	4.3	15	20	100
TRH C10-C14	mg/L	2.5	2.2	3	0.8	3	20	100
TRH C15-C28	mg/L	8.8	5.8	10.0	3.1	10	20	100
TRH C29-C36	mg/L	0.9	1.0	1.2	0.3	1.2	20	100
TRH C6-C9	mg/L	1.1	0.6	0.9	0.1	1	20	100
Total Recoverable Hydrocarbons - 2013 NEPM Fractions								
Naphthalene	mg/L	0.4	0.1	0.3	0.3	0.4	20	100
TRH >C10-C16	mg/L	3.3	3.0	3.2	3.3	4.0	20	100
TRH >C10-C16 less Naphthalene	mg/L	3.1	2.6	3.2	3.3	4.0	20	100
TRH >C16-C34	mg/L	8.7	5.8	10	11.0	10	20	100
TRH >C34-C40	mg/L	0.2	0.2	0.3	0.2	0.4	20	100
TRH C6-C10	mg/L	1.1	0.7	0.9	1.0	1.0	20	100
TRH C6-C10 less BTEX (F1)	mg/L	1.0	0.5	1.6	1.0	1.0	20	100

* COD is all recalcitrant, and any change to its biodegradability will need to be assessed for impact on treatment.
** TDS as sum of ions should be used for design basis.
*** Overarching design limit is 280 kg/d as N. If TKN concentration exceeds 2,000 mg/L, the hydraulic loading will need to adjust to this limit.

Table 2: Summary of PFAS Chemical Family Leachate Data from Shoal Bay Landfill (2017 - 2018) and Adopted Design Values.

		Leachate well data (2017 - 2018): DW2, DW3, TC Sump		Leachate Pond data (2017-2018): LP1, LP2		Selected Design Value	Tolerance	
Parameter	Units	Average	Median	Average	Median		+%	-%
Perfluorooctane sulfonic acid (PFOS)	µg/L	0.7	0.6	0.7	0.82	0.74	20	50
Perfluorooctanoic acid (PFOA)	µg/L	2.1	2.09	1.5	1.6	1.78	10	50
Perfluorobutane sulfonic acid (PFBS)	µg/L	13	12.7	8.9	8.46	10.9	20	50
Perfluoropentane sulfonic acid (PFPeS)	µg/L	0.1	0.05	0.2	0.08	0.16	20	100
Perfluorohexane sulfonic acid (PFHxS)	µg/L	0.6	0.525	0.7	0.63	0.65	20	100
Perfluoroheptane sulfonic acid (PFHpS)	µg/L	0.1	0.025	0.2	0.03	0.14	20	100
Perfluorodecane sulfonic acid (PFDS)	µg/L	0.1	0.025	0.7	0.03	0.43	20	100
Perfluorobutanoic acid (PFBA)	µg/L	0.7	0.25	0.7	0.18	0.7	20	100
Perfluoropentanoic acid (PFPeA)	µg/L	0.8	0.95	0.8	0.82	0.81	20	100
Perfluorohexanoic acid (PFHxA)	µg/L	2.5	2.475	2.1	2.03	2.31	20	100
Perfluoroheptanoic acid (PFHpA)	µg/L	0.7	0.67	0.7	0.59	0.71	20	100
Perfluorononanoic acid (PFNA)	µg/L	0.2	0.12	0.2	0.11	0.17	20	100
Perfluorodecanoic acid (PFDA)	µg/L	0.2	0.12	0.1	0.08	0.15	20	100
Perfluoroundecanoic acid (PFUnDA)	µg/L	0.1	0.025	0.1	0.03	0.11	20	100
Perfluorododecanoic acid (PFDoDA)	µg/L	0.1	0.025	0.1	0.03	0.11	20	100
Perfluorotridecanoic acid (PFTrDA)	µg/L	0.1	0.025	0.1	0.03	0.11	20	100
Perfluorotetradecanoic acid (PFTeDA)	µg/L	0.3	0.06	0.3	0.06	0.28	20	100
Perfluorooctane sulfonamide (FOSA)	µg/L	0.1	0.025	0.1	0.03	0.11	20	100
N-Methyl perfluorooctane sulfonamide (MeFOSA)	µg/L	0.3	0.06	0.3	0.06	0.27	20	100
N-Ethyl perfluorooctane sulfonamide (EtFOSA)	µg/L	0.3	0.06	0.3	0.06	0.27	20	100
N-Methyl perfluorooctane sulfonamidoethanol (MeFOSE)	µg/L	0.3	0.06	0.3	0.06	0.27	20	100
N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	µg/L	0.3	0.06	0.3	0.06	0.27	20	100
N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	µg/L	0.2	0.05	0.2	0.05	0.17	20	100
N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	µg/L	0.2	0.05	0.2	0.05	0.19	20	100
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	µg/L	0.1	0.025	0.1	0.03	0.13	20	100
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	µg/L	0.5	0.5	0.4	0.35	0.46	20	100
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	µg/L	0.1	0.0375	0.1	0.04	0.15	20	100
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	µg/L	0.1	0.025	0.1	0.03	0.11	20	100
Sum of PFAS	µg/L	21.1	20.9	15.5	17.3	18.3	20	100
Sum of PFHxS and PFOS	µg/L	1.2	1.165	2.9	1.66	2.06	20	100
Sum of PFAS (WA DER List)	µg/L	20.8	20.8	16.4	17.3	18.6	20	100

A detailed analysis of the proposed irrigation site and area required was undertaken to determine the effluent water quality requirements to allow sustainable irrigation at an application rate of 140 kL/day. Conclusions from the Pilot Plant, the Auditors Interim Advice (Zoic Environmental), Precise Environmental Land Irrigation Area Design and Management, and Final MEDLI report (available in Appendix A) identified treated leachate quality and required irrigation area as provided in

Table ***3*** and **Figure *3*** below.

Table 3: Environmental and Audit Report – Irrigation Parameters

PARAMETER	VALUE
Average volume to be irrigated	140 kL/d
Max effluent nitrogen concentration	170 mg/L
Irrigation area	6.5 ha

The PFAS level in the raw landfill leachate currently meets the 90% species protection guideline values for PFOS < 2 µg/L and PFOA < 632 µg/L. Further treatment is required to meet the 95% species protection limit for PFAS levels, as requested by the City of Darwin.

Table 4: PFAS effluent requirements (95% species protection)

PARAMETER	VALUE
PFOS	< 0.13 µg/L
PFOA	< 220 µg/L

The process of extracting these contaminants was determined during the Pilot Plant operations. The most efficient was foam fractionation undertaken prior to entering the SBLTP. The waste product "foamate" volume will be minimised to reduce destruction costs at an approved facility.

2.2. Treated Leachate Irrigation Area

The Shoal Bay Leachate Treatment and Disposal Area Facility is shown in **Figure *1***. This Irrigation Management Plan focuses on the centre pivot area on Figure 3.

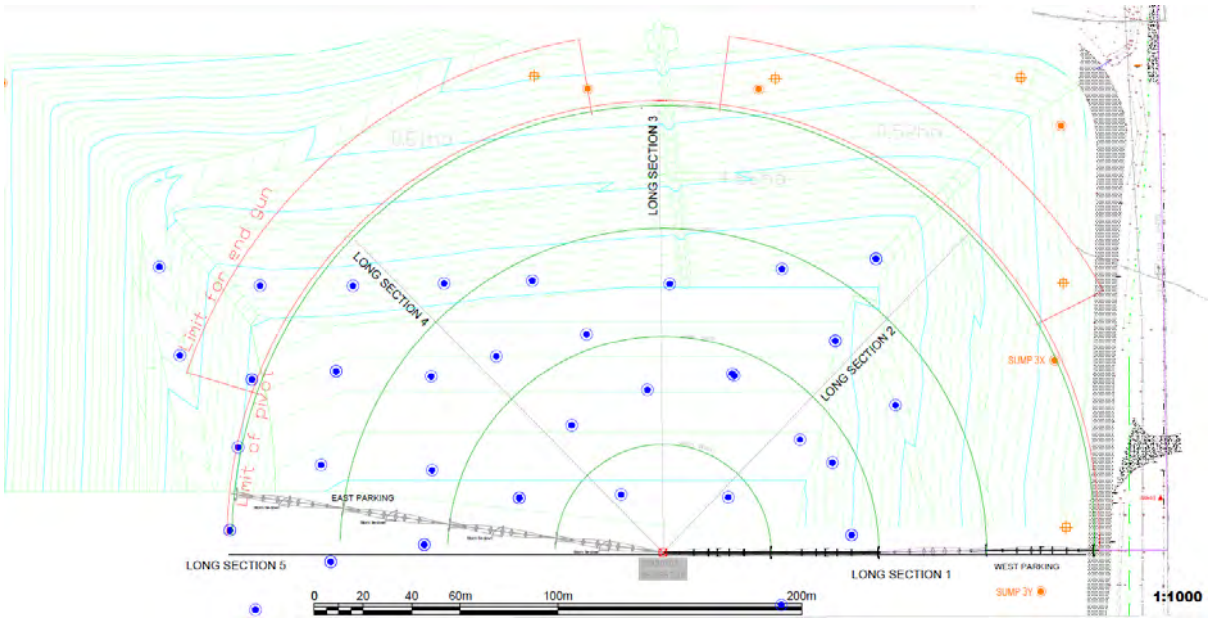


Figure 3: Map of Irrigation Area

2.3. Treated Leachate Characterisation

NSW Environmental Guidelines: Use of Effluent via Irrigation by NSW DEC recommends the initial characterisation of treated effluent in accord with Table 5 below to identify environmental issues. An assessment of the treated leachate characterised as Table 5 below is shown in Table 6.

Table 5: Treated Leachate Characterisation from Table 3.1 NSW Effluent via Irrigation Guidelines (2004).

	STRENGTH (AVERAGE CONCENTRATION MG/L)[1]		
CONSTITUENT	**LOW[2]**	**MEDIUM**	**HIGH**
Total nitrogen	<50	50–100	>100
Total phosphorus	<10	10–20	>20
BOD_5	<40	40–1,500	>1,500
TDS[3]	<600	600–1,000	>1,000–2,500
Other pollutants (e.g., metals, pesticides)	Effluent with more than five times[4] the ANZECC and ARMCANZ (2000) long- term water quality trigger values for irrigation waters must be considered high strength for the purpose of establishing a strength class for runoff and discharge controls and will require close examination to ensure soil is not contaminated		

Table 6: Treated Leachate Characterisation in accord with Table 3.1 and 3.3 NSW Effluent via Irrigation Guidelines (2004)

PARAMETER	TREATMENT LEACHATE	CATEGORY
Nitrogen	170mg/L	Medium
Phosphorus	8mg/L	Low
BOD_5	<5mg/L	Low
TDS	6870mg/L	High
Ec	10.7dS/m	High
Aluminium	<20mg/L	NC* as pH>6,5
Arsenic	<0.1mg/L	NC*
Beryllium	<0.1mg/L	NC*
Cadmium	<0.01mg/L	NC*
Chromium	<0.1mg/L	NC*
Cobalt	<0.05mg/L	NC*
Copper	<0.1mg/L	NC*
Iron	<10mg/L	NC*
Lead	<1mg/L	NC*
Lithium	<2.5mg/L	NC*
Manganese	<0.2mg/L	NC*
Mercury	<0.002mg/L	NC*
Molybdenum	<0.01mg/L	NC*
Nickel	<0.2mg/L	NC*
Selenium	0.05mg/L	NC*
Zinc	<1mg/L	NC*

*NC: Not of Concern as below trigger values for long term use on all soil types (up to 100 years) from Table 3.3 NSW Effluent via Irrigation Guidelines

3. Irrigation Overview

The irrigation management strategy focuses on continued compliance with the EPA licence, avoiding/minimising any adverse environmental and occupational health impacts and ensuring long term environmentally sustainable and responsible operation of the system. This section provides a detailed summary of the management procedures and philosophy with reference to the following:

- Control philosophy;
- Irrigation system design, operation and control;
- Irrigation system scheduling and maintenance; and
- Supplementary control programs including runoff controls, vegetation management, personal hygiene and safety, access controls and staff training.

Detailed information on the irrigation hardware, control system and associated works can be found in the corresponding product manuals.

3.1. Philosophy, Operation and Control

The primary role of the treated leachate irrigation system is to facilitate the dispersal of treated leachate while achieving the following principal objectives:

- Optimal irrigation of treated leachate to maximise vetiver plant growth,
- Maximise nitrogen uptake in vetiver plants and minimise leaching of nitrate outside of the irrigation area,
- Ensure salt build-up in soils doesn't affect the plants ability to use water and use nutrients,
- Ensure soil structure is not impacted by sodicity and therefore infiltration of treated leachate into the soil root zone, and
- Preclude treated leachate irrigation during the high rainfall or when soil is close to saturation.

The Shoal Bay irrigation management system is based on the sustainable use of an estimated 50ML/yr of treated leachate storage pond SP2 and irrigated onto 6.5ha on the landfill capping of Cells 3 and 4. Irrigation occurs during the dry season and paused during the wet season when high rainfall causes soil saturation. The control of the irrigation system has the following requirements:

- At all times meet the requirements of the EPA licence,
- Centre pivot delivers even distribution of treated leachate,
- Careful management of high rainfall in the wet season, and
- Draw down the storage pond prior to the wet season.

Automatic Rain and Wind switches are used to assess current weather conditions (rainfall and wind speed) against predetermined threshold values. Once the threshold values are exceeded the daily irrigation cycle is switched off until the next daily cycle is initiated, and the event logged with the central controller.

A soil moisture monitoring system consisting of capacitive resistance type sensors to measure soil and salinity levels at 10cm intervals to a depth of 400mm and then at 200mm intervals to 600mm. Recordings will be taken at nominal 30-minute time intervals, and remote reporting back to a remote base on a daily basis. Transmission of the data using Low Power Wide Area (LPWA) technology with a range to 20km. There shall be two monitoring points at the pivot site, one nominally 100 meters from the pivot point and one nominally 150m from the pivot point. Included with the soil monitoring system shall be a software/hardware package to be installed on the site computer which will receive log and trend soil moisture readings and allow the operator to set trigger and full points to be displayed graphically.

3.2. Irrigation Design

The centre pivot irrigator will be fixed and meet irrigation design criteria outlined in Table 7 below

Table 7: Irrigation Design Criteria for the 6.5ha Vetiver Irrigation Area.

ITEM	DETAIL	
1	Pivot length	176m
2	Flow rate with end gun ON	11lps
3	Maximum inlet pressure (pivot on level ground)	2 Bar
4	Sprinkler regulators	0.68 Bar
5	Sprinkler type (include weights)	Wobbler or Rotor
6	Minimum sprinkler range when inverted @ 1.8m height	8m radius. A sprinkler uniformity of 90% will be the minimum acceptable
7	Minimum pivot rotation time	3.5 hours
8	Wheel size	11.2 x 38 Agricultural
9	Pivot centre	Galvanised mild steel
10	Pivot main pipe	Poly lined
11	All wet parts (main pipe, tower tops, couplings, overhangs etc)	Poly lined
12	Span clearance	Nominal minimum 2.9m
13	Lights	End tower = strobe Pivot point = Constant ON when operating
14	End tower to include sand trap and drain.	
15	Overhang to include end gun (SR100) flush point with booster pump and 50mm solenoid valve. Pressure gauge on last dropper.	
16	Pivot structure, all steel work, structures and wheel rims to be HDG	
17	Span electric cables to be double jacketed. Wiring to motors along base beam and down leg to be protected from stock and bird attack. Plastic flexible conduit will not be accepted unless guaranteed against sun and bird damage for a minimum 10 years.	
18	Drive shafts to have crop and personnel shields.	
19	Main control panel to be constructed of non-corrosive material – stainless steel or hard plastics. Must have sunroof over and covering the panel by 200% of top surface.	
20	Controller includes: • Sunlight viewable display and local keypad/control. Manual over-ride switches for use in the event of controller fail. • Safety shut down for misalignment, or any potentially damaging fault • Low pressure shut down • Speed control from 0-100% • Direction control forward and reverse • Programable automatic start through settable programs with speed, direction, wet or dry and sector control. • Fertiliser injector relay with settable sector control.	

The irrigation system has been designed to minimize the risk of adverse operator health and safety by way of:

- Plumbing controls,
- Signage, and
- Scheduling (Irrigation timing managed to minimise the potential for contact with treated leachate)

3.3. Irrigation Scheduling

100% of treated leachate will be discharged through the irrigation system. There are two criteria considered for the irrigation scheduling.

1. Be able to discharge all generated plus any stored water within a given period
2. Be able to meet crop demand during peak periods.

Daily crop demand will vary with seasonal change, crop stage and rainfall events. Table 8 below details indicative irrigation demand vs supply for an average year. The table shows that there will most likely be a shortage of water toward the end of the year, and that may follow into following years. This is the proposed irrigation schedule for the 6.5ha vetiver irrigation.

Table 8: Average Irrigation Demand vs. Supply

014015 DARWIN AIRPORT												
Latitude: 12.42 Degrees South												
Longitude: 130.89 Degrees East												
Elevation: 30 m												
State: NT												
Statistic Element	January	February	March	April	May	June	July	August	September	October	November	December
	31	29	31	30	31	30	31	31	30	31	30	31
Mean rainfall (mm) for years 1941 to 2021	431.8	369.3	312.4	101.6	20.7	1.8	1.1	4.7	16.6	70.8	142	250.4
Mean daily evaporation (mm) for years 1957 to 2021	6	5.7	5.7	6.3	6.7	6.8	6.8	7.2	7.6	7.9	7.3	6.5
Mean monthly evaporation (mm) for years 1957 to 2022	186	165.3	176.7	189	207.7	204	210.8	223.2	228	244.9	219	201.5
Rainfall deficit (month)	0	0	0	87.4	187	202.2	209.7	218.5	211.4	174.1	77	0
Irrigation depth required/month	0	0	0	52.4	112.2	121.3	125.8	131.1	126.8	104.5	46.2	0
Treated leachate volume consumed/month (kL)	0	0	0	3408.6	7293	7885.8	8178.3	8521.5	8244.6	6789.9	3003	0
Treated leachate volume consumed/day (kL)	0	0	0	113.6	235.3	262.9	263.8	274.9	274.8	219	100.1	0
Wastewater in stock	4340	8400	12740	13531.4	10578.4	6892.6	3054.3	-1127.2	-5171.8	-7621.7	-6424.7	-2084.7
Storage volume	15000	ML					Unlocked					
Wastewater generation	140	kL/day										
Crop factor	0.6	Kc										
Crop area	6.5	Ha										
Max pump rate	40	kL/hr										
Average pump rate	36	kL/hr										

3.4. Irrigation Maintenance

Operating and Maintenance manuals are to be provided by the irrigation contractor for system components. Routine and as required maintenance of the irrigation system is a responsibility of the Operator, and records of works completed, date and contractors should be maintained in accordance with this IMP. Refer to the Appendices for further information on O&M items.

3.5. Supplementary Protocols

3.5.1. Surface Runoff

The proposed spray irrigation and operating system presents a very low risk of surface ponding and/or runoff, as irrigation is scheduled to cease when the soil's field capacity is reached. This is to be monitored with the EnviroPro soil moisture probes or equivalent with irrigation controller and datalogging. Probes will include a radio and antennae that send data in real time to the base radio and intelligraph software.

3.5.2. Crop Management

The Vetiver crop will be managed to optimise productivity and via the irrigation schedule outlined in Section 3.3. This will ensure the highest level of uptake of nutrients and heavy metals remaining in the treated leachate used for irrigation. The initial 12-24 months the vetiver crop will be slashed and left on site to build organic matter in the soil for improved soil structure, water holding capacity and weed suppression. Once satisfactory organic matter has been established in the Landfill Capping cover soil the vetiver will be slashed and material removed from site and potentially reused as compost or mulch. The material will be tested prior to utilisation as a compost or mulch product and certified for use.

3.5.3. Weed Management

The irrigation area and Vetiver will be managed to ensure that weed pressure is maintained to an acceptable level that will enable optimal performance of the Vetiver through best practice site hygiene. The cover crop and a proportion of weed pressure within the inter-rows will be maintained to ensure there is a balance of groundcover to mitigate erosion risks. The weed species that are the major threat to the site and the Vetiver are Gamba Grass, *Andropogon gayanus*, and Mission Grass, *Cenchrus polystachios*. These are exotic grass species that are currently occurring throughout the landfill site and have the propensity to colonise the irrigation area / Vetiver planting through seed dispersal. If allowed to establish throughout the Vetiver planting these robust exotic grasses have the potential to compromise the treatment performance of the Vetiver and create broader maintenance challenges for the site.

Weed management is to ensure the Vetiver establishment and this will include targeted herbicide spraying with selective and non-selective herbicides. Herbicide use will be limited to spot spraying with the objective to target invasive weed species that are expected to occur on occasion. Typical cover crops e.g. Japanese Millet, *Echinochloa esculenta*, will be managed until the Vetiver begins to dominate the site and it is anticipated that the Japanese Millet, or similar, will reach senescence at this point. Once established the Vetiver will itself become the erosion protection through its clumping form and root profile.

Ongoing maintenance of the site will include weed management, most likely within the inter-rows and access tracks. Slashing of the planted Vetiver rows, inter-rows and access tracks will be undertaken periodically. The post-slashing debris will assist with organic matter accumulating that will improve the soil structure over time providing enhanced conditions for the Vetiver.

3.5.4. Pest Management

Feral pigs are perhaps the greatest risk to the Vetiver as they uproot groundcover searching for food and to create niche habitats. Feral pigs could disturb the Vetiver and cover crop through uprooting and trampling that could lead to reduced performance and replanting being required. The associated impacts could include erosion & riling on the batters leading to deposition of soil, changing the soil composition and spreading exotic plant species through assisting seed transfer. Feral pigs can also spread plant pathogens such as *Phytophthora cinnamomi* that can cause die-back. The site will be maintained and monitored, and notification given to CoD of any incidences of feral pigs for suitable control.

Chewing and sucking pests are not perceived as a risk to Vetiver due its robust form which has proven to be highly resilient to pests and diseases. Incidences of pests can be managed through the periodic slashing that will reduce the foliage available for predation.

4. Irrigation Management and Controls

This section outlines the environmental management and control measures which have been established to ensure adequate preventative measures are applied to prevent environmental harm.

4.1. Soil Moisture Monitoring

A series of 40cm EnviroPro® soil moisture probes will be installed within the irrigation area. Each sensor has three outputs; soil moisture, temperature and salinity. The probe can be configured to output any combination of moisture, temperature, and salinity from any of the sensors down the profile.

The EnviroPro® has split electrode that significantly increases the area of measurement. Moisture readings are expressed as relative volumetric soil water content. Also, the EnviroPro® is a fully potted and sealed probe buried below ground level. Therefore, the probe head will not protrude from the soil surface.

Soil moisture levels will be kept around field holding capacity to provide optimal plant growth and avoid deep drainage and therefore interflow to the Landfill Capping batter toes. During the high rainfall periods in the wet season the centre pivot irrigation will be stopped until dry conditions return.

4.2. Soil Management

Key criteria for soil management are soil sodicity, salinity management, soil water holding capacity and heavy metals. The soil baseline analysis is provided in Appendix B.

4.2.1. Soil Sodicity

Soil sodicity refers to the amount of exchangeable sodium (Na) cations relative to other cations in the soil and is expressed in terms of exchangeable sodium percentage (ESP). Dispersion of soil or a poor soil structure may be associated with sodicity. Exchangeable sodium acts as a mechanism for weakening the bonds of soil aggregates creating a soil with poor structure that can impede water and plant root movement into and through the soil. The degree to which dispersion occurs is also dependent on the **soil's clay content and mineralogy**, pH, Ca/Mg ratio, electrical conductivity (EC), organic matter content and the presence of iron and aluminium oxides.

As the irrigation area is located on the new landfill capping of Cell 3 and 4, the soil selected for the landfill capping has a higher clay content than original specifications and therefore avoidance of soil sodicity is required given the clay content. Ground investigations are required during establishment to determine the ESP value required as trigger point for gypsum application or similar. Continual annual soil monitoring of the Exchangeable Sodium Percentage for soil sodicity is recommended and continual observation of infiltration rates and any surface ponding of treated leachate irrigated.

4.2.2. Soil Salinity

Soil salinity refers to the number of dissolved salts in the soil solution. Soil salinity levels are usually determined by measuring the EC of a soil suspension, which estimates the concentration of soluble salts in the soil. Treated leachate and fertilisers may raise soluble salt levels to the extent that they impede plant growth and/or create salt scalds thereby increasing the potential for soil erosion.

An indicator of salt concentration is the electrical conductivity of a water-saturated soil paste (ECe). Where the ECe (dS/m) of a soil is less than 2 dS/m, effects on plants are mostly negligible; between 2 and 4 dS/m, yields of `sensitive' plants become restricted; between 4 and 8 dS/m, yields of many crops are affected; when the ECe exceeds 8 dS/m, only salt-tolerant plants give satisfactory yields. Above 16 dS/m only very tolerant crops yield satisfactorily.

Vetiver was selected as it has a high salt tolerance and high nitrogen uptake potential. Table 9 and Table 10 below outline the modelled outputs of the vetiver.

Table 9: Salt Tolerance and Vetiver Outputs from the MEDLI model (Appendix A)

VETIVER PLANT – SALT TOLERANCE	VALUE
Salinity threshold EC sat. ext. (dS/m)	8.00
Proportion of yield decrease per dS/m increase (fraction/dS/m)	0.05

Table 10: Soil salinity and Vetiver Outputs from the MEDLI model (Appendix A)

SOIL SALINITY	VALUE
Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m)	3.23
Salt added by rainfall (kg/ha/year)	345
Average annual effluent salt added & leached at steady state (t/ha/year)	53
Average leaching fraction based on 10 year running averages (fraction)	0.65
Average water-uptake-weighted rootzone salinity sat. ext. (dS/m)	2.26
Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m)	6.67
Relative crop yield expected due to salinity (fraction)	1.00
Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction)	0

Soil salinity will be monitored by the soil moisture probes and action triggered if levels reach high concentrations prior to plant stress. The action required is a leaching fraction with potable water to

move salts down the profile of the soil media. It is envisage that the wet season each year will provide this function.

4.2.3. Available Water Holding Capacity

Soils with a reasonably high level of organic matter (i.e. at least 2% by weight) are desirable for irrigation schemes. Organic matter encourages soil microbial activity and increases cation exchange and water holding capacity thereby buffering the potential adverse impacts associated with overloading the soil temporarily with nutrients, contaminants, or water.

Soil proposed for the landfill capping is to have organic matter at 2% by volume and vetiver operation is to cut vetiver on a regular basis in years 1-2 to increase organic matter in soil and therefore maximise water holding capacity and adsorption of contaminants.

4.2.4. Heavy Metals

ANZECC and ARMCANZ (2000) Water Quality Guidelines (for irrigation) identify the maximum concentrations of metals in treated leachate for irrigation considered acceptable for continuous use.

Regular monitoring of levels for heavy metals is required for the first 24 months of irrigation, to ensure that it is managed appropriately and to review the fate of heavy metals. Crop dry matter analysis and heavy metal removal at the treatment plant are required to calculate the fate of heavy metals and review of this IMP undertaken.

5. Monitoring

5.1. Monitoring

5.1.1. Treated Leachate Monitoring

The proposed monitoring program is based on the recommendations outlined in the NSW Environmental Guidelines: Use of Effluent via Irrigation. These are detailed in Table 11 below.

Table 11: Treated Leachate Monitoring Program

PARAMETER	HIGH STRENGTH
Total Nitrogen (mg/L)	Quarterly
Organic Nitrogen (mg/L)	Quarterly
Ammonium (mg/L)	Quarterly
Nitrates (mg/L)	Quarterly
Total Phosphorus (mg/L)	Quarterly
Total Dissolved Salts (mg/L)	Quarterly
Sodium Adsorption Ratio (meq/L)	Quarterly

5.1.2. Soil Monitoring

Soil monitoring is required to assess and record the levels of sodicity, salinity, nutrients and heavy metals over time in the 6.5ha vetiver irrigation area. Soil monitoring points will be identified and marked on site after completion of the landfill capping and handover of the site to WCG. These soil monitoring points will be permanent, and an annual sampling program undertaken. Samples are to be analysed for the parameters shown in Table 12 below.

Table 12: Soil Monitoring Program

PARAMETER	SAMPLING FREQUENCY
pH	Annual
Electrical Conductivity (µs/cm)	Annual
Exchangeable Sodium Percentage (%)	Annual
Total Nitrogen (mg/kg)	Annual
Ammonium (mg/kg)	Annual
Nitrates (mg/kg)	Annual
Total Phosphorus (mg/kg)	Annual
Heavy metals (mg/kg)	Quarterly to assess concentration levels then Annual

5.1.3. Groundwater Monitoring

The irrigation area has an impervious HDPE liner base and therefore there is no connection with groundwater.

Appendices

Appendix A - MEDLI Output 6.5 Ha

Appendix B - Baseline Analysis of Soil

MEDLI REPORT - FULL RUN

Enterprise: **New Enterprise**

Description:
Shoal Bay Landfill

Client: **The Water and Carbon Group Pty Ltd**

MEDLI User: CAD\LM

Scenario Details:

DESCRIPTION

Climate Data: Shoal Bay , -12.42°, 130.89°

Run Period: 01/01/2010 to 31/12/2019 10 years, 0 days

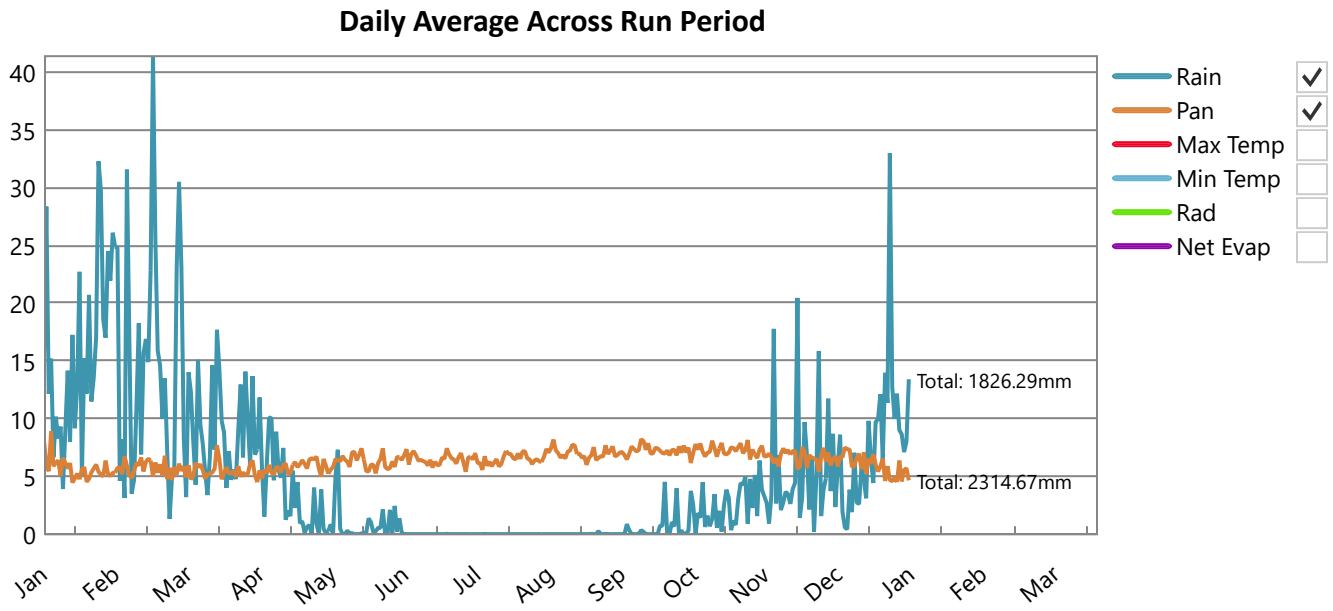
Climate Statistics:

	10th Percentile	50th Percentile	90th Percentile
Rainfall (mm/year)	1215	1752	2472
Pan Evaporation (mm/year)	2162	2338	2460

Climate Data:

Chart Table

Monthly Daily

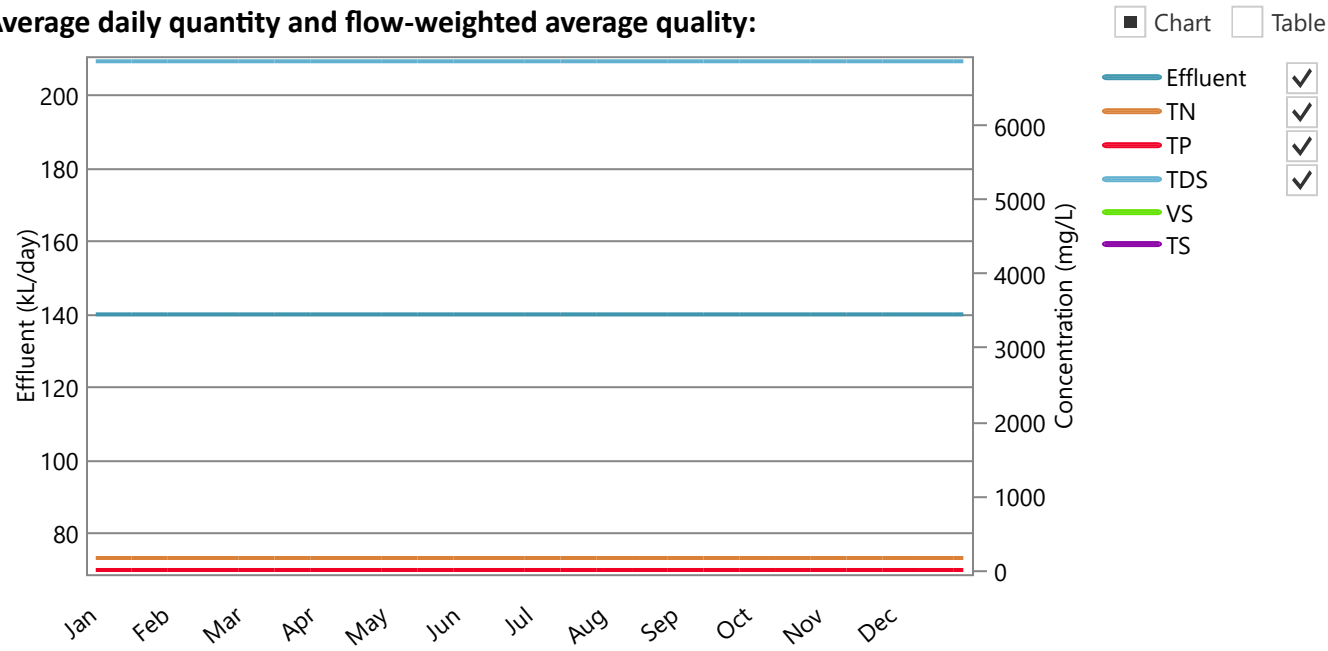


DESCRIPTION

Effluent type: New Generic System

Wastestream before any recycling or pretreatment

Average daily quantity and flow-weighted average quality:



Wastestream after any recycling and pretreatment if applicable

Effluent quantity: 51128.00 kL/year or 140.00 kL/day (Min-Max: 140.00 - 140.00)

Flow-weighted average (minimum - maximum) daily effluent quality entering pond system:

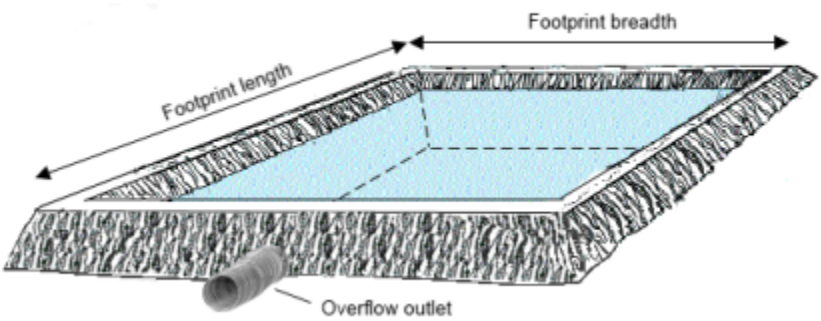
	Concentration (mg/L)	Load (kg/year)
Total Nitrogen	170.00 (170.00 - 170.00)	8691.76 (8687.00 - 8710.80)
Total Phosphorus	8.00 (8.00 - 8.00)	409.02 (408.80 - 409.92)
Total Dissolved Salts	6867.84 (6867.84 - 6867.84)	351138.92 (350946.62 - 351908.12)
Volatile Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Total Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)

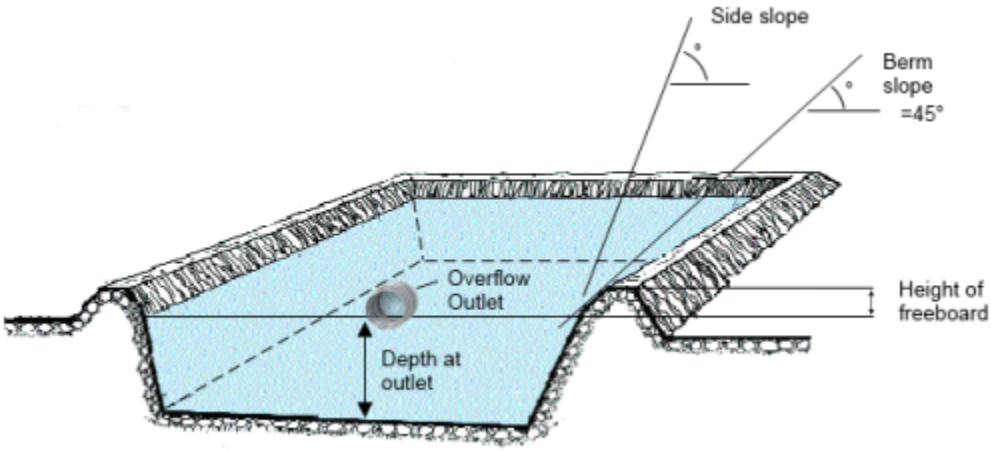
DESCRIPTION

Pond system: 1 closed storage tank

Pond system details:

	Pond 1
Maximum pond volume (kL)	15000.00
Minimum allowable pond volume (kL)	0.00
Pond depth at overflow outlet (m)	2.50
Maximum water surface area (m2)	6391.40
Pond footprint length (m)	79.95
Pond footprint width (m)	79.95
Pond catchment area (m2)	6391.40
Average active volume (kL)	3564.53





Irrigation pump limits:

Minimum pump rate limit (ML/day)	0.10
Maximum pump rate limit (ML/day)	1.00

Shandying water:

Annual allocation of fresh water available for shandying (kL/year)	0.00
Maximum rate of application of fresh water (ML/day)	0.00
Nitrogen concentration (mg/L)	0.00
Salinity (dS/m)	0.00
Minimum shandy water is used	False

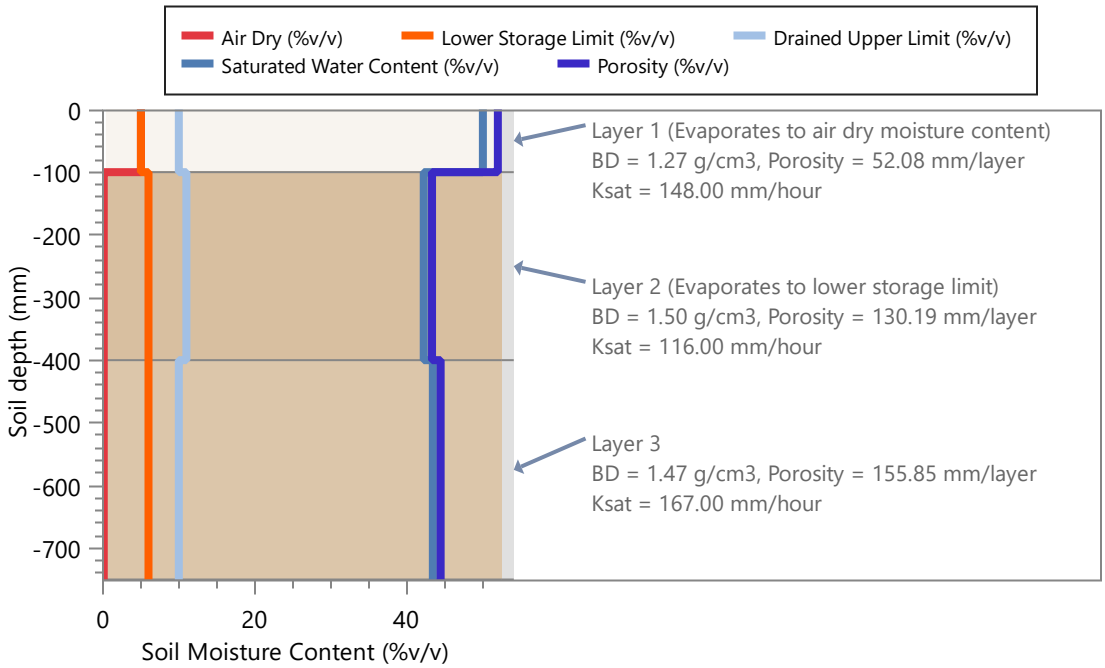
DESCRIPTION

Land: New Paddock

Area (ha): 6.50

Soil Type: Clay Sand Golders Specifications, 750.00 mm defined profile depth

Profile Porosity (mm)	338.11
Profile saturation water content (mm)	329.25
Profile drained upper limit (or field capacity) (mm)	78.00
Profile lower storage limit (or permanent wilting point) (mm)	44.00
Profile available water capacity (mm)	34.00
Profile limiting saturated hydraulic conductivity (mm/hour)	116.00
Surface saturated hydraulic conductivity (mm/hour)	148.00
Runoff curve number II (coefficient)	75.00
Soil evaporation U (mm)	6.00
Soil evaporation Cona (mm/sqrt day)	3.50



Plant Data: Continuous Vetiver Pasture, kick started

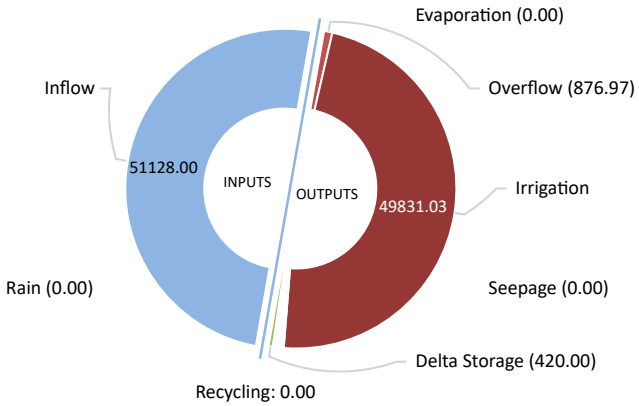
Average monthly cover (fraction) (minimum - maximum)	0.87 (0.78 - 0.94)
Maximum crop factor at 100% cover (mm/mm) (Maximum crop coefficient 0.9 x Pan coefficient 1)	0.90
Total plant cover (both green and dead) left after harvest (fraction)	1.00
Maximum potential root depth in defined soil profile (mm)	750.00
Salt tolerance	Tolerant
Salinity threshold EC sat. ext. (dS/m)	8.00
Proportion of yield decrease per dS/m increase (fraction/dS/m)	0.05

PERFORMANCE

Pond System Water Performance - Overflow: 1 closed storage tank

Capacity of wet weather storage pond: **15000 kL**

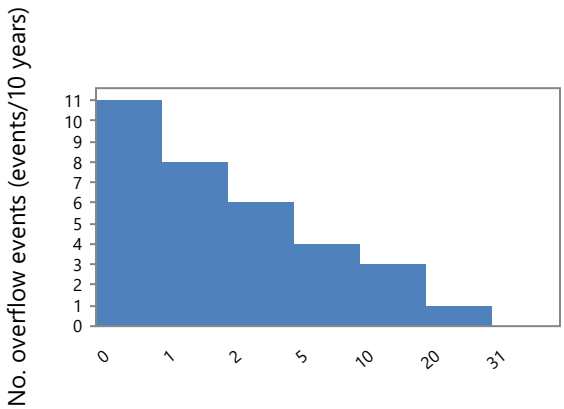
Pond System Water Balance (kL/year)



Name	Value
Rain	0.00
Inflow	51128.00
Recycling	0.00
Evaporation	0.00
Overflow	876.97
Irrigation	49831.03
Seepage	0.00
Delta Storage	420.00

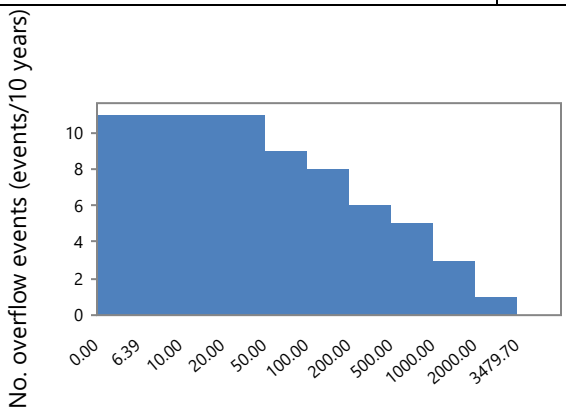
Overflow Diagnostics

Volume of overflow (kL/year)	876.97
No. days pond overflows (days/year)	7.80
Average duration of overflow (days)	7.09
Effluent Reuse (Proportion of Inflow + Net Rain Gain that is Irrigated) (fraction)	0.98
Probability of at least 90% reuse (fraction)	1.00



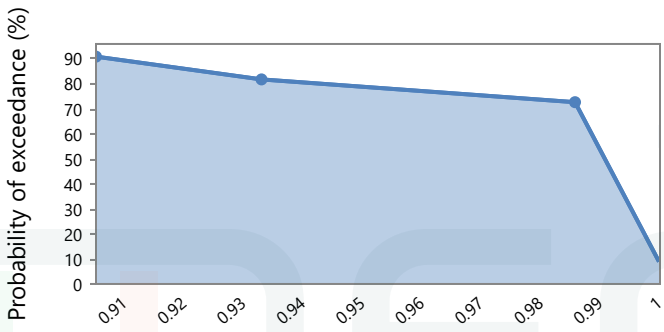
Overflow event duration exceeded (days)

Export plot



Overflow volume exceeded (kL)

Export plot



Annual reuse (fraction)

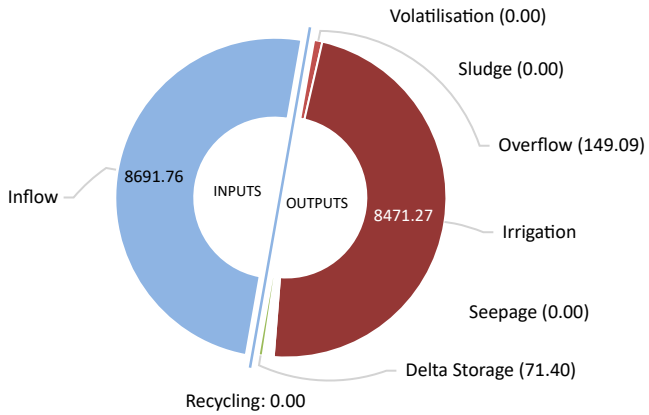
Export plot

PERFORMANCE

Pond System Performance - Nutrient: 1 closed storage tank

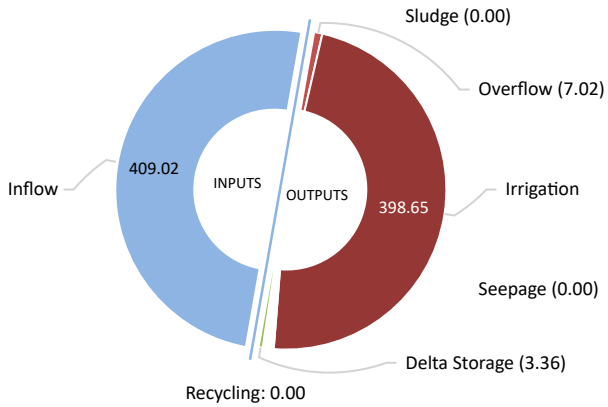
Pond System Nutrients and Salt Balance:

Nitrogen Balance (kg/year)



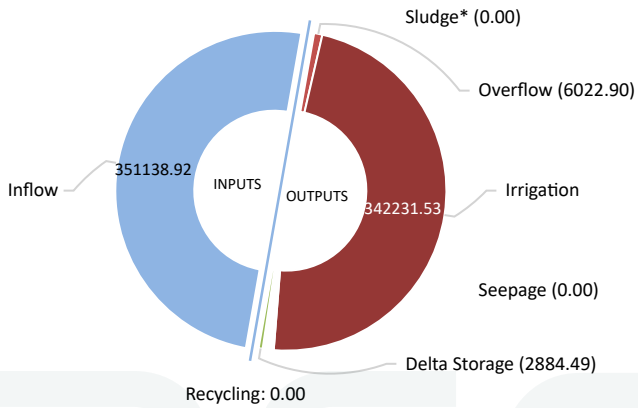
Name	Value
Inflow	8691.76
Recycling	0.00
Volatilisation	0.00
Sludge	0.00
Overflow	149.09
Irrigation	8471.27
Seepage	0.00
Delta Storage	71.40

Phosphorus Balance (kg/year)



Name	Value
Inflow	409.02
Recycling	0.00
Sludge	0.00
Overflow	7.02
Irrigation	398.65
Seepage	0.00
Delta Storage	3.36

Salt Balance (kg/year)



Name	Value
Inflow	351138.92
Recycling	0.00
Sludge*	0.00
Overflow	6022.90
Irrigation	342231.53
Seepage	0.00
Delta Storage	2884.49

* Salt removal in sludge is not calculated from the pond salt balance. However if salt could be assumed to be present in the sludge at the same concentration as in the pond supernatant (up to a maximum of salt added in inflow) - then salt accumulation in the sludge could be 0.00 kg/year

Pond System Sludge Accumulation: 0.00 kg dwt/year

PERFORMANCE

Pond System Performance - Nutrient: 1 closed storage tank

Pond Nutrient Concentrations and Salinity:

Average across simulation period	Pond 1
Average nitrogen concentration of pond liquid (mg/L)	170.00
Average phosphorus concentration of pond liquid (mg/L)	8.00
Average salinity of pond liquid (dS/m)	10.73

Value on final day of simulation period	Pond 1
Final nitrogen concentration of pond liquid (mg/L)	170.00
Final phosphorus concentration of pond liquid (mg/L)	8.00
Final salinity of pond liquid (dS/m)	10.73

PERFORMANCE

Irrigation Performance:

Water Use: (assumes 100% Irrigation Efficiency)

Pond water irrigated (kL/year)	49831.03
Average Shandy water irrigation (kL/year) (minimum - maximum)	0.00 (0.00 - 0.00)
Total water irrigated (kL/year)	49831.03
Proportion of irrigation events requiring shandying (fraction of events)	0.00
Proportion of years shandying water allocation of 0 kL/year is exceeded (fraction of years)	0.00
Average exceedance as a proportion of annual shandy water allocation (fraction of allocation) (minimum - maximum)	0.00 (0.00 - 0.00)

Irrigation Quality:

Average nitrogen concentration of irrigation water - before ammonia loss during irrigation (mg/L)	170.00
Average nitrogen concentration of irrigation water - after ammonia loss during irrigation (mg/L)	170.00
Average phosphorus concentration of irrigation water (mg/L)	8.00
Average salinity of irrigation water (dS/m)	10.73

Irrigation Diagnostics:

Proportion Days Irrigation Turned Off (fraction)	0.07
Proportion of Days rain prevents irrigation (fraction)	0.13
Proportion of Days water demand too small to trigger irrigation (fraction)	0.09
Proportion of Days water demand too small for irrigation pump (fraction)	0.06
Proportion of Days irrigation occurs (fraction)	0.65

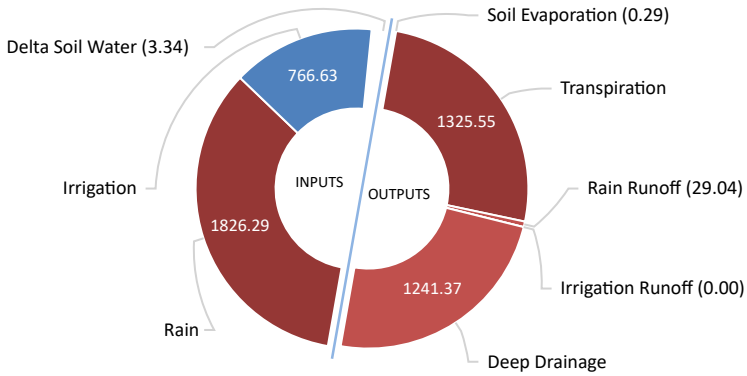
PERFORMANCE

Land Performance - Soil Water

Paddock: New Paddock, 6.5 ha
Soil Type: Clay Sand Golders Specifications, 34.00 mm PAWC at maximum root depth

Land Water Balance (mm/year):

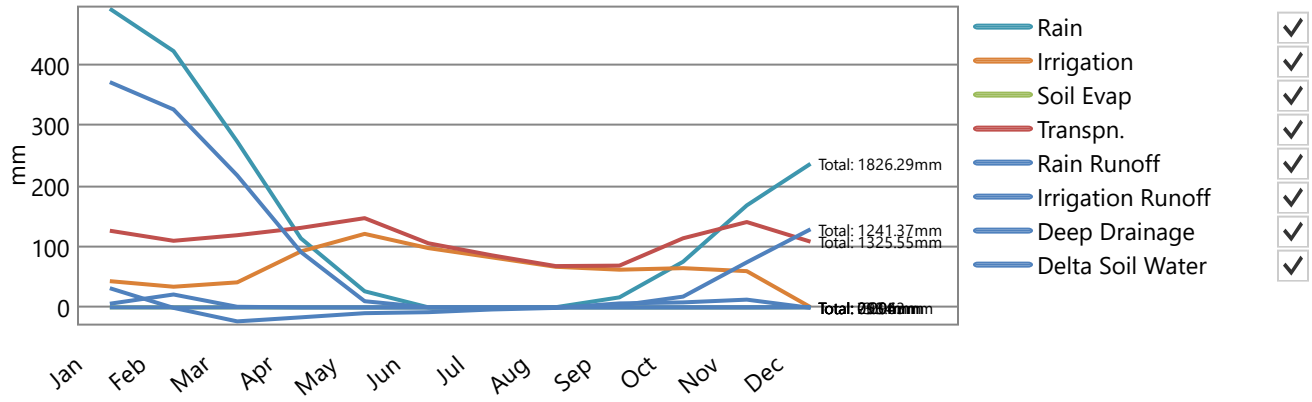
mm/year % Total inputs



Name	Value
Rain	1826.29
Irrigation	766.63
Soil Evaporation	0.29
Transpiration	1325.55
Rain Runoff	29.04
Irrigation Runoff	0.00
Deep Drainage	1241.37
Delta Soil Water	-3.34

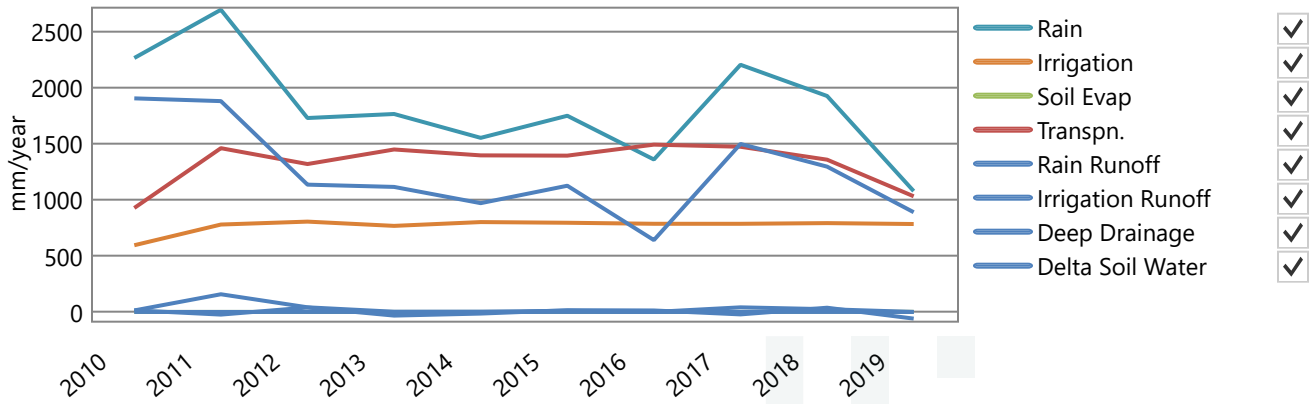
Average Monthly Totals (mm):

Chart Table



Average Annual Totals (mm/year):

Chart Table



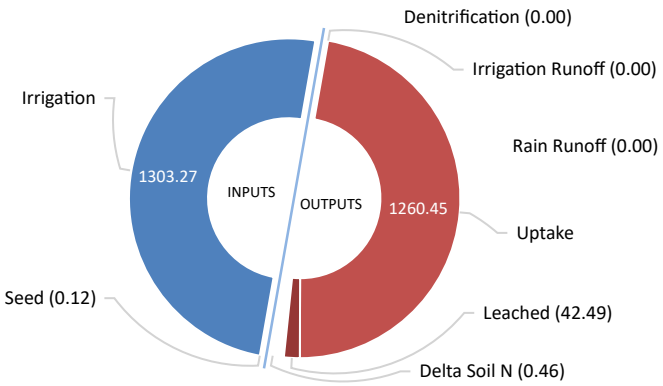
PERFORMANCE

Land Performance - Soil Nutrient

Paddock: New Paddock, 6.5 ha **Soil Type**: Clay Sand Golders Specifications

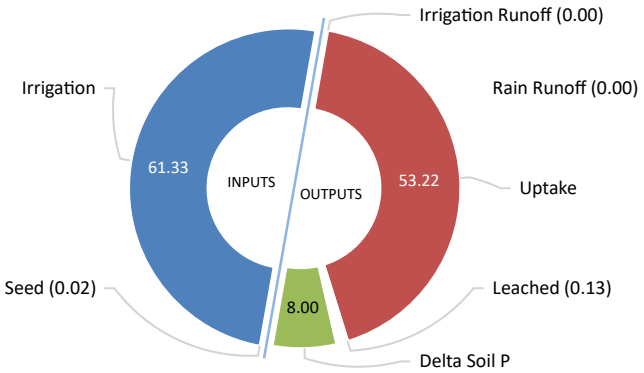
Irrigation ammonium volatilisation losses (kg/ha/year): 0.00
Proportion of total nitrogen in irrigated effluent as ammonium (fraction): 0.00

Land Nitrogen Balance (kg/ha/year)



Name	Value
Seed	0.12
Irrigation	1303.27
Denitrification	0.00
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	1260.45
Leached	42.49
Delta Soil N	0.46

Land Phosphorus Balance (kg/ha/year)



Name	Value
Seed	0.02
Irrigation	61.33
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	53.22
Leached	0.13
Delta Soil P	8.00

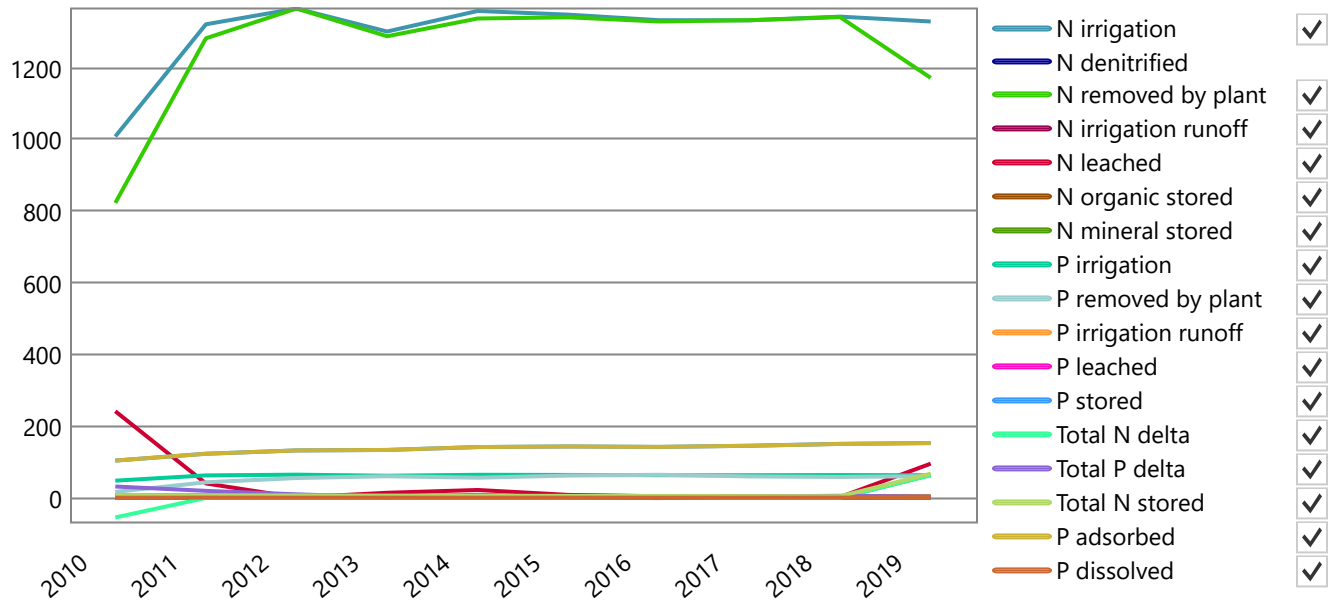
PERFORMANCE

Land Performance - Soil Nutrient

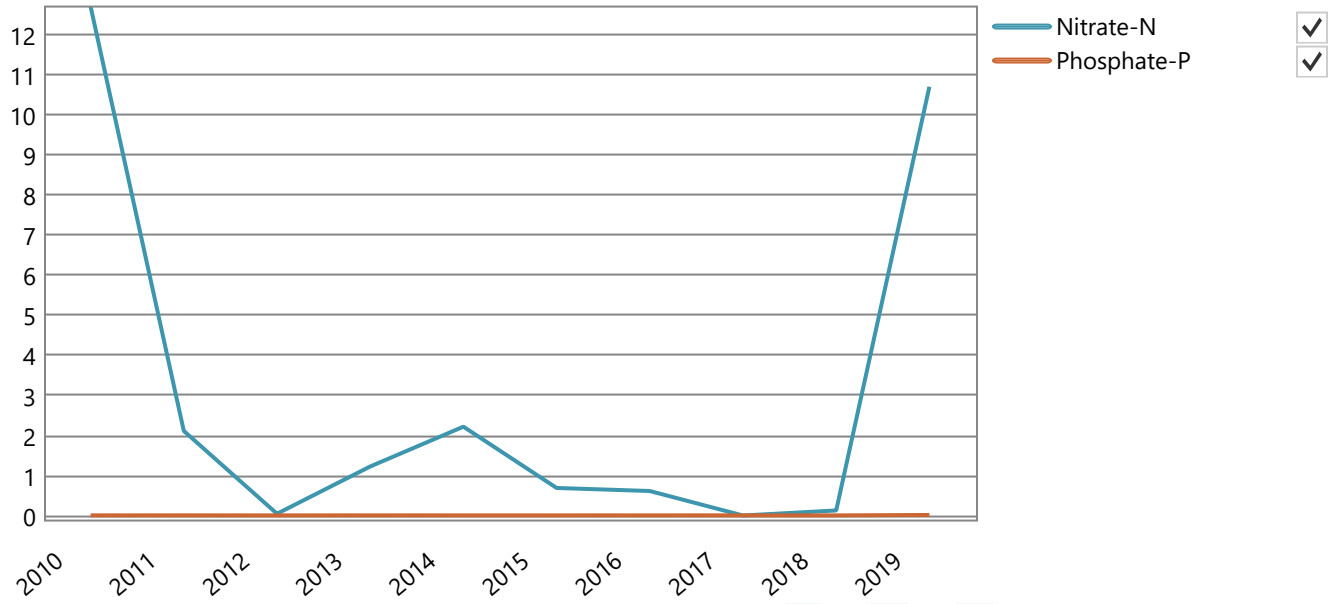
Paddock: New Paddock, 6.5 ha

Soil Type: Clay Sand Golders Specifications

Annual Nutrient Totals (kg/ha):



Annual Nutrient Leaching Concentration (mg/L):



PERFORMANCE

Plant Performance and Nutrients

Paddock: New Paddock, 6.5 ha

Soil Type: Clay Sand Golders Specifications

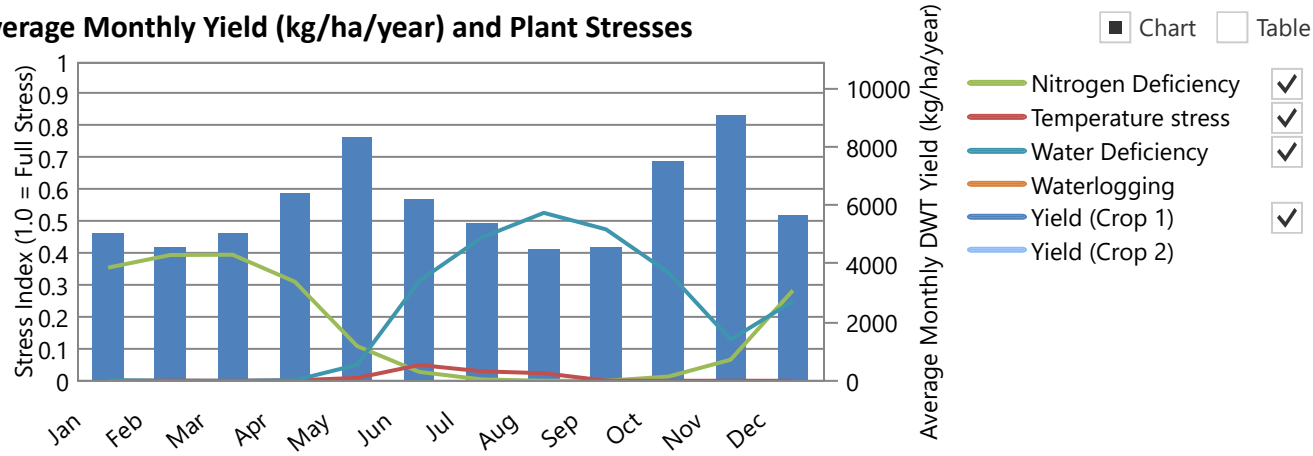
Plant: Continuous Vetiver Pasture, kick started

Average annual shoot dry matter yield (kg/ha/year)	72355.19 (49454.84 - 83163.99)
Average monthly plant (green) cover (fraction) (minimum - maximum)	0.87 (0.78 - 0.94)
Average monthly root depth (mm) (minimum - maximum)	732.55 (646.21 - 750.00)

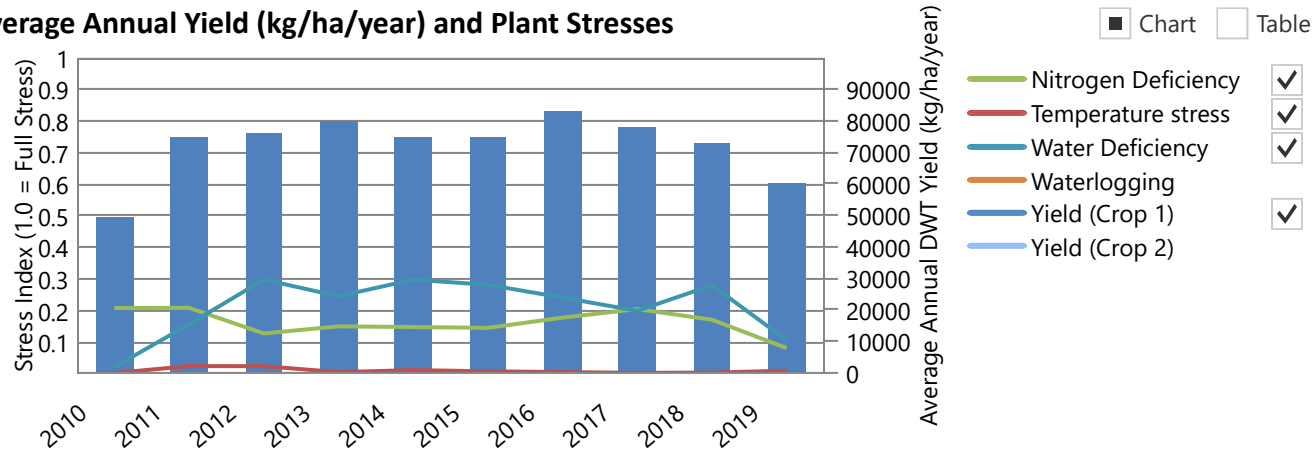
Nutrient Uptake (minimum - maximum):

Average annual net nitrogen removed by plant uptake (kg/ha/year)	1260.45 (822.33 - 1364.52)
Average annual net phosphorus removed by plant uptake (kg/ha/year)	53.22 (16.19 - 63.88)
Average annual shoot nitrogen concentration (fraction dwt)	0.02 (0.02 - 0.02)
Average annual shoot phosphorus concentration (fraction dwt)	0.001 (0.000 - 0.001)

Average Monthly Yield (kg/ha/year) and Plant Stresses



Average Annual Yield (kg/ha/year) and Plant Stresses



No. of harvests/year: 3.40 (normal), 0.10 (forced by crop death due to water stress (0.10))
No. days without crop/year (days/year): 1.00 due to nitrogen stress (0.10), water stress (0.90)

PERFORMANCE

Land Performance

Paddock: New Paddock, 6.5 ha **Soil Type**: Clay Sand Golders Specifications

Plant: Continuous Vetiver Pasture, kick started

Salt tolerance	Tolerant
Salinity threshold EC sat. ext. (dS/m)	8.00
Proportion of yield decrease per dS/m increase (fraction/dS/m)	0.05
No. years assumed for leaching to reach steady-state (years)	10.00

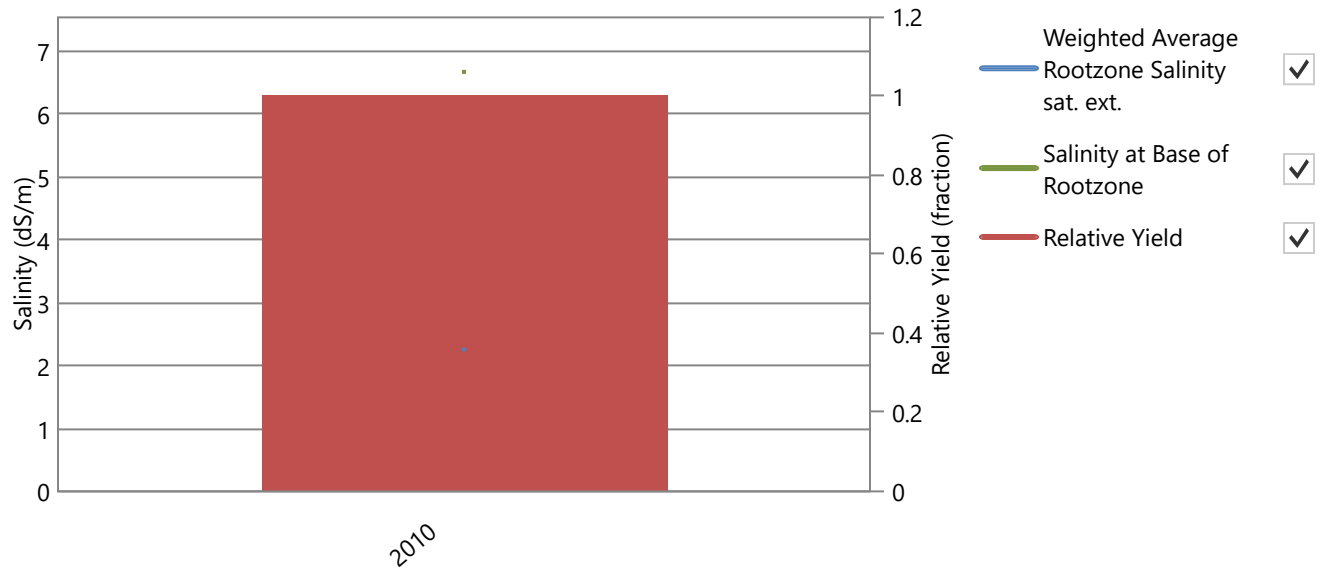
Soil Salinity:

Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m)	3.23
Salt added by rainfall (kg/ha/year)	345.07
Average annual effluent salt added & leached at steady state (kg/ha/year)	52996.08
Average leaching fraction based on 10 year running averages (fraction)	0.65
Average water-uptake-weighted rootzone salinity sat. ext. (dS/m)	2.26
Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m)	6.67
Relative crop yield expected due to salinity (fraction)	1.00
Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction)	0.00

Average Annual Rootzone Salinity and Relative Yield:

Chart Table

All values based on 10 year running averages



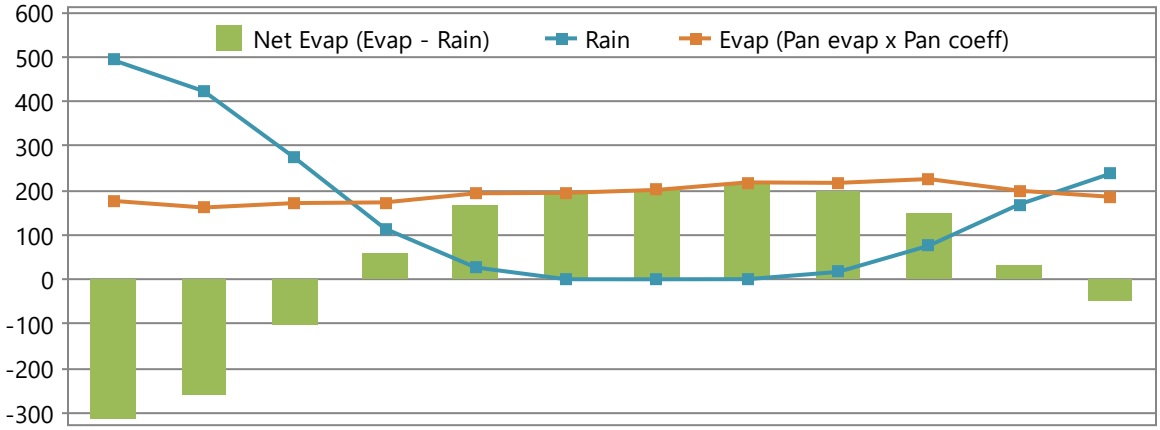
DIAGNOSTICS

Sustainability Diagnostics: New Enterprise

Averaged Historical Climate Data Used in Simulation (mm)

Location: Shoal Bay , -12.42°, 130.89°

Run Period: 01/01/2010 to 31/12/2019 10 years, 0 days



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	492.5	422.7	273.4	113.8	26.6	0.1	0.0	0.3	16.6	75.3	168.3	236.8	1826.3
Evap	176.2	161.3	171.3	172.9	193.2	194.3	200.9	217.8	216.7	225.3	199.1	185.6	2314.7
Net Evap	-316.3	-261.3	-102.1	59.1	166.6	194.2	200.8	217.5	200.1	150.0	30.9	-51.3	488.4
Net Evap/day	-10.2	-9.3	-3.3	2.0	5.4	6.5	6.5	7.0	6.7	4.8	1.0	-1.7	1.3

DIAGNOSTICS

Sustainability Diagnostics: New Enterprise

Pond System: 1 closed storage tank

New Generic System - 51128.00 kL/year or 140.00 kL/day generated on average

Effluent entering pond system after any pretreatment and recycling

Average (Minimum-Maximum) influent quality calculated for 365.20 non-zero flow days, after any pretreatment and recycling.

Constituent	Concentration (mg/L)	Load (kg/year)
Total Nitrogen	170.00 (170.00 - 170.00)	8691.76 (8687.00 - 8710.80)
Total Phosphorus	8.00 (8.00 - 8.00)	409.02 (408.80 - 409.92)
Total Dissolved Salts	6867.84 (6867.84 - 6867.84)	351138.92 (350946.62 - 351908.12)
Volatile Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Total Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)

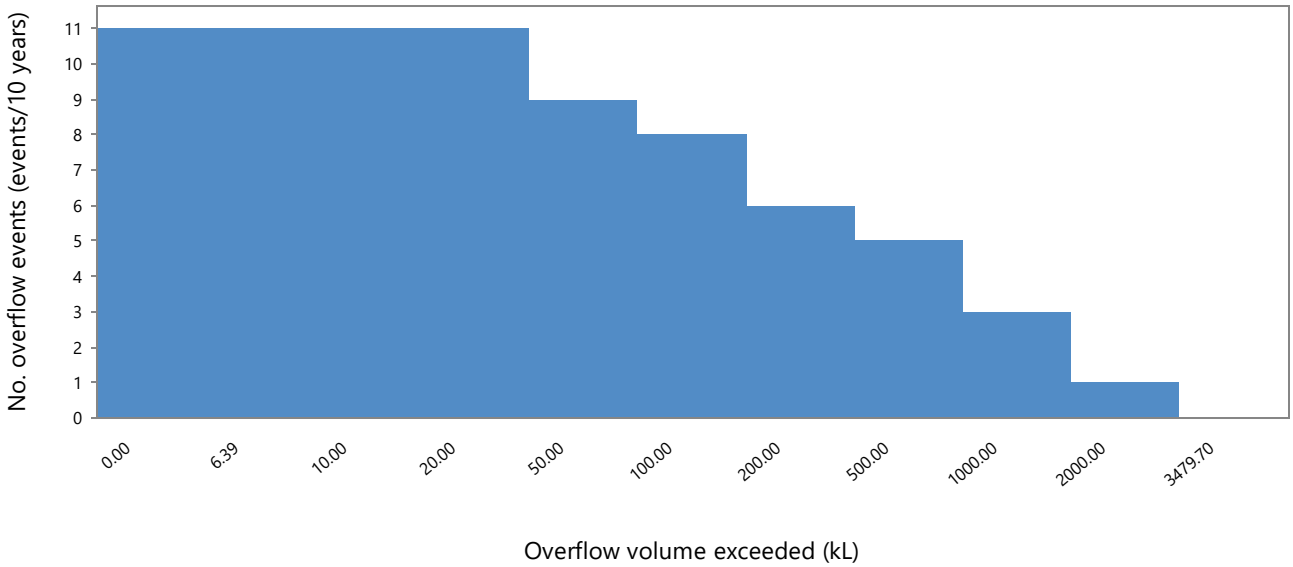
Last pond (Wet weather store): 15000.00 kL

Theoretical hydraulic retention time (days)	107.14
Average volume of overflow (kL/year)	876.97
No. overflow events per year exceeding threshold* of 6.39 kL (no./year)	1.10
Average duration of overflow (days)	7.09
Effluent Reuse (Proportion of Inflow + Net Rain Gain that is Irrigated) (fraction)	0.98
Probability of at least 90% effluent reuse (fraction)	1.00
Average salinity of last pond (dS/m)	10.73
Salinity of last pond on final day of simulation (dS/m)	10.73
Ammonia loss from pond system water area (kg/m2/year)	0.00

* The threshold is the volume equivalent to the top 1 mm depth of water of a full pond

Overflow exceedance:

Chart Table



Export plot

DIAGNOSTICS

Sustainability Diagnostics: New Enterprise

Irrigation Information

Irrigation: 6.5 ha total area (assumed 100% irrigation efficiency)

	Quantity/year	Quantity/ha/year
Total irrigation applied (kL)	49831.03	7666.31
Total nitrogen applied (kg)	8471.27	1303.27
Total phosphorus applied (kg)	398.65	61.33
Total salts applied (kg)	342231.53	52651.01

Shandying

Annual allocation of fresh water for shandying (kL/year)	0.00
Average Shandy water irrigation (kL/year) (minimum - maximum)	0.00 (0.00 - 0.00)
Average exceedance as a proportion of annual shandy water allocation (% of allocation) (minimum - maximum)	0.00 (0.00 - 0.00)
Proportion of irrigation events requiring shandying (fraction of events)	0.00
Minimum shandy water is used	False

Irrigation Issues

Proportion of Days irrigation is turned off (fraction)	0.07
Proportion of Days irrigation is prevented when triggered (fraction)	0.19
Proportion of Days water demand is too small to trigger irrigation (fraction)	0.09
Proportion of Days irrigation occurs (fraction)	0.65

DIAGNOSTICS

Sustainability Diagnostics: New Enterprise

Paddock Land: New Paddock: 6.5 ha

Irrigation: Centre Pivot with 0.26% ammonium loss during irrigation

Irrigation triggered when soil water deficit reaches 0.00 mm and rainfall is less than or equal to 10.00 mm
Irrigate up to a soil water content of drained upper limit plus 0.00 mm
Irrigation window from 1/1 to 30/11 including the days specified
A minimum of 0 days must be skipped between irrigation events

Soil Water Balance (mm): Clay Sand Golders Specifications, 34.00 mm PAWC at maximum root depth

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	492.5	422.7	273.4	113.8	26.6	0.1	0.0	0.3	16.6	75.3	168.3	236.8	1826.3
Irrigation	43.3	34.1	41.3	92.4	121.3	97.8	82.4	67.0	62.2	64.7	59.8	0.4	766.6
Soil Evap	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3
Transpn.	126.5	109.8	119.1	131.2	147.2	105.8	85.8	68.1	68.9	114.0	140.8	108.4	1325.6
Rain Runoff	6.1	21.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	29.0
Irr. Runoff	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drainage	371.5	326.4	217.7	91.3	10.2	0.0	0.1	0.0	3.3	17.8	74.3	128.8	1241.4
Delta	31.7	-0.8	-23.0	-16.4	-9.5	-7.9	-3.4	-0.9	6.6	8.2	12.8	-0.7	-3.3

Soil Nitrogen Balance

Average annual effluent nitrogen added (kg/ha/year)	1303.27
Average annual soil nitrogen removed by plant uptake (kg/ha/year)	1260.45
Average annual soil nitrogen removed by denitrification (kg/ha/year)	0.00
Average annual soil nitrogen leached (kg/ha/year)	42.49
Average annual nitrate-N loading to groundwater (kg/ha/year)	42.49
Soil organic-N kg/ha (Initial - Final)	7.87 - 3.72
	54.58 - 63.30
Average nitrate-N concentration of deep drainage (mg/L)	3.42
Max. annual nitrate-N concentration of deep drainage (mg/L)	12.70

Soil Phosphorus Balance

Average annual effluent phosphorus added (kg/ha/year)	61.33
Average annual soil phosphorus removed by plant uptake (kg/ha/year)	53.22
Average annual soil phosphorus leached (kg/ha/year)	0.13
Dissolved phosphorus (kg/ha) (Initial - Final)	0.02 - 0.02
Adsorbed phosphorus (kg/ha) (Initial - Final)	72.36 - 152.36
Average phosphate-P concentration in rootzone (mg/L)	0.02
Average phosphate-P concentration of deep drainage (mg/L)	0.01
Max. annual phosphate-P concentration of deep drainage (mg/L)	0.02
Design soil profile storage life based on average infiltrated water phosphorus concn. of 2.39 mg/L (years)	7.69

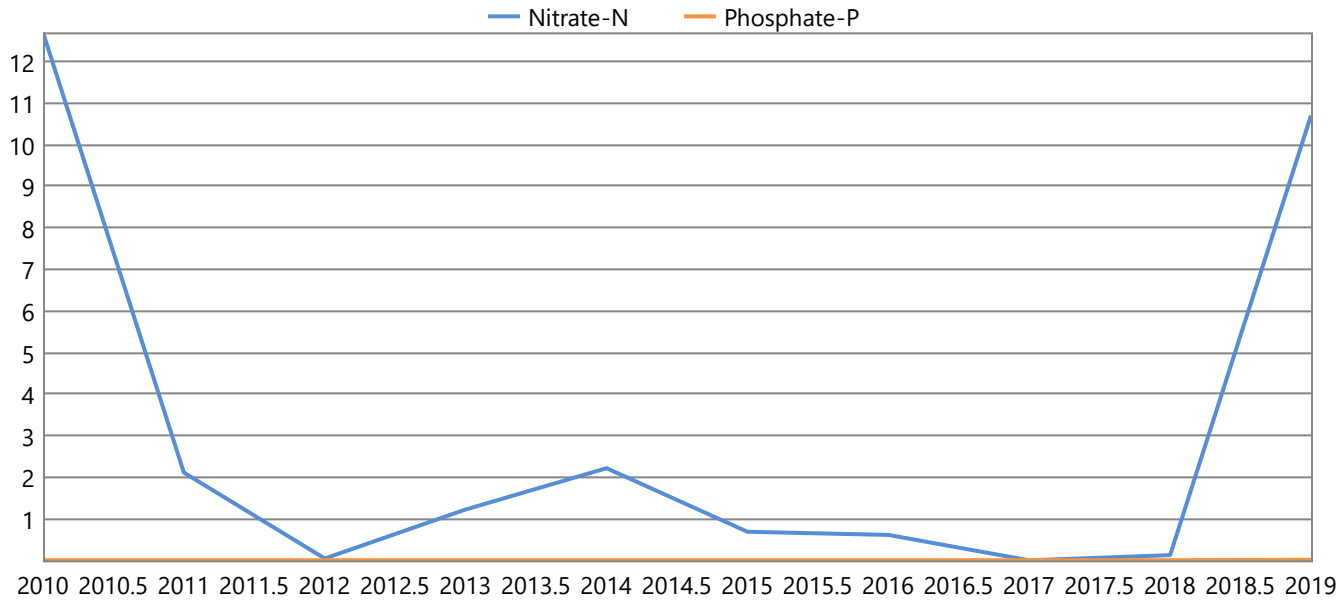
DIAGNOSTICS

Sustainability Diagnostics: New Enterprise

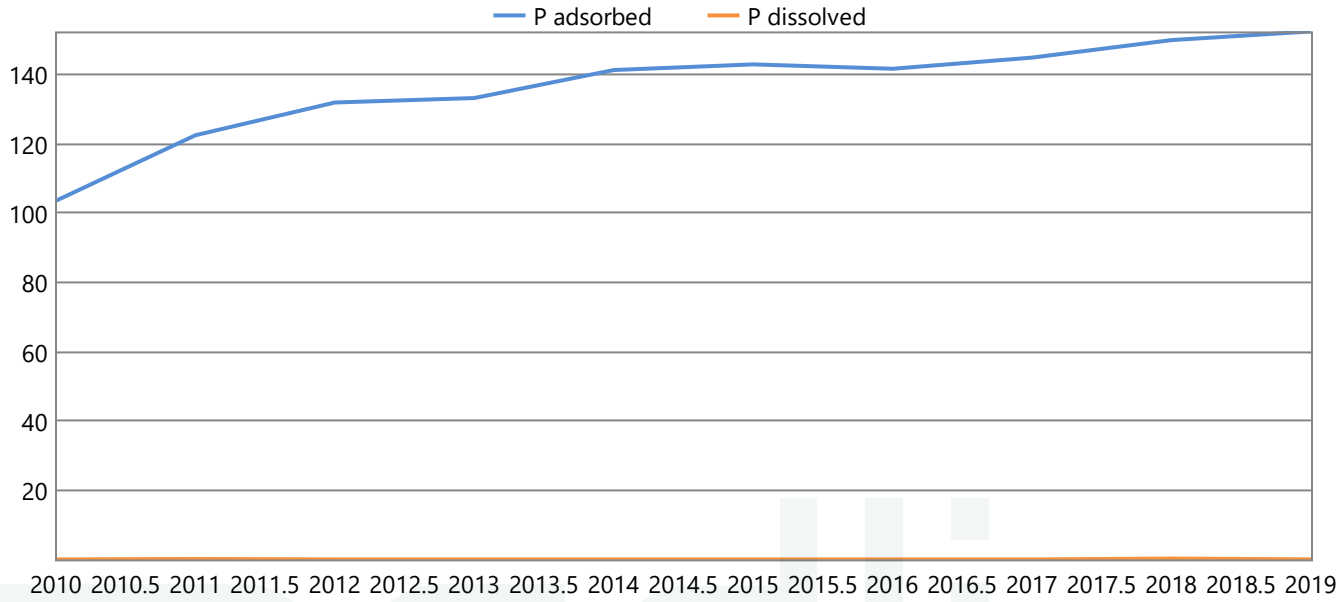
Paddock Land: New Paddock: 6.5 ha

Irrigation: Centre Pivot with 0.26% ammonium loss during irrigation

Annual nutrient leachate concentration (mg/L)



Annual Phosphate-P in soil (kg/ha)



DIAGNOSTICS

Sustainability Diagnostics: New Enterprise

Paddock Plant Performance: New Paddock: 6.5 ha

Average Plant Performance (Minimum - Maximum): Continuous Vetiver Pasture, kick started

Average annual shoot dry matter yield (kg/ha/year)	72355.19 (49454.84 - 83163.99)
Average monthly plant (green) cover (fraction)	0.87 (0.78 - 0.94)
Average monthly crop factor (fraction)	0.78 (0.70 - 0.84)
Total plant cover (both green and dead) left after harvest (fraction)	1.00
Average monthly root depth (mm)	732.55 (646.21 - 750.00)
Average number of normal harvests per year (no./year)	3.40 (1.00 - 4.00)
Average number of normal harvests for last five years only (no./year)	3.60
Average number of crop deaths per year (no./year)	0.10 (0.00 - 1.00)
Average number of crop deaths for last five years only (no./year)	0.20
Average annual nitrogen deficiency index (0 = no stress, 1 = full stress) (coefficient)	0.16 (0.08 - 0.21)
Average January temperature stress index (0 = no stress, 1 = full stress) (coefficient)	0.00 (0.00 - 0.00)
Average July temperature stress index (0 = no stress, 1 = full stress) (coefficient)	0.03 (0.00 - 0.07)
Average monthly water stress index (0 = no stress, 1 = full stress) (coefficient)	0.21 (0.00 - 0.53)
Average monthly waterlogging index (0 = no stress, 1 = full stress) (coefficient)	0.00 (0.00 - 0.00)
No. days without crop/year (days)	1.00

Soil Salinity - Plant salinity tolerance: Tolerant

Assumes 1.0 dS/m Electrical Conductivity = 640 mg/L Total Dissolved Salts

All values based on 10 year running averages

Salinity of infiltrated water (Average salinity of rainwater = 0.03 dS/m) (dS/m)	3.23
Salt added by rainfall (kg/ha/year)	345.07
Average annual effluent salt added & leached at steady state (kg/ha/year)	52996.08
Average leaching fraction based on 10 year running averages (fraction)	0.65
Average water-uptake-weighted rootzone salinity sat. ext. (dS/m)	2.26
Salinity of the soil solution (at drained upper limit) at base of rootzone (dS/m)	6.67
Relative crop yield expected due to salinity (fraction)	1.00
Proportion of years that crop yields would be expected to fall below 90% of potential due to salinity (fraction)	0.00

DIAGNOSTICS

Run Messages

Messages generated when the scenario was run:

WARNING: Irrigation water salinity exceeds 10 dS/m. Leaf scorching and yield reduction likely. Careful irrigation management needed.
Full run chosen

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES2136789**	Page	: 1 of 4
Client	: **THE WATER & CARBON GROUP**	Laboratory	: Environmental Division Sydney
Contact	: MR CLIFF DUCKWORTH	Contact	: Customer Services ES
Address	: DARWIN	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: SBLTS	Date Samples Received	: 27-Oct-2021 07:00
Order number	: ----	Date Analysis Commenced	: 28-Oct-2021
C-O-C number	: ----	Issue Date	: 05-Nov-2021 09:23
Sampler	: ROB MCKENZIE		
Site	: ----		
Quote number	: EN/333		
No. of samples received	: 3		
No. of samples analysed	: 3		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

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

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

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.

Signatories	*Position*	*Accreditation Category*
Aleksandar Vujkovic	Laboratory Technician	Newcastle - Inorganics, Mayfield West, NSW
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Edwandy Fadjar	Organic Coordinator	Sydney Inorganics, Smithfield, NSW
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

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.

- EA150H: Soil Particle Density required for Hydrometer analysis according to AS 1289.3.5.1 2006 was not requested by the client. Typical sediment SPD values used for calculations and consequently NATA endorsement does not apply to hydrometer results.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	WCG 1	WCG 2	WCG 3	----	----
			Sampling date / time	22-Oct-2021 12:00	22-Oct-2021 12:00	22-Oct-2021 12:00	----	----
Compound	CAS Number	LOR	Unit	ES2136789-001	ES2136789-002	ES2136789-003	--------	--------
				Result	Result	Result	----	----
EA006: Sodium Adsorption Ratio (SAR)								
Sodium Adsorption Ratio	----	0.01	-	2.34	2.52	2.43	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	5.9	8.1	8.0	----	----
EA150: Particle Sizing								
+75µm	----	1	%	51	51	54	----	----
+150µm	----	1	%	38	38	41	----	----
+300µm	----	1	%	28	25	32	----	----
+425µm	----	1	%	26	23	30	----	----
+600µm	----	1	%	25	22	29	----	----
+1180µm	----	1	%	22	19	26	----	----
+2.36mm	----	1	%	16	11	18	----	----
+4.75mm	----	1	%	7	3	9	----	----
+9.5mm	----	1	%	<1	<1	<1	----	----
+19.0mm	----	1	%	<1	<1	<1	----	----
+37.5mm	----	1	%	<1	<1	<1	----	----
+75.0mm	----	1	%	<1	<1	<1	----	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	34	37	36	----	----
Silt (2-60 µm)	----	1	%	12	10	9	----	----
Sand (0.06-2.00 mm)	----	1	%	36	40	35	----	----
Gravel (>2mm)	----	1	%	18	13	20	----	----
Cobbles (>6cm)	----	1	%	<1	<1	<1	----	----
EG005(ED093)T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	9	10	8	----	----
Barium	7440-39-3	10	mg/kg	10	10	10	----	----
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	----	----
Boron	7440-42-8	50	mg/kg	<50	<50	<50	----	----
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	----	----
Chromium	7440-47-3	2	mg/kg	94	114	104	----	----
Cobalt	7440-48-4	2	mg/kg	<2	<2	<2	----	----
Copper	7440-50-8	5	mg/kg	<5	<5	5	----	----
Lead	7439-92-1	5	mg/kg	12	12	12	----	----
Manganese	7439-96-5	5	mg/kg	66	62	71	----	----
Nickel	7440-02-0	2	mg/kg	5	5	5	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	WCG 1	WCG 2	WCG 3	----	----
				Sampling date / time	22-Oct-2021 12:00	22-Oct-2021 12:00	22-Oct-2021 12:00	----	----
Compound	CAS Number	LOR	Unit		ES2136789-001	ES2136789-002	ES2136789-003	--------	--------
					Result	Result	Result	----	----
EG005(ED093)T: Total Metals by ICP-AES - Continued									
Selenium	7782-49-2	5	mg/kg		<5	<5	<5	----	----
Vanadium	7440-62-2	5	mg/kg		**188**	**200**	**184**	----	----
Zinc	7440-66-6	5	mg/kg		<5	<5	**5**	----	----
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg		<0.1	<0.1	<0.1	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		**0.6**	**0.7**	**0.7**	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		**700**	**890**	**930**	----	----
EK062: Total Nitrogen as N (TKN + NOx)									
^ **Total Nitrogen as N**	----	20	mg/kg		**700**	**890**	**930**	----	----
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		**166**	**202**	**209**	----	----

Inter-Laboratory Testing

Analysis conducted by ALS Brisbane, NATA accreditation no. 825, site no. 818 (Chemistry) 18958 (Biology).

(SOIL) EA006: Sodium Adsorption Ratio (SAR)

Analysis conducted by ALS Newcastle, NATA accreditation no. 825, site no. 1656 (Chemistry) 9854 (Biology).

(SOIL) EA150: Soil Classification based on Particle Size

(SOIL) EA150: Particle Sizing

Appendix E4 Leachate Management Plan

Leachate Management Action Plan - Shoal Bay Waste Management Facility

7 November 2023

Table of Contents

1. Background

The leachate management action plan is a summary of leachate generation and treatment data for the past 12 months and provides a forecast of the leachate balance for the next 12 months and beyond. It includes the following topics:

- leachate infrastructures
- leachate generation rates
- leachate treatment system and treatment capacity
- treated leachate irrigation (stage 3 and stage 4)
- raw leachate irrigation (stage 5 and southern batter of stage 3)
- legacy leachate stored within cells
- challenges and opportunities for leachate treatment

2. Onsite leachate management infrastructure

Table 1: Leachate infrastructures onsite as of 24 October 2023 (Fig 1).

Infrastructure	**Purpose**	**Capacity (KL)**	**Status**
Pond 1	Leachate storage	15,000	Operational
Pond 2	Leachate storage	15,000	Operational
Pond 3	Treated leachate storage	15,000	Soon to become operational
Temporary Tank 1	Leachate storage	3,000	Under repair soon to be operational
Temporary Tank 2	Leachate storage	3,000	Under repair soon to be operational
Temporary Tank 3	Leachate storage	13,000	Under repair soon to be operational

The nominal total capacity available for leachate storage is 49,000 KL (table 1) with a maximum capacity of 52,000 KL which includes the buffer capacities in Ponds 1 and 2 for emergency storage. Pond 3 can store leachate but is currently nominated for storing treated leachate and has nominal capacity of 15,000 KL.

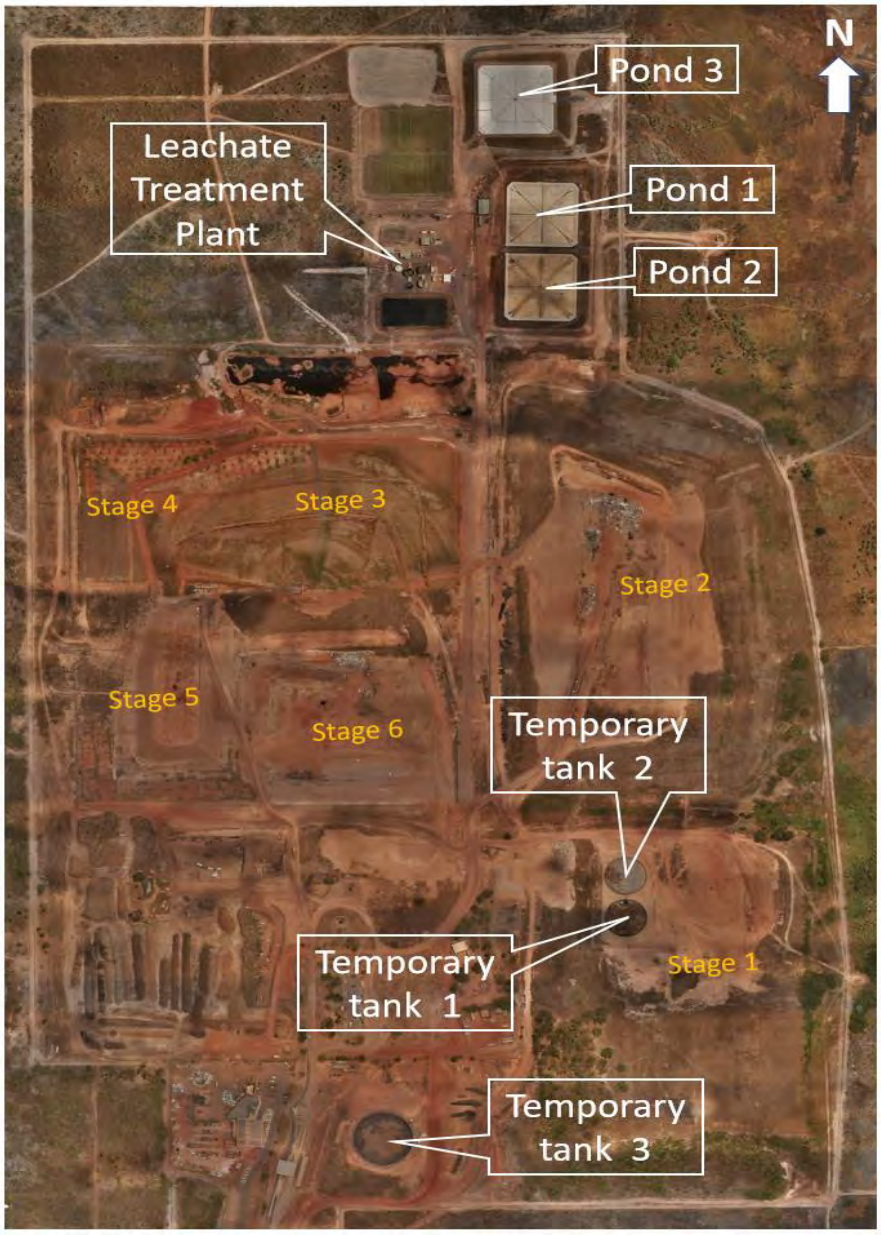


Figure 1: Leachate infrastructures at SBWMF.

3. Leachate generation rates

Over the last 12 months, from November 22 to October 23, the total leachate generation (Fig 2) was approximately 43,000 KL. The highest monthly generation of over 9000 KL of leachate occurred in March 23, which correlates with one of the wettest February rainfalls experienced at Darwin. The total rainfall recorded for the year was 2,189 mm, which is well above the annual mean of 1,724 mm. Therefore, some variation in the leachate generation can be expected in the coming year depending on the rainfall. The BoM is predicting slightly drier condition for the coming 23/24 wet season.

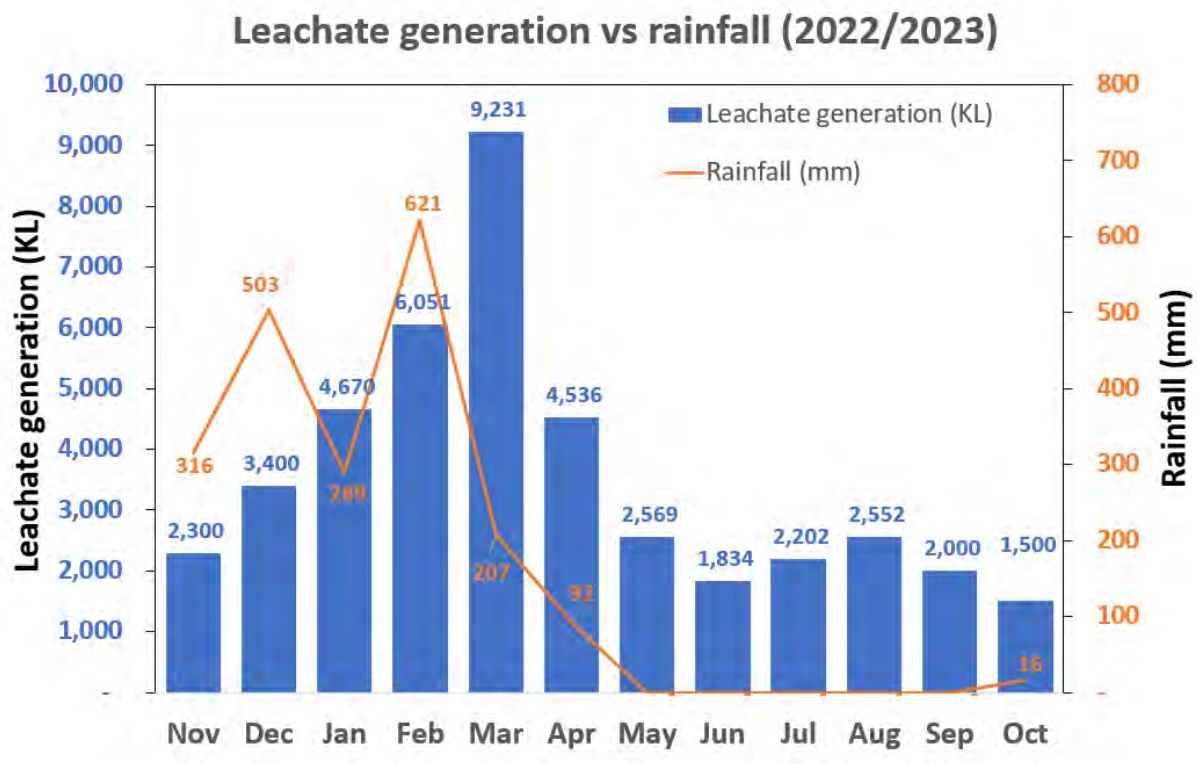


Figure 2: Monthly leachate generation and rainfall data.

4. Leachate treatment and treated leachate irrigation

The commissioning Leachate Treatment Plant (LTP) has a combination of PFAS removal and biological nutrient removal systems. The LTP is designed with a maximum treatment capacity of 140 KL/day, but up to 150 KL/day of leachate treatment has been reported during the commissioning phase of the plant.

Since June 2023 the LTP has operated at the maximum plant capacity with average production of 138 KL/day (Fig 3). It can be safely assumed that the plant can operate close to maximum capacity during normal circumstances. However, the LTP is still under commissioning phase, future years may encounter technical issues to be resolved that have the ability to reduce leachate treatment rates. The LTP Operator has been proactive and efficient in resolving the plant operational issues thus far. Similarly, treated leachate irrigation has also produced some promising results, averaging around 127 KL/day with max irrigation reported over 220 KL/day (Fig 3).

The major limiting factors for leachate treatment are the limited storage available for treated leachate and the ability to irrigate the annual treated leachate generated during the dry months. Based on the experience from last year, it is likely that minimal treated leachate irrigation will occur between November through to April, where treated leachate must be stored in Pond 3. City of Darwin is still waiting final approval from EPA for its use.

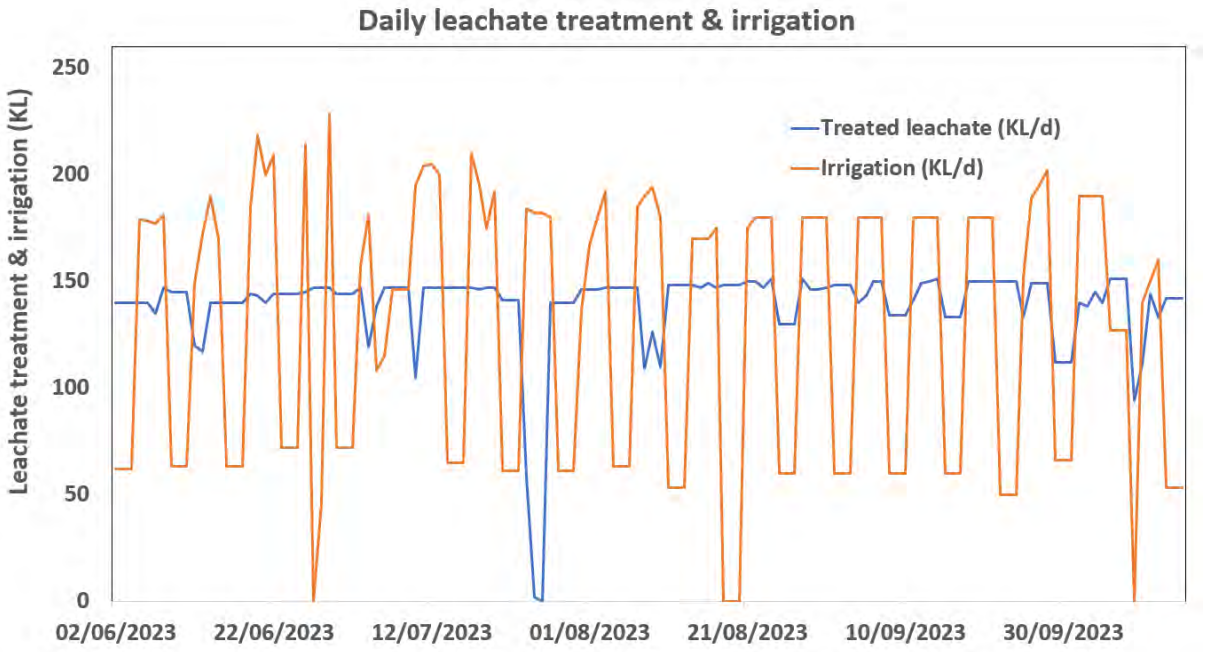


Figure 3:Daily leachate treatment at LTP and treated leachate irrigation during the dry season.

The other alternative leachate disposal is raw leachate irrigation on top of stage 5 and the southern batter of stage 3 over a total available area of 10,000 m^2 (Fig. 4). During the last dry season (1 June 2023- 15 Sept 2023) approximately 30 KL/day of leachate was irrigated and disposed through evaporation. The maximum irrigation reported was greater than 90 KL/d. As seen in Fig 3, there is significant opportunity to optimise raw leachate irrigation in the coming dry season through proper planning and utilising the most suitable pumps/equipment for the job. The days with no irrigation or low daily irrigation were mainly associated with issues related to leachate pumps not being able to pump leachate on top of Stage 5. Moving forward, the landfill Operator is aware of the issues that need to be resolved to ensure that optimum irrigation occurs on stage 5 from next dry season.

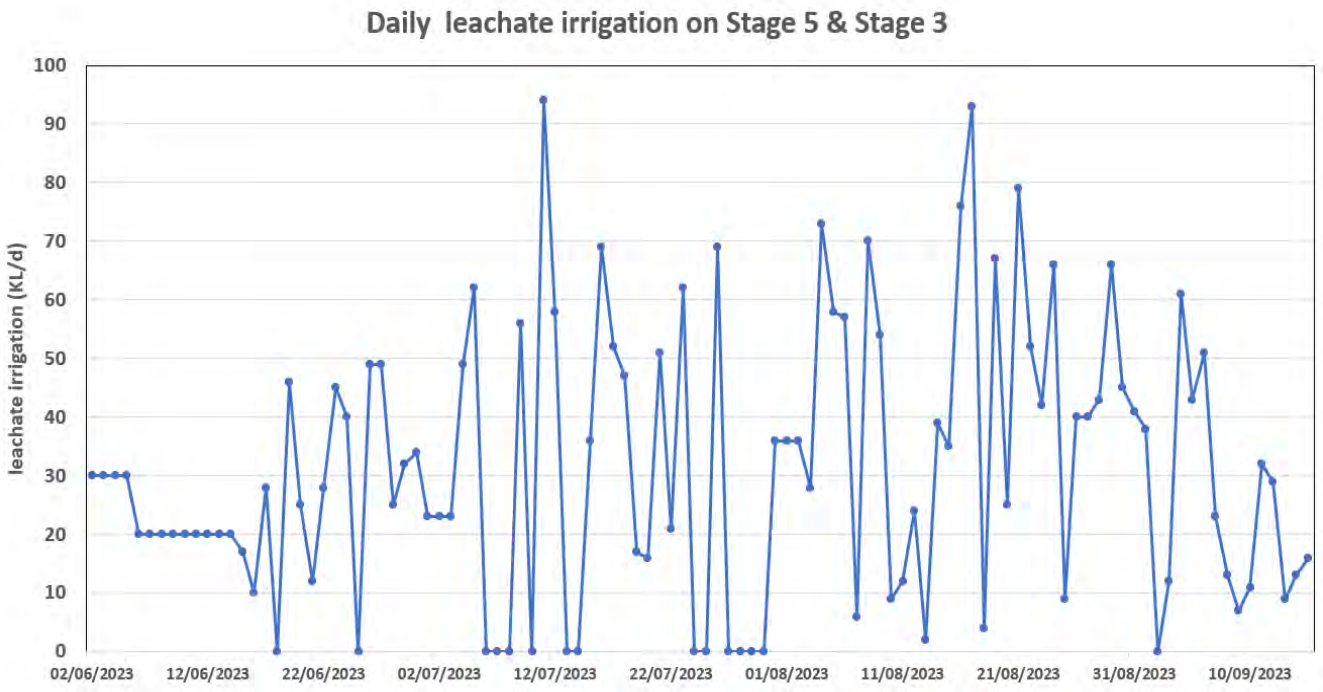


Figure 4: Daily leachate irrigation on Stage 5 & southern batter of Stage 3.

5. Long term leachate balance

The leachate balance (Fig 5) shows significant leachate disposal happening between November 2022 and November 2023, including the drawdown of more than 7,000 KL of legacy leachate in 2023. The onsite leachate volume started at approximately 40,000 KL in November 2023, peaked over 50,000 KL in April 2023 (max storage available is 52,000 KL) and it is expected to drop down to about 28,000 KL by the end of November 2023. The ramping up of LTP production to its maximum operating capacity and raw leachate irrigation on stage 5 and 3 certainly helped in the reduction of the onsite leachate volumes, including the treatment of leachate generated daily from the landfill. It is important to note that the during the past wet season, there was no restriction on the storage of treated leachate as it was all stored in the borrow pit. Approximately 12,000 KL of treated leachate was transferred from the LTP to the borrow pit, excluding 3000-4000 KL of rainwater contribution from the wetland. The borrow pit is not permitted for regular use under the Shoal Bay environmental protection licence and won't be available for the coming wet season, so the only storage of treated leachate will be in Pond 3 (15,000 KL) and possibly a small temporary tank (3,000 KL). Therefore, the LTP production during the coming wet season and in the future will be dictated by the available storage for the treated leachate, ability to irrigate during the wet season and undertaking significant treated leachate irrigation during the dry season.

Fig 5 provides a forecast on the cumulative onsite leachate storage (Table 1) based on three different scenarios of LTP operation during the wet season. The cumulative leachate balance

under all scenarios includes 5000 KL of raw leachate that can be irrigated on Stage 5 & Stage 3 during the dry season.

- Scenario 1 - LTP is at max production (140 KL/d) throughout the year
- Scenario 2 - LTP is at high production (120 KL/d) from November - May & 140 KL/d for other months
- Scenario 3 - LTP is at low production (100 KL/d) from November - May & 140 KL/d for other months

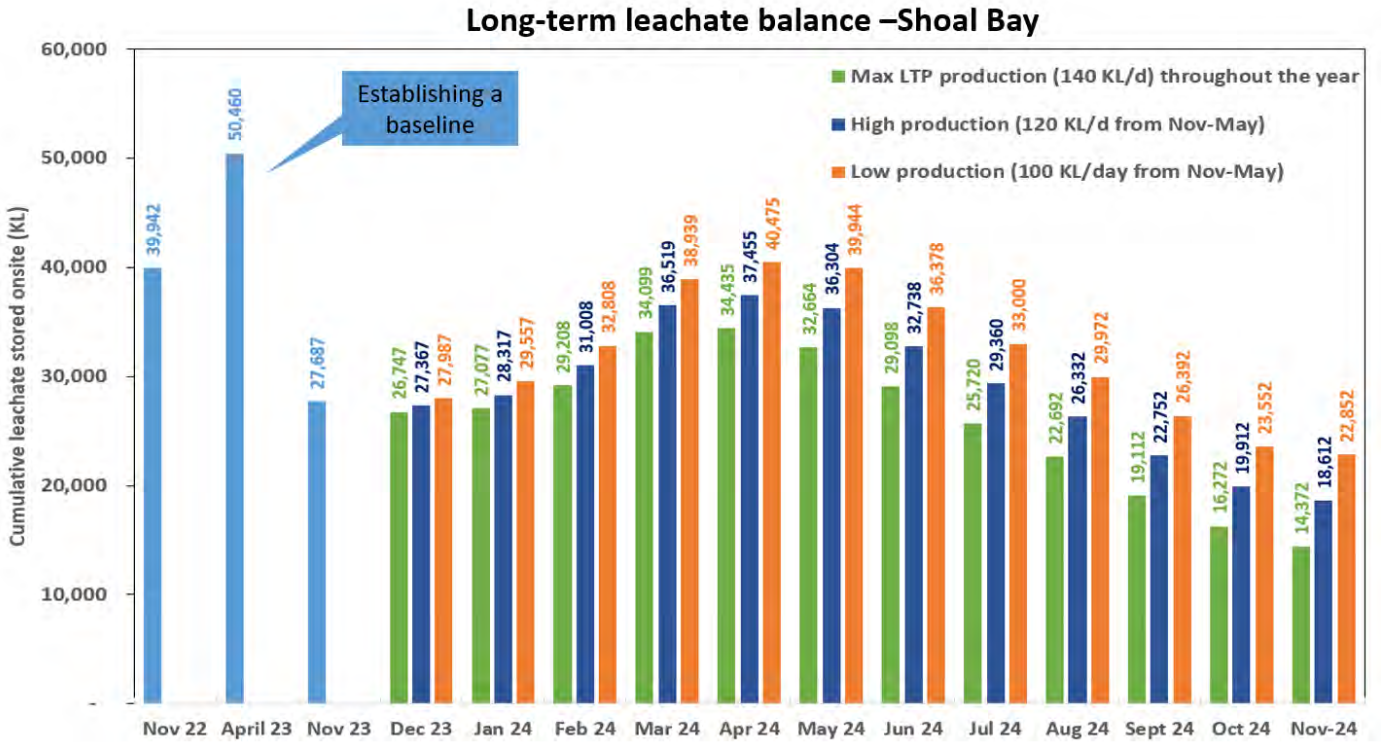


Figure 5: One year leachate balance forecast for Shoal Bay.

For all three scenarios the onsite leachate balance in November 2024 will be in an improved position than in November 2023. Scenario 1, maximum leachate treatment, is the preferred option (Table 2) however, there will be limited storage for treated leachate (scenario requires approximately 30,000 KL of storage capacity) unless a significant treated leachate irrigation can occur during the wet season. Scenarios 2 and 3 are more realistically matched with the storage availability for treated leachate and the required irrigation rate of the treated leachate during the dry season.

Table 2: Potential treated leachate storage and irrigation requirement

Treated leachate volumes	**Max production**	**High production**	**Low production**
Treated leachate to be stored (KL) during the wet season (November – May, inclusive)	29,680	25,440	21,200
Total treated leachate for irrigation (KL) (stored from the wet season + daily production during the dry season (May – November, inclusive)	55,440	50,600	45,760
Required irrigation rate over the dry season (KL/day over 6 months)	308	281	254

6. Legacy leachate in landfill cells

The leachate levels in the cells are periodically monitored using gas bubblers installed on the gas collection wells and from the leachate telemetry installed onsite. There are 44 gas wells spread over Stage 3, 4 & 5 which are monitored for leachate levels. The amount of free-flowing leachate is estimated as base area of each stage multiplied by leachate height porosity (%) as free-flowing leachate volume/volume of saturated waste[1]. The 10% porosity of free-flowing leachate used in the leachate management plan[1] is likely overestimated, and there is no reference to any sources. Other detailed research[2] have reported a mean porosity of 4.6%, which is adopted in this report for estimating leachate in the cells. The leachate estimate in the cells are provided in Table 3 based on the methodology described above. It is estimated that approximately over 42,000 KL of leachate is currently stored in the cells. Currently there is no site-specific data to work out the porosity factor for Shoal Bay. The current system of leachate data recorded and proposed telemetry upgrades should provide some useful information in determining site specific data in the future. The latest leachate readings were taken on 10 October 2023. Moving forward, leachate levels will be monitored weekly during the wet season (Nov-April) and monthly during the dry season (May-Oct).

As per last year's leachate generation data and limited LTP production expected during the wet season, legacy leachate treatment will be a long-term process over 4-8 years (Fig. 6). The leachate generation rates and LTP production during the wet season over the years will

[1] Microsoft Word - Colsterworth Leachate Management Plan June 2019 (environment-agency.gov.uk)

[2] Microsoft PowerPoint - KNOX.ppt (geolsoc.org.uk)

lead to variable leachate drawdown from the cells. During September and October 2023 more than 7,000 KL of leachate was treated from Stage 5 cell.

Table 3: leachate levels and volumes within cells.

Stages	Floor area (m^2)	Average leachate levels (m)	Estimated vol (KL) at 4.6% porosity	Note
Stage 3	60,000	6.5	17,940	leachate levels from gas wells
Stage 4	26,000	6	7,176	leachate levels from gas wells
Stage 5	36,500	6	10,074	leachate levels from gas wells
Stage 6	37,900	4	6,974	leachate levels from Airwell telemetry
Total estimated leachate (KL)			**42,164**	Free flowing leachate is % porosity (vol/vol saturated) waste

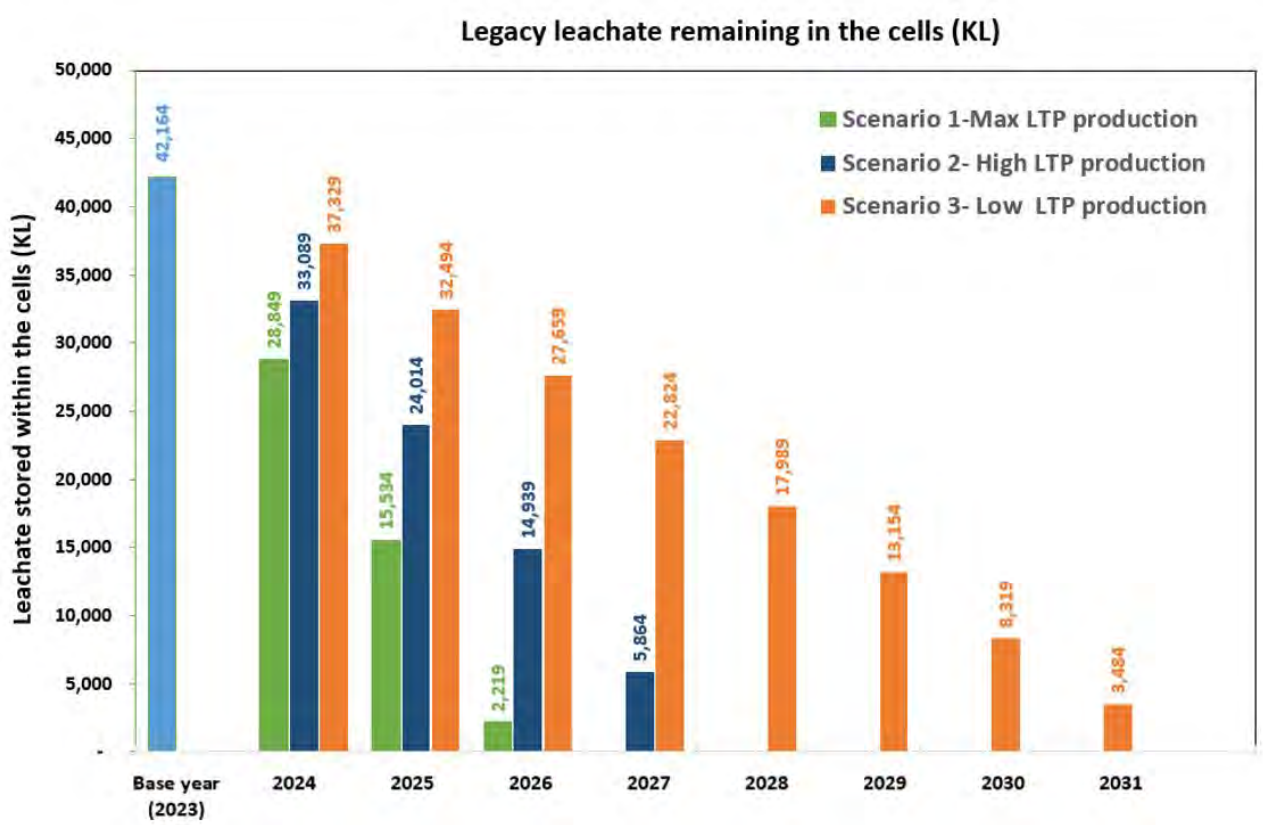


Figure 6: Legacy leachate remaining within the cells.

7. Overall outlook

- There is limited data on the LTP production and irrigation capability during the wet season to establish a highly accurate forecast.
- Leachate data maintained so far suggests that a combination of LTP operation and raw leachate irrigation should be sufficient to manage the annual leachate generation from the landfill cells.
- City of Darwin must optimise irrigation of raw leachate over stage 5, stage 3 and possibly on stage 6 if feasible during the dry season
- During September and October 2023 more than 7,000 KL of legacy leachate was treated from Stage 5
- About 42,000 KL of legacy leachate is estimated within the cells as of 10 October 2023
- As per the current data, treatment of legacy leachate will take between 4-8 years, significantly depending on leachate generation, LTP production and leachate irrigation/evaporation in the coming years.

8. Supplementary information

Table 4: Leachate generation & treatment scenarios.

Months (2022-2023)	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
Days	30	31	31	28	31	30	31	30	31	31	31	31	
Leachate generation (monthly-actual past data)	2,300	3,400	4,670	6,051	9,231	4,536	2,569	1,834	2,202	2,552	2,000	1,500	42,845
Leachate irrigation (40 KL/day)	-	-	-	-	-	-	-	1,200	1,240	1,240	1,240	-	4,920
LTp Treatment max (140 KL/d)	4,200	4,340	4,340	3,920	4,340	4,200	4,340	4,200	4,340	4,340	4,340	4,340	51,240
LTP treatment (120 KL/day)	3,600	3,720	3,720	3,360	3,720	3,600	3,720	4,200	4,340	4,340	4,340	4,340	47,000
LTP treatment (100 KL/day)	3,000	3,100	3,100	2,800	3,100	3,000	3,100	4,200	4,340	4,340	4,340	4,340	42,760
Net accumulation at 140 Kl/d	- 1,900	- 940	330	2,131	4,891	336	- 1,771	- 3,566	- 3,378	- 3,028	- 3,580	- 2,840	- 13,315
Net accumulation at 120 Kl/d	- 1,300	- 320	950	2,691	5,511	936	- 1,151	- 3,566	- 3,378	- 3,028	- 3,580	- 2,840	- 9,075
Net accumulation at 100 Kl/d	- 700	300	1,570	3,251	6,131	1,536	- 531	- 3,566	- 3,378	- 3,028	- 3,580	- 2,840	- 4,835
Rainfall (mm)	316	503	289	621	207	92	-	-	-	-	-	16	2,044
**Note: Jun-Oct is operating at max capacity 140 KL/d for all scenarios													

Table 5: Expected cumulative leachate storage onsite.

Nov 2023-Oct 2023	Nov-22	Apr-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24
Max LTP production (140 KL/d) throughout the year	39,942	50,460	27,687	26,747	27,077	29,208	34,099	34,435	32,664	29,098	25,720	22,692	19,112	16,272	14,372
High production (120 KL/d from Nov-May)	39,942	50,460	27,687	27,367	28,317	31,008	36,519	37,455	36,304	32,738	29,360	26,332	22,752	19,912	18,612
Low production (100 KL/day from Nov-May)	39,942	50,460	27,687	27,987	29,557	32,808	38,939	40,475	39,944	36,378	33,000	29,972	26,392	23,552	22,852