Appendix B Supporting Documents

Appendix B1 EMP

Environmental Management Plan

Shoal Bay Waste Management Facility

City of Darwin

DOCUMENT CONTROL RECORD

Job	EZ22109
Document ID	217373-59
Author(s)	Emma Lewis, Paula Martinez, Adele Faraone

DOCUMENT HISTORY

Rev	Reviewed by	Approved by	Issued to	Date
DRAFT	C. Hutchinson	-	City of Darwin	05/06/2020
DRAFT	C. Hutchinson	-	City of Darwin	05/08/2020
1	C. Hutchinson	C. Hutchinson	City of Darwin	12/08/2020
2	C. Hutchinson	C. Hutchinson	City of Darwin	21/08/2020
3	Emma Smith	Emma Smith	City of Darwin	08/12/2021
4	Emma Smith	Emma Smith	City of Darwin	13/12/2021
5	Emma Lewis	Emma Lewis	City of Darwin	11/08/2022
6	City of Darwin	City of Darwin	City of Darwin	08/03/2023
7	Adele Faraone	Pema Dorji (City of Darwin)	City of Darwin	17/07/2023

Recipients are responsible for eliminating all superseded documents in their possession.

EcOz Pty Ltd.
ABN: 81 143 989 039
Level 1, 70 Cavenagh Street
DARWIN NT 0800
GPO Box 381, Darwin NT 0800

Telephone: +61 8 8981 1100
Email: ecoz@ecoz.com.au
Internet: www.ecoz.com.au

RELIANCE, USES and LIMITATIONS

This report is copyright and is to be used only for its intended purpose by the intended recipient, and is not to be copied or used in any other way. The report may be relied upon for its intended purpose within the limits of the following disclaimer.

This study, report and analyses have been based on the information available to EcOz Environmental Consultants at the time of preparation. EcOz Environmental Consultants accepts responsibility for the report and its conclusions to the extent that the information was sufficient and accurate at the time of preparation. EcOz Environmental Consultants does not take responsibility for errors and omissions due to incorrect information or information not available to EcOz Environmental Consultants at the time of preparation of the study, report or analyses.

TABLE OF CONTENTS

1 INTRODUCTION 1

1.1 Background 1

1.2 Objectives 1

1.3 Responsibilities 1

1.4 Applicable environmental legislation 4

1.5 Approvals and licences 5

1.6 Environmental Policy 5

1.7 Related documents 5

2 FACILITY OVERVIEW 7

2.1 Waste types and volumes 7

2.2 Operational hours 7

2.3 Facilities, access, and layout 7

2.4 Landfill operations 10

2.4.1 Waste disposal method 10

2.4.2 Additional cover for special wastes 10

2.4.3 Performance criteria 11

2.5 Landform and site development 11

3 CONCEPTUAL SITE MODEL 17

3.1 Environmental setting 17

3.1.1 Surrounding land use 17

3.1.2 Sensitive receptors 17

3.1.3 Site land use 18

3.1.4 Climate 18

3.1.5 Land units and soils 18

3.1.6 Surface water drainage 19

3.1.7 Geology and hydrogeology 21

3.1.8 Surface water, groundwater, leachate and soil quality 21

3.1.9 Acid sulfate soils 22

3.2 Potential contaminants and receptors 22

3.2.1 Potential sources of contamination 22

3.2.2 Contaminants of potential concern 23

3.2.3 Potential receptors 23

3.2.4 Potential exposure pathways 24

4 RISK ASSESSMENT 25

4.1 Methodology 25

4.1.1 Risk ranking 25

4.2 Risk assessment 27

5 ENVIRONMENTAL MANAGEMENT 32

5.1 Overview 32
5.2 General environmental management 32
5.3 Waste acceptance and disposal 33
5.4 Listed waste 33
5.4.1 Listed waste objectives and targets 33
5.4.2 Listed waste tracking 34
5.4.3 Listed waste management 34
5.4.4 Listed waste management measures 34
5.5 Storage and use of hazardous substances 38
5.6 Water quality 38
5.6.1 Treatment concepts and principles 39
5.6.2 Water monitoring 46
5.6.3 Water management 49
5.7 Leachate 50
5.7.1 Leachate overview 50
5.7.2 Leachate management 55
5.8 Dust and odour 56
5.9 Landfill gas 57
5.9.1 Overview 57
5.9.2 Management 59
5.9.3 Monitoring 59
5.10 Noise 59
5.11 Litter 60
5.12 Flora and fauna 60
5.13 Pests and weeds 61
5.14 Fire prevention 61
6 COMMUNICATION AND CONSULTATION 63
6.1 Inductions and training 63
6.2 Stakeholders 63
6.3 Communication and consultation 63
6.3.1 Internal communication 63
6.3.2 Awareness 63
6.3.3 Community consultation 64
6.3.4 External stakeholders 64
6.4 Complaint management 64
7 AUDITS AND REPORTING 65
7.1 Audits 65
7.2 Non-conformance and corrective actions 65
7.3 Incident management 65
7.4 Reporting 65

7.5 Reviews 66
7.6 Document control 66
8 EMERGENCY RESPONSE PLAN 67
8.1 Potential emergency incidents 67
8.2 Emergency contacts 67
8.3 Objectives, targets, and indicators of the ERP 67
8.4 Emergency response procedures 68
8.4.1 General emergency preparedness 68
8.4.2 Fire 69
8.4.3 Spills 69
8.4.4 Leachate breakouts 70
8.4.5 Storm surge or flooding 70
8.4.6 Environmental incidents 70
8.4.7 Medical emergencies 71
8.5 Emergency Training 71
8.6 Equipment 71
9 CLOSURE 72
9.1 Closure objectives 72
9.2 Closure considerations 72
9.3 Final landform 73
9.4 Capping 73
9.4.1 Stage 3 / Stage 4 73
9.5 Revegetation 74
9.6 Final land use 75
9.7 Landfill gas 75
9.8 Leachate 75
10 POST CLOSURE 79
10.1 Monitoring 79
10.2 Settlement 79
10.3 Maintenance 80
11 REFERENCES 81

Tables

Table 1-1. Responsibilities and contact details 1
Table 1-2. Applicable legislation 4
Table 1-3. Listed wastes authorised for handling under EPL188-3 5
Table 2-1. Landfill waste quantities handled at SBWMF in addition to listed wastes 7
Table 2-2. Types and quantities of recycled waste handled at SBWMF in addition to listed wastes 7
Table 2-3. SBWMF facilities 8
Table 2-4. SBWMF waste disposal performance criteria 11
Table 2-5. Summary of landfill stage lifespans 14

Table 2-6. Summary of future development precincts 14
Table 3-1. Land units within the SBWMF site 19
Table 4-1. Consequence ranking 26
Table 4-2. Qualitative measures of likelihood 26
Table 4-3. Risk rankings from combined consequences and likelihood 26
Table 4-4. Environmental aspects and impacts register 27
Table 5-1. General environmental management 32
Table 5-2. General and recyclable waste management 33
Table 5-3. Listed waste management objectives, targets and performance measures 34
Table 5-4. Special waste management 34
Table 5-5. Contaminated soil management 35
Table 5-6. Asbestos and asbestos containing material management 36
Table 5-7. Battery and paint management 36
Table 5-8. Waste tyre management 37
Table 5-9. Waste oil management 37
Table 5-10. Storage and use of chemicals, oils, and fuels 38
Table 5-11. Water categories for management 39
Table 5-12. Proposed controls, maintenance triggers and actions 44
Table 5-13. Leachate monitoring sites and offsite monitoring site details 46
Table 5-14. Groundwater monitoring bore details 48
Table 5-15. Landfill stages and leachate collection systems. 50
Table 5-16. Estimated leachate collection volume estimates (ML) 51
Table 5-17. Leachate management 55
Table 5-18. Dust, odour and aesthetics management 56
Table 5-19. Landfill gas management 59
Table 5-20. Noise management 59
Table 5-21. Litter management 60
Table 5-22. Flora and fauna management 60
Table 5-23. Pest and weed management 61
Table 5-24. Fire prevention management 61
Table 8-1. Emergency contact details 67
Table 8-2. Emergency objectives, targets and indicators summary 68
Table 10-1. Post-closure environmental monitoring program 79

Figures

Figure 1-1. SMWMF location 2
Figure 1-2. Uncleared UXO area 3
Figure 2-1. SBWMF site facilities and access routes 9
Figure 2-2. Area method of landfilling (NT EPA 2013) 10
Figure 2-3. Proposed C&D waste recycling and pre-sorting pad on Stage 1 12
Figure 2-4. Proposed location for tyre shredding pad (adapted from Google Earth 2023) 13
Figure 2-5. Landfill cell staging 15
Figure 2-6. Future development precincts 16
Figure 3-1. Graph of mean temperature and rainfall at Darwin Airport (Station no. 014015) 18
Figure 3-2. Mapped land units at SBWMF 20
Figure 5-1. Typical layout of a level spreader 40
Figure 5-2. Stormwater management for Stages 2 to 6 and green waste 41
Figure 5-3. Stormwater management for Stages 7 to 8 and green waste 42
Figure 5-4. Stormwater management for Stages 9 to 10 43
Figure 5-5. SBWMF constructed general waste landfill cells and leachate collection pump locations 53

Figure 5-6. SBWMF engineered general waste landfill stages leachate collection systems 54
Figure 5-7. Active Landfill Gas System at SBWMF 58
Figure 9-1. Capping profile of Stage 3 / Stage 4 74
Figure 9-2. Pre-settlement landform 76
Figure 9-3. Post-settlement landform 77
Figure 9-4. Final capping plan 78

Appendices

Appendix A City of Darwin Environmental Policy
Appendix B Water Quality Monitoring Plan
Appendix C Landfill Gas Monitoring Plan
Appendix D Stockpile Management Plan
Appendix E Site Inspection Checklist
Appendix F Stage 3 /4 Capping Design
Appendix G Irrigation Management Plan
Appendix H Emergency Leachate Management Procedure, shoal bay waste management facility
Appendix I Leachate Storage Pond 3 Detail Design

ACRONYMS

ANZECC	Australian and New Zealand Environment and Conservation Council
ARI	Average Recurrence Interval
AS	Australian Standard
BoM	Bureau of Meteorology
CoD	City of Darwin
CSM	Conceptual Site Model
DoD	Department of Defence
EMP	Environmental Management Plan
EPA	Environment Protection Approval
EPL	Environment Protection Licence
GCL	Geosynthetic Clay Line
IMP	Irrigation Management Plan
LFG	Landfill Gas
LGMP	Landfill Gas Monitoring Plan
LDP	Landfill Development Plan
LTP	Leachate Treatment Plant
ML	Megalitre
NT EPA	Northern Territory Environment Protection Authority
SDS	Safety Data Sheet
SWMP	Site Water Monitoring Plan
SBWMF	Shoal Bay Waste Management Facility
UXO	Unexploded Ordinance
WMPC Act	*Waste Management and Pollution Control Act*

1 INTRODUCTION

1.1 Background

The Shoal Bay Waste Management Facility (SBWMF) is a municipal waste resource recovery and disposal site operated by the City of Darwin (CoD). The SBWMF services both domestic and commercial customers in the Darwin area.

The SBWMF is located 13 km north-east of Darwin City within Lot 3952, Town of Sanderson, in the suburb of Holmes (see Figure 1-1). CoD lease the entire property area from the Commonwealth Department of Defence (DoD). Under the terms and conditions of the lease, only a portion of the property is designated as a Waste Management Project Area in which CoD is authorised to conduct waste management and ancillary activities. The remainder of the site consists of an uncleared unexploded ordinance (UXO) area (Figure 1-2).

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 800 m to the south-west with a bushland buffer in between.

1.2 Objectives

This holistic and integrated Environmental Management Plan (EMP) details the environmental management measures undertaken at SBWMF to minimise potential impacts to the surrounding environment.

Specifically, it identifies the environmental risks associated with SBWMF operations, and details the environmental management measures, controls and monitoring that will be implemented by all staff and contractors operating within the site.

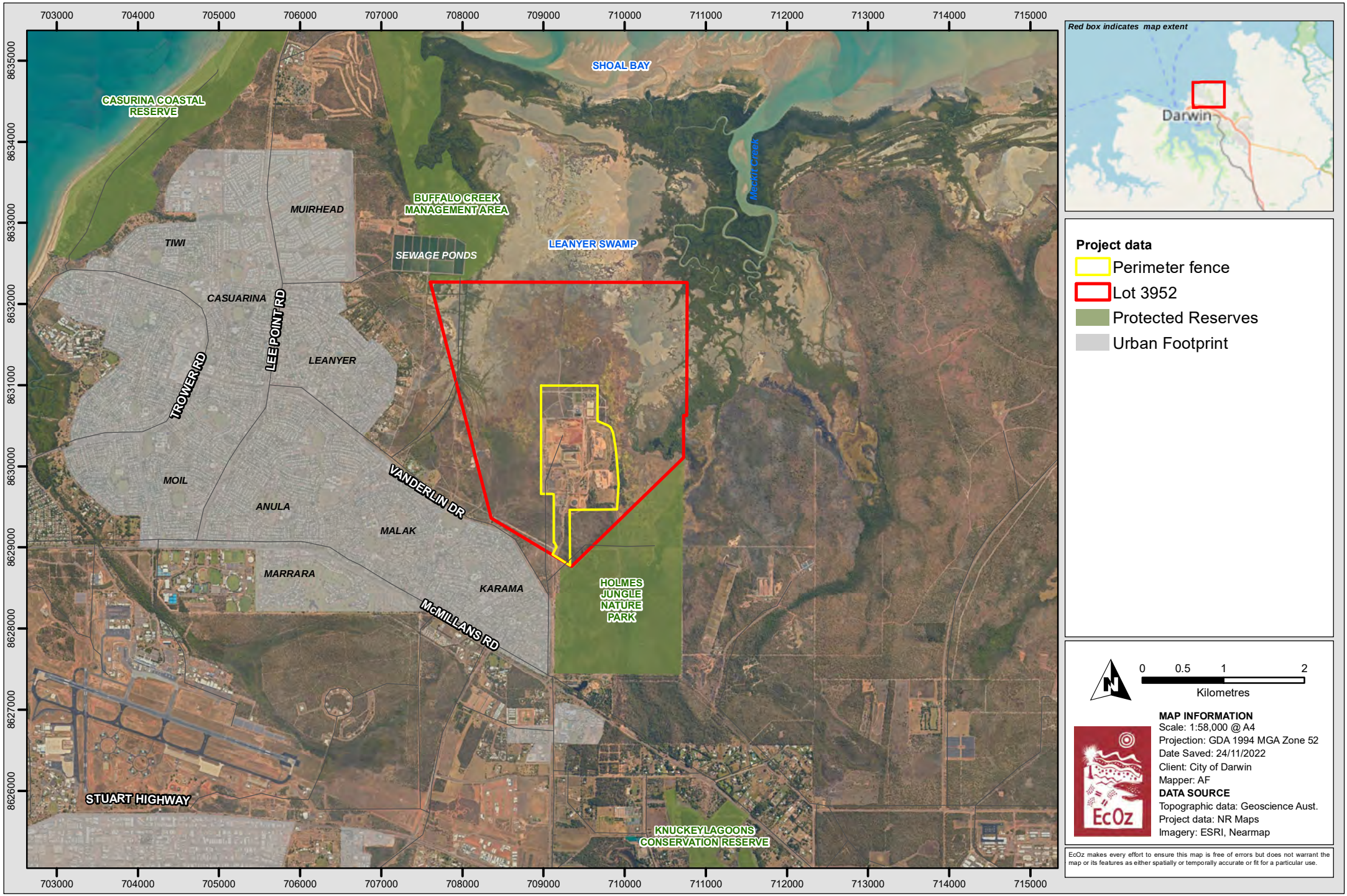
This EMP has been developed to comply with the relevant environmental legislation; and to adhere to the conditions of all applicable licences, approvals and permits.

1.3 Responsibilities

Table 1-1 below outlines the responsibilities for implementing this EMP.

Table 1-1. Responsibilities and contact details

Responsibility	Responsible personnel	Contact details
Develop EMP	• City of Darwin • Environmental Consultant	General Manager Engineering and City Services City of Darwin Ph: 08 8930 0300 E: darwin@darwin.nt.gov.au Environmental Consultant EcOz Environmental Consultants Ph: 08 8981 1100 E: ecoz@ecoz.com.au
Develop and maintain environmental procedures	• City of Darwin • Environmental Consultant	
Implement management measures	• City of Darwin • SBWMF Operating Contractor	
Assure EMP compliance and reporting	• City of Darwin • SBWMF Operating Contractor	



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Fig 1-1. SBWMF location.mxd

Figure 1-1. SBWMF location



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Fig 1-2. Uncleared Unexploded ordinance Area.mxd

Figure 1-2. Uncleared UXO Area

1.4 Applicable environmental legislation

Table 1-2 lists the applicable environmental Commonwealth and Northern Territory legislation for SBWMF operations.

Table 1-2. Applicable legislation

Environmental aspect	Applicable legislation
Air quality	• *Ozone Protection Act 1989 (Cwlth)* • *Waste Management and Pollution Control Act (NT) (WMPC Act)* • *National Environment Protection Council. 2003 National Environment* • *Protection (Ambient Air Quality) Measure (NEPM)* • *National Environment Protection Council. 2011 National Environment* • *Protection (Air Toxics) Measure (NEPM)* • *National Environment Protection Council. 1998 National Environment* • *Protection (National Pollutant Inventory) Measure (NEPM)*
Bushfire	• *Bushfires Act (NT)* • *Fire and Emergency Act (NT)*
Dangerous goods	• *Dangerous Goods Act (NT)* • *Road Transport (Dangerous Goods) Act 1995 (NT)* • *Dangerous Goods (Storage and Handling) Regulations 2000 (NT)* • *Road Transport Reform (Dangerous Goods) Act 1995 (Cwlth)*
Flora and Fauna (including weeds and pests)	• *Animal Welfare Act (NT)* • *Bushfires Act (NT)* • *Environment Protection and Biodiversity Conservation Act 1999 (Cwlth)* • *Fisheries Act (NT)* • *National Environmental Protection Council (Northern Territory) Act (NT)* • *Plant Health Act (NT)* • *Public and Environmental Health Act (NT)* • *Public Health (General Sanitation, Mosquito Prevention, Rat Exclusion and Prevention) Regulations (NT)* • *Soil Conservation and Land Utilisation Act (NT)* • *Territory Parks and Wildlife Conservation Act (NT)* • *Weeds Management Act (NT)*
Heritage	• *Australian Heritage Commission Act 1975 (Cwlth)* • *Heritage Act (NT)* • *National Heritage Trust of Australia Act 1997 (Cwlth)*
Noise	• *Environmental Protection and Biodiversity Conservation Act 1999 (Cwlth)* • *Waste Management and Pollution Control Act (NT)*
Waste and Hazardous Waste	• *Environmental Offences and Penalties Act (NT)* • *Work Health and Safety (National Uniform Legislation) Act (NT)* • *Hazardous Waste (Regulation of Exports and Imports) Act 1989 (Cwlth)* • *Litter Act (NT)* • *National Environment Protection Council. 2011. National Environment* • *Protection (Used Packaging Materials) Measure as varied 16 September 2011* • *Public and Environmental Health Act (NT)* • *Public Health (General Sanitation, Mosquito Prevention, Rat Exclusion and Prevention) Regulations (NT)* • *Waste Management and Pollution Control Act (NT)*
Water (surface and groundwater)	• *Water Act (NT)* • *Waste Management and Pollution Control Act (NT)*
Future Development	• *Environment Protection Act (NT)* • *Waste Management and Pollution Control Act (NT)*

1.5 Approvals and licences

Conditions of the SBWMF lease agreement between the CoD and DoD include compliance with all applicable environmental legislation, and that the placement of waste is only to be within the allocated area.

Pursuant to Section 30, Part 2 of Schedule 2 of the *Waste Management and Pollution Control Act* (*WMPC Act*), a landfill servicing the waste disposal requirements of more than 1000 persons (such as the SBWF) requires an Environment Protection Licence (EPL). The Northern Territory Environment Protection Authority (NT EPA) have issued EPL188 to the CoD, covering the SBWMF (current version EPL188-03). EPL188 prescribes the conditions the SBWMF must meet to remain compliant.

Under EPL188, the SBWMF is also authorised to handle wastes that are classified as 'listed wastes' under the *WMPC Act*. Table 1-3 outlines the specified listed waste types authorised for storage, treatment, recycling and disposal at the SBWMF.

Any future proposed changes or developments at the SBWMF not covered under the current EPL188, requires prior approval and issue of an Environment Protection Approval (EPA) under Schedule 2 of the *WMPC Act*. Once construction is complete, the changes or developments must then be included as an amendment to the licence.

Table 1-3. Listed wastes authorised for handling under EPL188-3

Listed Waste	Collection	Transport	Storage	Treatment	Recycling	Disposal
Acidic solutions or acids in solid form	×	×	✓	×	×	×
Animal effluent and residues	×	×	×	×	×	✓
Asbestos	×	×	×	×	×	✓
Clinical and related wastes	×	×	×	×	×	✓
Lead, lead compounds	×	×	✓	×	×	×
Sewerage sludge and residues including nightsoil and septic tank sludge	×	×	×	×	×	✓
Soils contaminated with a listed waste	×	×	×	×	×	✓
Tyres	×	×	✓	✓	✓	✓
Waste from the production, formulation and use of inks, dyes, pigments, paints, lacquers, and varnish	×	×	✓	×	×	×
Waste mineral oils unfit for their original intended use	×	×	✓	×	×	×

1.6 Environmental Policy

CoD will ensure that the requirements of this EMP, the CoD Environmental Policy, and all operational procedures are understood, implemented, and maintained by all employees, contractors and subcontractors, at all levels involved in SBWMF operations. A copy of CoD's Environmental Policy is provided as Appendix A.

1.7 Related documents

In addition to, and to support this EMP, CoD has prepared the following documents to assist with the planning, operation and monitoring of waste management at SBWMF:

- General Waste Landfill Development Plan

- Encompasses current and future stages of lined waste disposal cells for the disposal of general waste until 2034
- Proposed stage layouts, order of construction, airspace capacity, final landform and final capping

- Inert Waste Landfill Development Plan
  - Proposed filling plan, airspace capacity and final landform for Stage 2
- Water Balance, Leachate and Stormwater Management Strategies
  - Includes a site-wide water balance model and assessment of appropriate leachate and stormwater management strategies to cover current and proposed future operations
  - Details the separation of clean and dirty water around the site and appropriate erosion and sediment controls required to minimise the risk of sediment-laden runoff
- SBWMF Master Development Plan
  - Identifies key site constraints and future development plans for the SBWMF site
- Disaster Waste Management Plan
  - Details the responsibilities and procedures to be followed in preparation for and in response to waste generated as a result of a disaster (i.e. cyclone, flood, earthquake etc.) that impacts the wider municipality
  - Includes procedures and processes specific to SBWMF to assist in disaster waste management
- Environmental Management Plan Leachate Treatment and Irrigation
  - Incorporates the treatment methodology, treated leachate quality targets, monitoring and maintenance requirements to facilitate leachate treatment and disposal.
- Irrigation Management Plan
  - Outlines the management activities that form the operation of the irrigation area, comprising operation, maintenance, and environmental management activities, as well as control measures that will be implemented to avoid environmental impacts
- Stockpile Management Plan
  - Details the rationale, design, potential risks, mitigation measures and controls to be implemented at the SBWMF regarding stockpile management
- Landfill Gas Monitoring Plan
  - Includes the rationale and design of landfill gas monitoring to be undertaken at the SBWMF

2 FACILITY OVERVIEW

2.1 Waste types and volumes

The SBWMF currently (as of 2022) accepts the waste types outlined in Table 2-1 and Table 2-2 below.

Table 2-1. Landfill waste quantities handled at SBWMF in addition to listed wastes
Information obtained from NT EPA (2022)

Description of waste/ source	Quantity (tonne)
Inert Waste (Virgin excavated material; concrete and bricks)	21,432
Municipal Waste	48,893
Commercial & Industrial (includes clean fill 198,832 tonne)	292,406
Construction & Demolition (fittings, fixtures, cabinetry, steel framework, roofing material, furniture, construction materials)	10,270

Table 2-2. Types and quantities of recycled waste handled at SBWMF in addition to listed wastes
Information obtained from NT EPA (2022)

Type of waste	Quantity	Unit (tonne, Litre)
e-waste	48	Tonne
White goods/Scrap Metal	2,664	Tonne
Green waste	12,866	Tonne
Used Lead Acid Batteries	89	Tonne
Cardboard	160	Tonne
Gas bottles & Fire extinguishers	11	Tonne
Paint	20	Tonne
Concrete for crushing	9,055	Tonne
Chemicals	1,695	Litre
Oil (motor)	46,301	Litre
Cooking oil	1,500	Litre

The site manages a total waste throughput of approximately 180,000 tonnes per annum including all listed wastes handled and recyclables salvaged.

2.2 Operational hours

SBWMF standard operating hours are seven days a week from 7:00 am to 6:00 pm, with the exception of Christmas Day.

2.3 Facilities, access, and layout

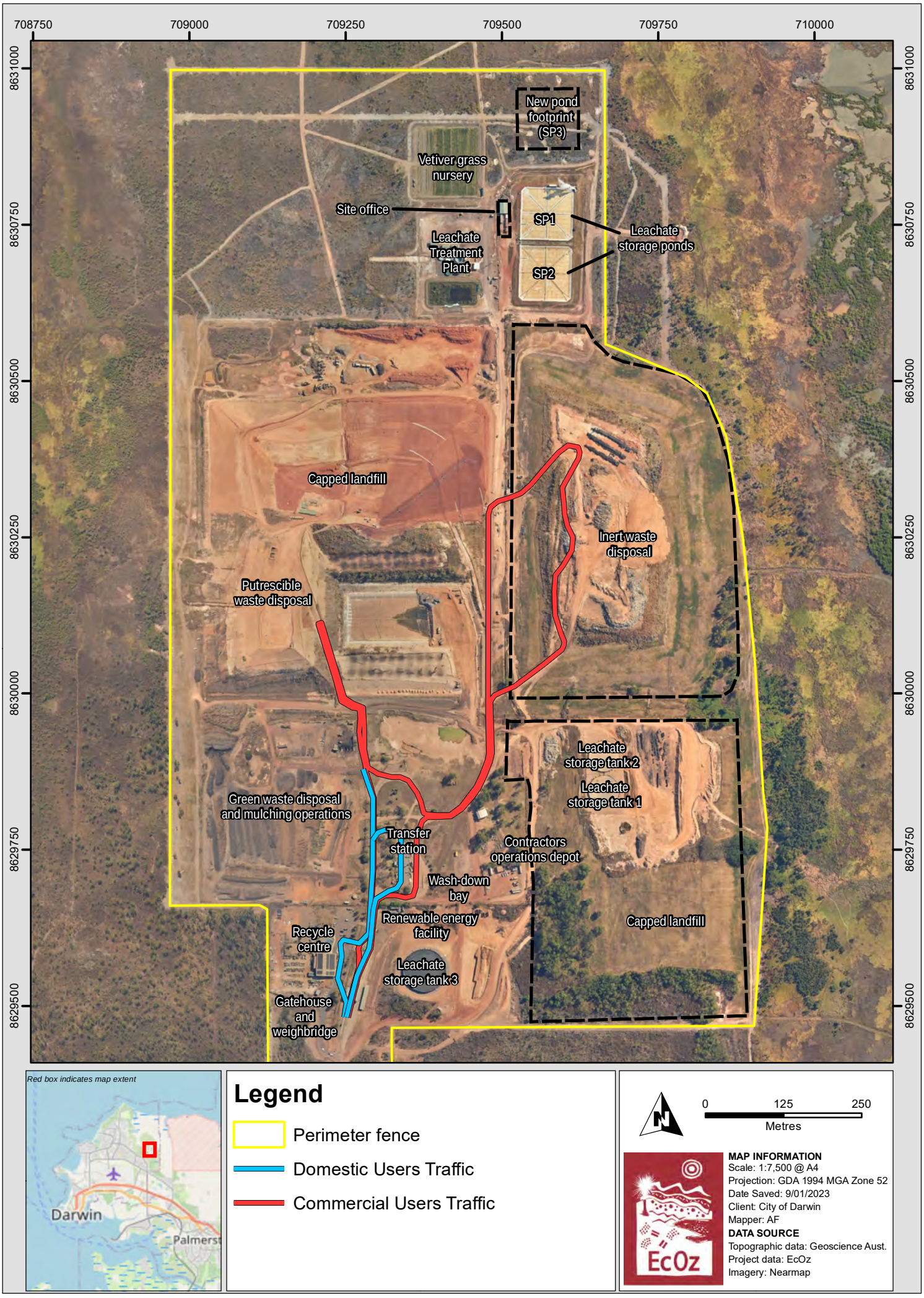
The SBWMF facilities are shown in Figure 2-1 and outlined in Table 2-3.

Access to the SBWMF (with exception to the recycle centre) is via the gatehouse. Domestic users can enter the facility through a pre-approved access boom-gate or via the gatehouse operator. Domestic users can only access the green waste area or transfer station to dispose of waste. Commercial users accessing the facility, must use the weighbridge for assessment of waste type and to complete payment. Commercial users are then directed to correct disposal area within the facility, depending on waste type (i.e. putrescible waste, inert

waste, green waste, etc). All users have access to the recycle centre without having to pass through the gatehouse.

Table 2-3. SBWMF facilities

Facility	Description
Recycle centre	A facility where users can drop off unwanted goods to be recycled, repurposed or resold to other users. The facility accepts a wide range of goods, including building materials, furniture, electronics and bric-a-brac.
Gatehouse and weighbridge	Located at the entrance to the site, the gatehouse includes office space and amenities for staff and a dual weighbridge system to allow for tracking of incoming and outgoing materials.
Transfer station	The transfer station is primarily for domestic users to drop off household waste for recycling, landfill or disposal off-site to a licenced facility. The transfer station allows for segregation of general, recyclable and domestic quantities of listed wastes. Users access the facility directly with their vehicles to unload.
Inert waste disposal	All inert waste loads are directed to the inert waste disposal cell. Where possible, recyclable materials such as steel and concrete are salvaged from the tip face prior to burial. The inert cell also caters for the disposal of asbestos products and asbestos containing material.
Putrescible waste disposal	All putrescible waste loads and listed wastes licenced for burial are directed to the active lined landfill cell for disposal.
Green waste disposal and mulching operations	All green waste loads are directed to the green waste disposal area for stockpiling. The green waste is then processed into mulch products for reuse on site or resold as a commercial product.
Renewable energy facility	Landfill gas is harvested from the landfill by a third-party contractor and directed to an on-site gas processing facility. The facility consists of a 1.1 MW engine which converts the gas to electrical power for supply back into the grid.
Leachate storage ponds and treatment area	Located at the northern end of the site are three leachate ponds of 15 ML capacity each, which are lined and covered ponds that store leachate extracted from the putrescible waste cells. Directly to the east of the storage ponds is the leachate treatment plant.
Temporary leachate storage tanks	One tank of 13 ML near the weighbridge and two tanks of 3 ML each on Stage 1. All these tanks are covered and have leak detection mechanism in place.
Wash-down bay	A wash-down bay is located near the site exit for use by commercial users after disposing of waste to landfill. The wash-down water is collected in a sump, processed through an oily-water separator and then irrigated as required over an existing landfill area.
Contractors' operations depot	A hardstand compound located at the southern end of site adjacent to Stage 1. The compound area is comprised of a series of demountable buildings and sheds and a workshop area for minor servicing of plant and equipment.



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Figure 2-1. SBWMF site facilities and access routes.mxd

Figure 2-1. SBWMF site facilities and access routes

2.4 Landfill operations

2.4.1 Waste disposal method

SBWMF utilises the area method of landfilling, whereby waste is disposed of at an active tip face and is then compacted in a mound above ground (as opposed to trench filling below ground), as depicted in Figure 2-2.

Each day the waste is covered with a heavy-duty tarp using a deployment system attached to standard landfill machinery. The tarp system is a widely accepted form of landfill daily cover and can be quickly deployed over the tip face. Other alternative methods of daily cover accepted at the site include mulch (during dry periods only) or clean fill (year-round). Material for cover is sourced from clean fill material accepted at the facility or imported as required. Daily cover is applied at a minimum thickness of 150 mm most of which can be retrieved on the following day prior to new waste disposal.

As the active tip area moves progressively along the length of the cell (building up the height), the waste disposal areas are covered with a 300 mm intermediate layer of cover material to minimise rainfall infiltration. Intermediate layers are sloped and graded to prevent ponding of water. As the landform progresses in height, intermediate cover is removed or penetrated as much as possible prior to waste placement to prevent impermeable layers potentially leading to perched leachate.

2.4.2 Additional cover for special wastes

Waste products brought to SBWMF as special wastes are to be disposed on a pre-prepared deep burial pit. Deep burial pits are excavated within the active landfill to the required depth for the volume of waste to be disposed. Once the waste has been off-loaded into the pit, the waste is immediately covered with 150 mm of cover material. Each deep burial pit is filled in at the end of each shift.

Asbestos waste is disposed of in the dedicated asbestos disposal area. Deposited asbestos waste at the asbestos area must immediately be covered by suitable material to prevent the release of fibres into the air. Final cover of the asbestos shall be to a minimum thickness of 3 m in the case of asbestos fibre and dust wastes, and 1 m in the case of stabilised asbestos wastes in a bonded matrix. Final cover of the asbestos is to incorporate orange marker mesh identifying that asbestos is buried below to the depth required as above.

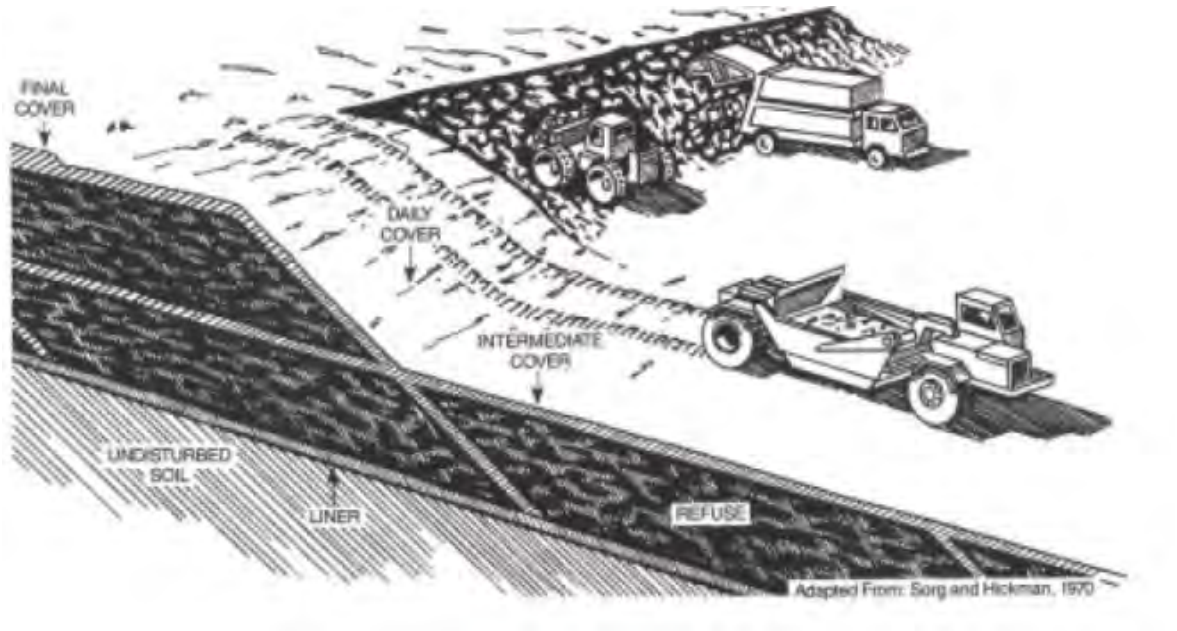


Figure 2-2. Area method of landfilling (NT EPA 2013)

2.4.3 Performance criteria

To preserve landfill airspace and ensure appropriate placement and compaction of waste, the performance criteria detailed in Table 2-4 have been adopted by SBWMF.

Table 2-4. SBWMF waste disposal performance criteria

Parameter	Performance Criteria	Notes
Waste layer thickness	Max 0.6 m	• Waste layers shall be placed at approximately 600 mm uncompacted thickness
Total lift height	Min 2.0 m	• Minimum daily lift height 2.0 m after being compacted in layers • Maximum height to be governed by placement methodology on site and the safety of exceeding 2 m
Waste disposal area (daily cell/tip face)	Max 900 m^2 (e.g. Approx. 30 m (L) x 30 (W))	• Disposal area shall be managed to ensure safety at all times and to minimise the extent of exposed waste and usage of soil daily cover material • The tip face shall be clearly identified with high visibility markers and signage to promote safety to staff and users
Final batter slope construction	Slope 3 (W): 1 (H)	• The final batters slope around the edge of the extent of waste and forming the final landform shall be a maximum of 3 (wide): 1 (high)
Target Waste Density	Min 850 kg/m^3	• Confirmed by comparison of survey and weighbridge data
Daily cover	Active tip face covered daily	• Tarp system deployed at the end of each shift
Alternative daily cover	Min 150 mm – clean fill or mulch	• Applied daily and cut back for reuse at next day • Mulch only to be applied during dry periods
Intermediate cover	Min 300 mm	• Cut back and reused prior to placing additional waste
Final capping	Min 1.0 m (estimated)	• Minimum 1.0 m (0.3 intermediate cover, 0.6m low permeability subsoil and 0.1m topsoil) – but dependent on final capping design

2.5 Landform and site development

Waste disposal and landfilling activities have been occurring at the site since the 1980's. The initial Stages 1 and 2 are located on the eastern side of the operational area and are unlined cells that previously accepted all waste types. After ceasing filling activities in Stage 2, inert wastes started to be placed on the area. By August 2020, the Stage 2 landform had a reduced level (RL) of 30 m AHD and 7 years of airspace remaining for filling (GHD 2021a). Therefore, a concept design for the expansion of Stage 2 has been developed and considers areas to the West, North and East of Stage 2 for its expansion (see *Shoal Bay Waste Disposal Site- Stage 2 Expansion Concept Design Report* by GHD, 2021a).

A C&D waste recycling and pre-sorting is proposed on Stage 1 within a footprint of about 15000 m^2 (refer to Figure 2-3). About 40,000 tonnes of C&D waste such as concrete and steel will be pre-sorted on Stage 1 before the final disposal of the waste in the designated landfill cells. This initiative will reduce the waste disposed at Stage 2 as well as increase the recycling rate of construction and demolition waste as per CoD's Waste and Resource Recovery Strategy. Currently, the C&D pre-sorting is carried out on Stage 2 and there is limited space for efficient recycling/pre-sorting activities.



Figure 2-3. Proposed C&D waste recycling and pre-sorting pad on Stage 1

To increase the recycling initiative and to divert waste from the landfill, a tyre shredding project is planned within a 10,000 m^2 on the east of weighbridge (Figure 2-4). The area will be mainly used to set up a tyre shredding machine, stockpiling of tyres and shredded tyres including recovered steel, and a laydown for plant and equipment. The proposed tyre shredding facility will grind the tyres into small granules (30-100 mm depending on requirements) and all the steel can be recovered for recycling. The grounded tyres will be used as construction materials as road surfacing additives as well as raw materials for the development of various industrial and commercial products such as flooring material and flexible concrete, and also as fuel source for energy generation. About 3,700 tonnes of end-of-life-tyres is expected to be diverted from the landfill under the initiative.



Figure 2-4. Proposed location for tyre shredding pad (adapted from Google Earth 2023)

Stage 3 was constructed between 2001 and 2007, with a geo-membrane liner and was progressively filled with general waste during this time. In 2013, Stage 4 was constructed on the north-west corner of Stage 3 by tying in the new geomembrane liner with existing infrastructure. Filling activities in Stage 3 and 4 ceased in 2018. These stages were capped in late 2022; see Section 9.4.1 for capping details.

Stage 5 and Stage 6 were constructed in 2017 and 2021 respectively. Waste is currently being disposed of in these Stages, with Stage 5 cell approaching capacity (Cardno 2022).

Stage 5 cell and onwards consist of a composite liner system built to best-practice standards, including leachate collection systems. All new cells and liner designs are subject to an Environment Protection Approval regulated by the NT EPA.

CoD have developed a landfill filling plan that shows the sequence and timing for Stages 5 to 10 to be constructed south of Stage 3. Figure 2-5 shows the current and future staged landfill cells, which is estimated to manage average waste disposal volumes over the next 15 to 20 years. Landfill cell development (including the current Stage 5) volumes and associated lifespan estimates are included in Table 2-5 below.

Table 2-5. Summary of landfill stage lifespans

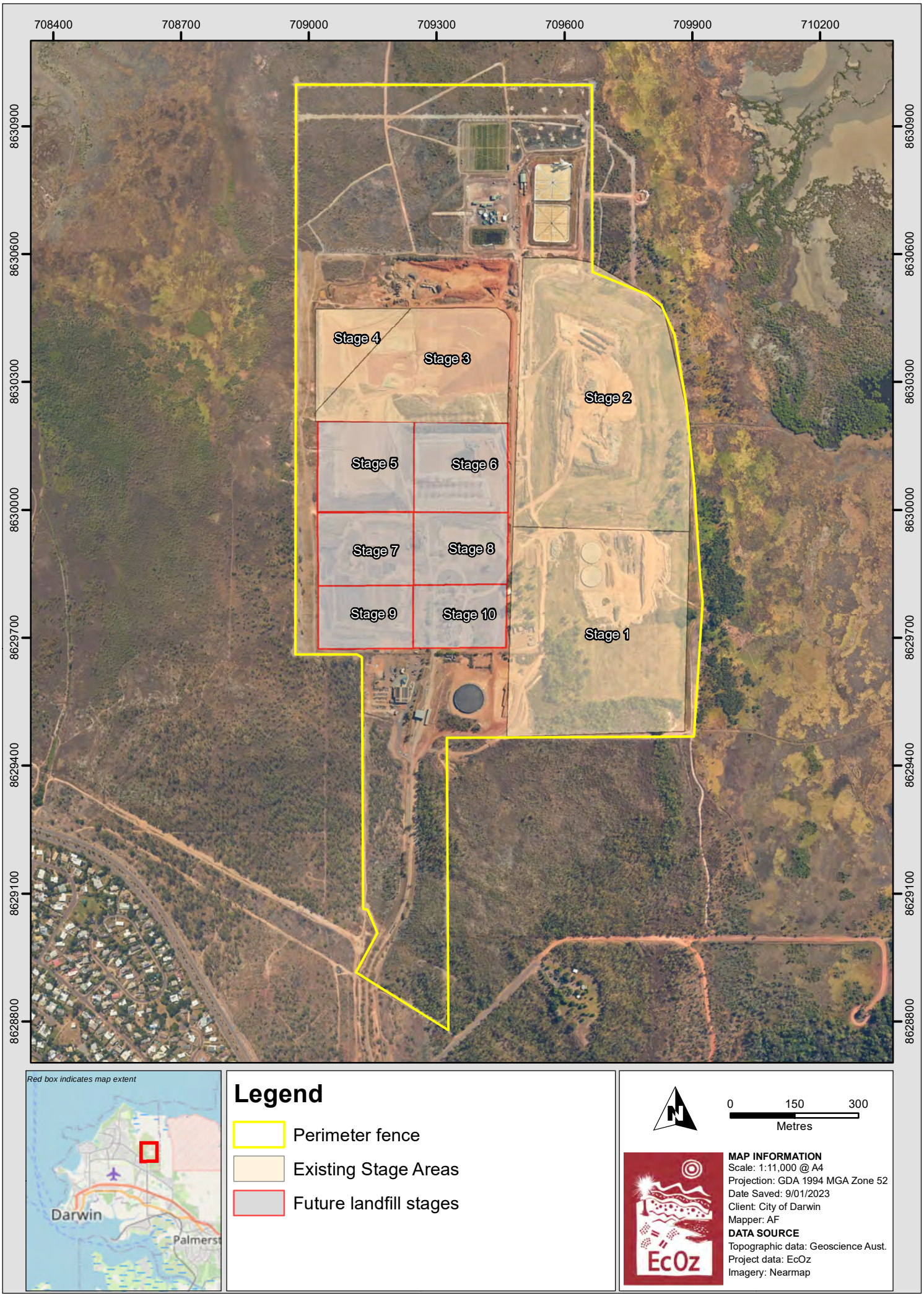
Taken from Golder (2016b)

Stage	Estimated airspace (m^3)	Lower range filling rate lifespan	Upper range filling rate lifespan
Stage 5	510,000	35 months	27 months
Stage 6	950,000	65 months	50 months
Stage 7	450,000	31 months	23 months
Stage 8	1,220,000	83 months	64 months
Stage 9	525,000	36 months	28 months
Stage 10	1,180,000	81 months	62 months
Totals	**4,835,000**	**331 months**	**254 months**

As the landform progresses, the current site layout of the SBWMF is required to change in order to accommodate the new cells whilst ensuring continuation of ancillary site activities. The site *Master Development Plan* details the future development plans for the facility. The plan identifies 13 future development precinct areas and three stormwater management areas, which are summarised in Table 2-6 and shown in Figure 2-6. An initial investigation and conceptual plan has already been developed for an emergency waste holding and processing area (WEHPA) adjacent to SBWMF (GHD 2021b). However, these future proposed land uses are still subject to the appropriate design and approvals prior to implementation.

Table 2-6. Summary of future development precincts

Precinct	Area (ha)	Current use/constraints	Future proposed land use
1	12.2	Stage 1/vacant laydown	Green waste management site and a proposed temporary C&D waste recycling/pre-sorting pad
2	18.1	Stage 2/inert landfill	Unchanged
2A	5.7	Stage 2/inert landfill	Unchanged, concrete/steel management
3	20.2	Stages 3 to 6/landfill	Unchanged
4	14.1	Green waste and transfer station	Stages 7 to 10 putrescible landfill
5	3.0	Leachate storage ponds	Unchanged
6	2.5	Recycle shop/vacant	Unchanged, commercial waste operation
7	1.0	Renewable energy facility/vacant	Transfer Station
8	0.5	Vacant	Renewable energy facility
9	1.0	Landfill operations	Unchanged
10	2.6	Vacant	Alternative waste processing facility
11	16.6	Vacant/UXO	Disaster waste management, commercial waste operation
12	31.1	Vacant/UXO	Disaster waste management, commercial waste operation
13	26.4	Vacant	Future landfill, leachate treatment
Stormwater Area A	6.6	Vacant/stormwater	Stage 2 inert landfill stormwater management
Stormwater Area B	7.0	Vacant/UXO	Future green waste stormwater management
Stormwater Area C	31.1	Vacant/UXO	Landfill, waste processing stormwater management



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Figure 2-3. Future general waste stage layout plan.mxd

Figure 2-5. Landfill cell staging



Figure 2-6. Future development precincts
Taken from Golder (2020)

3 CONCEPTUAL SITE MODEL

A conceptual site model (CSM) is required to assess the interconnections between the contaminants of potential concern, migration pathways and potential receptors (source > pathway > receptor model). A CSM describes the possible pathways by which exposure to potential contamination may occur. For exposure to occur, a complete pathway must exist between the source of contamination and the receptor (source > pathway > receptor), i.e. the person or ecosystem components potentially affected or harmed by the contamination.

A risk may only exist where a plausible source > pathway > receptor linkage is present, and where the quantity or concentration of a contaminant is sufficient to pose harm.

An exposure pathway will typically consist of the following elements:

- A source of contamination
- A release mechanism (i.e. spill, leak, migration in soil, leaching to water, emissions to air)
- Retention in the transport medium (i.e. soil, groundwater, surface water or air)
- An exposure point (i.e. where a person(s) flora or fauna comes into contact with contaminated soil, air, dust, groundwater, surface water)
- An exposure route (i.e. inhalation, ingestion, absorption).

3.1 Environmental setting

The environmental setting of the SBWMF is summarised below and is subsequently used to inform the CSM.

3.1.1 Surrounding land use

The land surrounding the SBWMF to the north and the east consists of floodplains, wetlands, and mangroves of the Leanyer Swamp, including Meckitt Creek.

The Buffalo Creek Management Area is located to the north-west of the SBWMF and includes the Leanyer Sanderson Waste Stabilisation Ponds.

Immediately to the west of the SBWMF is undeveloped bushland, with remnant dirt tracks from previous public access, and to the south is the Homes Jungle Nature Reserve.

The residential suburb of Karama is to the south-west of SBWMF, and the suburb of Muirhead is further to the west of the site.

The SBWMF site is zoned as No Planning Scheme Controls (CA) under the *NT Planning Scheme*. Leanyer Swamp to the north and east is zoned Conservation (CN). The undeveloped bushland to the west of the site is zoned a combination of CA and Community Purpose (CP), and the nearest residential area of Karama is zoned Single Dwelling (SD).

3.1.2 Sensitive receptors

Nearby sensitive receptors include the floodplains, wetlands, and mangroves of Leanyer Swamp to the north and east of the site and the Homes Jungle Nature Reserve to the south. The Homes Jungle Nature Reserve is a listed NT reserve for the purpose of protecting large numbers of birds, mammals and reptiles that depend on cool monsoon vine thicket and rainforest habitat. Palm Creek flows directly through the Homes Jungle Nature Park, and to the east of the site, then joins with Meckitt Creek to the north-east of the SBWMF.

The nearest residential area to the SBWMF is the suburb of Karama, which is approximately 800 m from the south-west boundary.

3.1.3 Site land use

Landfilling activities have been undertaken at the site since the 1980's. Prior to this, the Department of Defence utilised the site for military training exercises. A large proportion of the site (outside of the approved Waste Management Project Area and current operational area) remains un-cleared for unexploded ordinance.

3.1.4 Climate

The SBWMF is in a region classified as having a monsoonal tropical climate, with a distinct dry season (approximately April to October) and wet season (November to March). Typically, for this region, humidity, maximum and minimum temperatures are highest in the wet season, and annual evaporation far exceeds annual rainfall.

The Darwin Airport (station no. 014015) is the closest Bureau of Meteorology (BoM) weather station to the SBWMF area with long-term consistent data. This station is located approximately 2 km away. The average annual rainfall recorded for this station is 1724 mm (BoM 2022). The variation in temperature and rainfall across the seasons is shown in Figure 3-1.

Climate variation throughout the year directly influences the management of surface water at SBWMF, including the potential for leachate generation and contamination of surface waters within the site. Surface water drainage and quality are further discussed in the following sections.

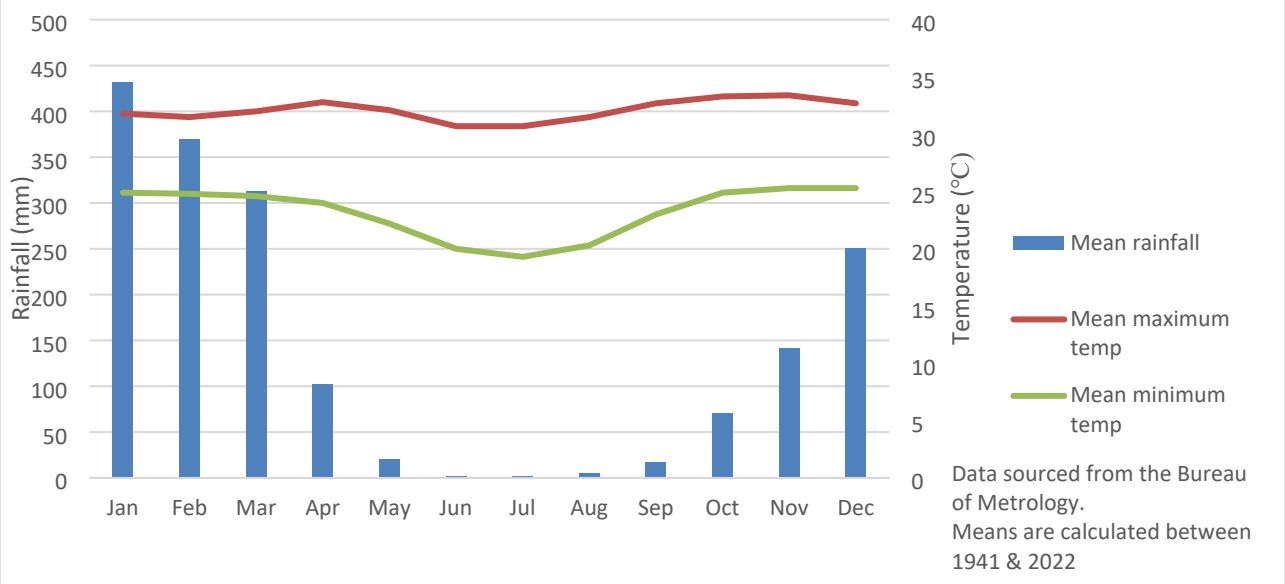


Figure 3-1. Graph of mean temperature and rainfall at Darwin Airport (Station no. 014015)

3.1.5 Land units and soils

Land unit mapping by Fogarty *et al.* (1984) indicates that the area comprises three different land units, 1c, 3d and 4c, as described in Table 3-1 and shown in Figure 3-2. Most of the site is covered by land unit 3d, with a small section of 1c to the west, and small section of 4c to the east.

Directly west of the site, there is a drainage system-based landform (land unit 6b), and to the north-east is a swamp system-based landform (land unit 8c).

There are two recognised landform types within the SBWMF site, rises and plains, with most of the site classified as plains, with two small area of rises on the western side and the south-eastern section of the site.

Drainage associated with the identified landforms and land units tends to be rapid draining for the majority of the site (i.e. land units 1c and 3d), with the area to the west classified as prone to Wet season waterlogging.

Table 3-1. Land units within the SBWMF site

Land unit	Landform Class	Landform Description	Soil	Vegetation description	Slope	Drainage
1c	Rises	Rises and short steep slopes	Organosols / rudosols	Woodland of *Eucalyptus tetrodonta*, *E. miniata*, over *S. intrans* and *H. triticeus.*	5 - 15%	Rapid draining, nil to low level of seasonal soil waterlogging
3d	Plains	Gently undulating upland surface	Rudosols	Open woodland of *Eucalyptus miniata*, *E. tetrodonta* over Sorghum spp.	1 – 3%	Rapid draining, low level of seasonal waterlogging
4c		Gentle lower slopes	Hydrosols	Open forest *Eucalyptus tetrodonta*, *E. papuana* over mixed grasses.	0.5 – 1.5%	Slow drainage, Wet season waterlogging soil with often dry season seepage

3.1.6 Surface water drainage

Within the SBWMF there are no defined surface water drainage lines. Palm Creek flows directly through the Homes Jungle Nature Park, and to the east of the site, then joins with Meckitt Creek to the north-east of the SBWMF.

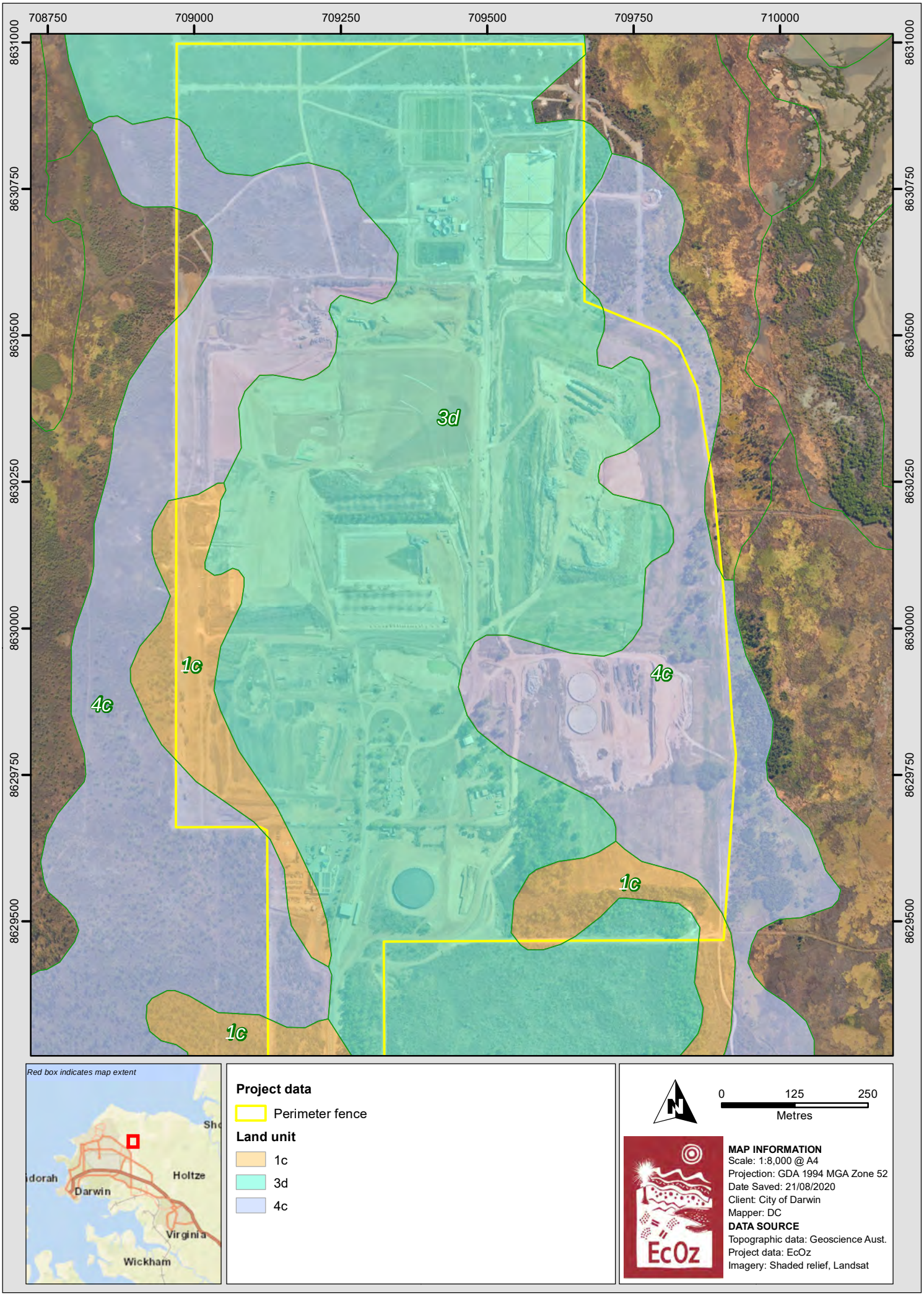
Surface water from the eastern portions of the SBWMF flows north towards the Meckitt Creek floodplain (CDM Smith 2019). Flows from the western portion of the site are towards the Leanyer Swamp and Buffalo Creek. Both Meckitt Creek and Buffalo Creek are mangrove-lined tidal inlets of Shoal Bay; a coastal embayment with extensive sand and mud flats.

The site is mainly characterised by rapid drainage landforms (see Table 3-1), therefore localised flow is managed through the onsite surface water drainage system, which consists of stormwater structures and open drains. Surface water is diverted away from the landfill cells that have the possibility of contaminating surface waters and towards water management infrastructure (CDM Smith 2019).

SBWMF is not within a Water Control District or within a Water Plan Management Zone, however it is within the Darwin Harbour Region for Water Beneficial Uses and has been identified for four beneficial uses including:

- Aquaculture
- Environment
- Cultural
- Rural stock and domestic.

The operational area sits outside the estimated highest astronomical tide zone and the 1 in 100-year Average Recurrence Interval (ARI) primary storm surge impact zone, however may experience some impacts from a 1 in 1,000 or 10,000 ARI storm surge around the perimeter of the operations (GHD 2014).



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20118 - Shoal Bay Leachate Treatment SAQP\01 Project Files\Figure X-X. Land units.mxd

Figure 3-2. Mapped land units at SBWMF

3.1.7 Geology and hydrogeology

The site is located within the Money Shoal Basin, which is of sedimentary succession composition. The 2013 Northern Territory Geological Survey describes the basin as a tilted passive margin basin with no specific depocentre (Ahmad & Munson 2013). The basin generally consists of formations that are monoclonal and relatively under formed. The Money Shoal Basin overlies the Arafura Basin, the Pine Creek Orogen and the McArthur Basin.

Groundwater aquifers beneath the site are described in detail in the *Shoal Bay Waste Disposal Site, Hydrogeological Investigation* (URS 2015). Lithology encountered during groundwater bore drilling for the investigation comprised top soils (silts and clays), generally underlain by weathered (lateritised) siltstone over most of the site, and claystone east of Stage 1. Beneath this, sandstone was encountered at depths of 9 to 20 m below the surface across most of the site. Groundwater exists within the unconsolidated overlying sediments, and fractured and weathered underlying bedrock. Bore yields are generally very poor; less than 5 L/sec.

The shallow (water table) aquifer is recharged by the direct infiltration of rainfall and runoff, and groundwater levels vary seasonally in accordance with rainfall totals. Seasonal groundwater standing water levels (SWLs), measured as part of the SBWMF water quality monitoring program since 2016, are greater than 12 m below ground level at the end of the Dry season, and usually less than 2 m from the ground surface during the peak of the wet season.

Higher yielding weathered and fractured carbonate rock aquifers occur in the wider region, with yields commonly greater than 5 L/sec. The *Groundwater Supply Prospects and Hydrogeology of the Cox Peninsula Region* map identifies a high yielding carbonate aquifer south-east of the SBWMF, trending in a northerly direction (NRETAS 2008). Groundwater from this aquifer discharges to the surface within the Holmes Jungle Nature Park and maintains streamflow through the Dry season. This spring and associated shallow groundwater support the Holmes Jungle Nature Park. Further to the south-east around the Knuckey Lagoon area, a large number of bores draw groundwater from this carbonate aquifer for domestic and agricultural purposes.

There are no groundwater bores or groundwater users down gradient of the SBWMF; although an important environmental consideration is the supply of groundwater seepage into wetlands and tidal inlets during the dry season.

The carbonate rock aquifer and associated springs, Holmes Jungle Nature Park and groundwater users are all located up gradient of the SBWMF. No significant areas of carbonate rock aquifer are located down gradient of the SBWMF and no carbonate rocks were encountered when drilling the 32 groundwater bores, to depths of up to 30 m below ground level, across the site for the hydrogeological investigation (URS 2015).

As part of the environmental monitoring program for SBWMF a total of 39 groundwater bores have been drilled. The bores drill depth varies between 3 to 30 m.

3.1.8 Surface water, groundwater, leachate and soil quality

Surface water, groundwater, leachate and soil quality within the SBWMF has been monitored since at least the 1980's as per the EPL requirements applying at the time. Current monitoring requirements are prescribed in EPL188-03, Attachments 2 through 9.

Water quality parameters measured through the monitoring plan include physical parameters (pH, electrical conductivity, dissolved oxygen), major cations and anions, nutrients, metals, and total recoverable hydrocarbons.

Surface water typically records elevated ammonia and lead concentrations above guideline values, with the majority of other parameters measured within guideline limits. Groundwater and leachate water frequently record elevated ammonia, copper, lead and zinc concentrations above guideline values. The migration of

leachate water into the surface and groundwater is known to be causing the transportation of some contaminants.

Groundwater quality is highly variable in terms of salinity, pH, metals and nutrients (CDM Smith 2019). Groundwater down gradient of the SBWMF is saline due to its close proximity to the coast and tidal saline intrusion; see the Groundwater Resources of the Darwin Area map (DIPE 2003). There are no groundwater bores or groundwater uses down gradient of SBWMF other than that potentially associated with environmental supply of groundwater seepage into wetlands and tidal inlets.

The carbonate rock aquifer and associated springs, Holmes Jungle Nature Park and groundwater users are all located up gradient of the SBWMF. No significant areas of carbonate rock aquifer are located down gradient of the SBWMF, and no carbonate rocks were encountered when drilling the 39 groundwater bores, to depths of up to 30 m below ground level, across the site for the hydrogeological investigation (URS 2016).

3.1.9 Acid sulfate soils

The SBWMF is bound by floodplains, wetlands, and mangroves of Leanyer Swamp to the north and the east of the site boundaries. Acid sulfate soils (ASS) are associated with these types of areas. ASS risk modelling for the Darwin Region (50 k) predicts that there is a high risk of ASS occurrence on the eastern, north-eastern and north-western boundaries of the SBWMF. This modelling suggests that potential ASS would be present generally below three meters depth, however, in some high probability areas, potential ASS could be present within the upper one meter of the surface when within the tidal zone.

3.2 Potential contaminants and receptors

This section provides an overview of the potential contaminates and receptors associated with the SBWMF.

3.2.1 Potential sources of contamination

Known on-site sources of potential contamination

Known on-site sources of potential contamination include:

- Landfill leachate occurs in the landfill due to the decomposition/degradation of the waste
- Landfill gas occurs in the landfill due to the decomposition/degradation of the waste
- Stormwater that may come into contact with waste and become contaminated.
- Wheel wash water that may come into contact with waste or oil and grease from vehicles and become contaminated.

Other possible on-site sources of potential contamination include:

- Chemical and container storage areas have the potential for spills and/or leaks of stored chemicals
- Recycling areas have the potential for spills and/or leaks from the storage of oil, batteries and gas bottles
- Workshop/compound areas which contain stores of oil, grease, fuel and other chemicals used on operations at SBWMF have the potential for spills and/or leaks.
-
- Overflow from the Leachate Treatment Plant
- Overirrigation of treated leachate on the Stage 3/4 cap

Potential off-site sources of contamination

Surrounding land uses may potentially be responsible for sources of contamination to the hydrogeological environment, including:

- The adjacent unexploded ordinance (UXO) area and military training ground
- Urban stormwater runoff
- The former Leanyer landfill (pre-dating SBWMF)
- Potential use of herbicides, pesticides or nitrogen based fertilisers at properties located up-hydraulic gradient of the site.

3.2.2 Contaminants of potential concern

Contaminants of potential concern at the SBWMF include:

- Nitrogen compounds (ammonia and nitrate)
- Metals
- Phenolic compounds
- Benzene, toluene, ethylbenzene, xylene and naphthalene (BTEXN)
- Total organic carbon (TOC)
- Volatile fatty acids (VFAs)
- Total recoverable hydrocarbon (TRH)
- Per- and polyfluoroalkyl substances (PFAS)
- Chloride
- Sodium
- Salinity
- Methane
- Combustion gases (sulphur dioxide, oxides of nitrogen as NO2, carbon monoxide, carbon dioxide, oxygen)
- Volatile Organic compounds (VOC)
- Hydrogen sulphide
- Odour
- Particulate matter
- Acid gases (HCl and HF)
- Sulphuric acid mist
- Heavy metals
- Dioxins, furans and polychlorinated biphenyls (PCBs)
- Sludge/bio-solids from LTP operation

3.2.3 Potential receptors

Potential receptors for contamination resulting from activities at SBWMF include (but are not limited to):

- Nearby groundwater users (although no bores down-gradient of SBWMF are currently registered)
- Holmes Jungle Nature Park and Leanyer Swamp and their ecosystems
- Surrounding land/ecosystems (e.g. floodplains, wetlands and mangrove communities)
- Buffalo Creek Management Area
- Recreational users and maintenance workers of the reserves and accessible areas surrounding the landfill
- Residents and workers within the urban areas of Karama and Casuarina
- Any staff or users of the SBWMF.

3.2.4 Potential exposure pathways

The possible exposure pathways are identified as natural and/or manmade pathways for the preferential migration of contaminants in the liquid and/or gaseous state. Potential contaminant migration pathways for contaminants resulting from activities at SBWMF include (but are not limited to):

- Leachate migration from the landfill to soil and groundwater
- Leachate impacted surface water runoff from the landfill
- Contaminated surface water runoff from chemical and container storage areas, recycling area, green waste area and workshop/compound areas
- Direct emission of landfill gas (methane) to atmosphere
- Accidental leachate spill from operational areas from LTP
- Dust emission and littering from C&D waste pre-sorting activities on Stage 1

Exposure to human receptors can occur through three routes; dermal contact, ingestion and inhalation. Ecosystem exposure occurs through leaching, migration, ingestion, dermal contact and inhalation. Potential exposure routes to potential receptors include (but are not limited to):

- Infiltration of leachate, leachate impacted or otherwise impacted water to the groundwater system
- Overland flow of leachate, leachate impacted or otherwise impacted water to the surface water system
- Direct or in-direct exposure to water users of both groundwater and surface water
- Direct exposure of leachate, leachate impacted or otherwise impacted water or soil leading to dermal contact, inhalation or accidental ingestion by on-site staff or users of the SBWMF
- Direct exposure to landfill gas and dust through inhalation by on-site staff or users of SBWMF or surrounding environment users.
- Direct exposure and bioaccumulation for terrestrial and aquatic environments with chemicals, treated or concentrated leachate emitted by LTP and are deposited to soil and waterways

These potential contamination sources and exposure pathways require management measures, and monitoring, to minimise risks to receptors. The risk assessment (Section 4) and environmental management plans (Section 5) asses these risks and put in place appropriate management measures and monitoring.

4 RISK ASSESSMENT

4.1 Methodology

The risk assessment process involves identification of environmental aspects and impacts, and is systematic and consistent with the following international best practice standard methodologies:

- AS/NZS ISO 31000:2009: Risk management - Principles and Guidelines (Standard).
- HB 203:2006: Environmental risk management - Principles and Process (Guide).
- HB 158:2010: Delivering assurance based on ISO 31000:2009 - Risk management - Principles and Guidelines (Guide).

Environmental aspects are defined as the elements of an organisation's activities, products or services that can interact with the environment (e.g. use of machinery, storage of wastes). Environmental impacts are any change to the environment, whether adverse or beneficial, wholly, or partially resulting from the organisations environmental aspects.

Identifying the environmental aspects and impacts relevant to the works undertaken at SBWMF allows an assessment of the environmental risk to be completed, using a standard consequence and likelihood matrix. Management or mitigation measures can be assigned to each aspect, with a residual risk calculated based on the resulting potential impacts. Environmental management activities can then be prioritised according to risk. Risks have only been assessed for activities related to the operations undertaken at SBWMF.

4.1.1 Risk ranking

The ranking for event consequence is shown in Table 4-1. The likelihood of an event occurring provides a measure of the known or anticipated frequency of occurrences (Table 4-2). Combining likelihood with consequence provides guidance on risk levels of each aspect and enables key risks to be identified and management strategies to be prioritised (Table 4-3). The risk assessment for the activities associated with SBWMF is provided in Table 4-4.

Table 4-1. Consequence ranking

Consequence		
1	Insignificant	No/low measurable impact on the environment.
2	Minor	Some minor, temporary environmental impact.
3	Moderate	Contained temporary or permanent minor, localised environmental damage.
4	Major	Severe environmental damage.
5	Catastrophic	Environmental disaster.

Table 4-2. Qualitative measures of likelihood

Probability/Likelihood			Likelihood criteria
A	Rare	May occur only in exceptional circumstances.	0-1%
B	Unlikely	Could occur at some time.	2-10%
C	Moderate	Might possibly occur at some time.	11-50%
D	Likely	Will probably occur in most circumstances.	51-90%
E	Almost certain	Expected to occur in most circumstances.	91-100%

Table 4-3. Risk rankings from combined consequences and likelihood

		Consequence				
Likelihood		1	2	3	4	5
	A	1	3	6	10	15
	B	2	5	9	14	19
	C	4	8	13	18	22
	D	7	12	17	21	24
	E	11	16	20	23	25

Where;

Red = extreme risk intolerable

Orange = high risk intolerable or tolerable

Yellow = medium risk tolerable or acceptable

Green = low risk acceptable

4.2 Risk assessment

Table 4-4. Environmental aspects and impacts register

Environmental concern	Operational Aspect	Potential Impact	Initial Risk			Management Measure / Controls	Residual Risk		
			Likelihood	Consequence	Risk Score		Likelihood	Consequence	Risk Score
Water quality	On site water management i.e. stormwater diversion, leachate generation, wash down water generation	Contamination of water quality including: • Infiltration of leachate into groundwater due to seepage from landfill • Overland drainage of leachate to receiving surface waters via stormwater • Failure of leachate ponds or leachate treatment system • Overflow of leachate ponds	C	3	**H (13)**	• Waste acceptance and segregation procedures are adhered to, to ensure waste is accepted into lined cells and only inert waste is placed in unlined cells • Regular inspections are conducted of landfill operations to ensure compliance of procedures • Waste is covered as required i.e. daily covers, temporary covers and/or capping • Stormwater diversions are installed and maintained to divert clean stormwater away from operational areas • Leachate collection systems are installed, maintained and regularly inspected to ensure their effectiveness • Installation and maintenance of a leachate treatment system • Leachate ponds are lined to prevent seepage to groundwater, and covered to prevent surface water infiltration • Emergency backflow infrastructure is installed and working effectively to return leachate from ponds to landfill • All wash down bay water is captured and contained • Water quality monitoring program is undertaken according to procedures, and any impacts are detected in a timely manner to be addressed by contingency management measures	B	3	**M (9)**
	Spills of chemicals, hydrocarbons or hazardous substances when handling wastes	• Contamination of receiving surface waters via stormwater drainage	C	2	**M (8)**	• Hazardous substances to be stored in appropriately bunded containers or within impervious areas • Regular removal of hazardous substances from storage containers at the Transfer Station • Spill response plans are developed, and all personnel and contractors have been trained in spill response procedures • Spill kits are located throughout the site and are adequately stocked and sized for potential spills • Approvals are required and obtained prior to receipt of any unidentified/unnamed chemicals • Waste oil tanks are regularly inspected, maintained and decanted when required	B	2	**L (5)**

Environmental concern	Operational Aspect	Potential Impact	Initial Risk			Management Measure / Controls	Residual Risk		
			Likelihood	Consequence	Risk Score		Likelihood	Consequence	Risk Score
						• All bulk fuel or oil tanks are to meet all AS1940 requirements i.e. double bunded			
	Leachate spills on surface on LTP operational area	• Contamination of receiving surface waters via stormwater drainage	B	2	**L (5)**	• LTP operational area has a concrete bund to contain accidental leachate spills • Regular monitoring of all aspects of LTP operation, including integrity of tanks, pumps, valves and pipelines • Spill kit on site for minor spills • Regular site inspection	A	1	**L (1)**
	On site operations leading to erosion of sediments from disturbed areas, generation of sediment laden runoff	• Contamination of receiving surface waters, through uncontrolled water release	C	2	**M (8)**	• Installation of erosion and sediment controls • Implementation of a regular inspection and maintenance program for erosion and sediment controls • Stormwater infrastructure designed to direct clean runoff from disturbed areas • Stormwater infrastructure designed to capture runoff within operation/disturbed areas • Leachate system effectively capturing leachate volumes generated on site • Rehabilitation and revegetation for exposed slopes and disturbed areas to be implemented in accordance with the closure and post closure plans	B	2	**L (5)**
Waste management	On site waste management i.e. cross contamination of wastes, asbestos handling, windblown litter, sludge and PFAS contaminated waste from LTP operation	• Reduced recycling ability due to cross contamination • Human health risk due to inappropriate management of asbestos • Reduced visual amenity leading to community complaints	C	3	**H (13)**	• Waste acceptance and segregation procedures are adhered to, to ensure waste is accepted into lined cells and only inert waste is placed in unlined cells • Waste segregation requirements are clearly labelled with signage at the Transfer Station • An asbestos disposal cell is appropriately constructed and signed • Waste is covered as required i.e. daily covers, temporary covers and/or capping • Recyclable materials that are incorrectly deposited are salvaged following regular inspections • Approvals are required and obtained prior to receipt of any Special Wastes • Litter fences are installed, regularly inspected and maintained as required • Regular inspections and clean-up operations are undertaken to prevent wind-blown litter leaving site boundaries	B	3	**M (9)**

Environmental concern	Operational Aspect	Potential Impact	Initial Risk			Management Measure / Controls	Residual Risk		
			Likelihood	Consequence	Risk Score		Likelihood	Consequence	Risk Score
						• All the waste generated from LTP operation will be disposed as per the landfill acceptance criteria or transported to licensed facilities for further disposal			
Environmental and Public Nuisance (Noise, Dust, Odours and Greenhouse Gas Emissions)	On site operations generating excessive noise, dust, offensive odours and/or excessive greenhouse gases	• Off-site dust deposition resulting in community complaints • Excessive noise causing community disturbance and resulting in community complaints • Offensive odours causing community disturbance resulting in community complaints • Fugitive methane gas emission release resulting in an increased in net greenhouse gases emitting to the atmosphere.	C	2	**M (8)**	• Water trucks are in regular use and static dust suppression techniques i.e. stockpile sprinklers, are implemented when dust is being generated on site • Operations are confined to site opening hours, afterhours works will only occur through prior arrangement with appropriate notification and controls implemented • A vegetation buffer is maintained between the site and the nearest sensitive receptors • Waste is covered as required i.e. daily covers, temporary covers and/or capping • All community complaints are recorded, responded to, and any corrective actions and/or community follow up is recorded • The landfill gas management system is installed, regularly inspected and maintained to capture methane in the waste cells • All plant and equipment is regularly inspected and maintained i.e. pre-start inspections and routine maintenance schedules are implemented	B	2	**L (5)**
	Vehicle movements to and from the site resulting in mud tracked on public roads	• Reduced visual amenity leading to community complaints	C	2	**M (8)**	• A wheel wash is located at the site exit point and is regularly inspected and maintained • Access roads to and from the site are regularly inspected and maintained when required	B	2	**L (5)**
	Operation of LTP	Major contaminants from LTP operation include generation of PFAS contaminated waste and sludge from the biological treatment of leachate	D	1	**L (7)**	• The samples of sludge and PFAS contaminated waste will be analysed prior to disposal at approved facilities	C	1	**L (4)**
Flora and Fauna	Vehicle movements resulting in harm to fauna via vehicle strike or unapproved clearing	• Injury or death to native fauna resulting from on-site operations	C	2	**M (8)**	• Only authorised access tracks are utilised in site operations • Installation and maintenance of a boundary fence	B	2	**L (5)**
	Uncontrolled release of contaminated water in areas of native vegetation and habitat	• Flora stress or die back resulting from exposure to contaminated water and soils	C	2	**M (8)**	• Leachate collection systems are installed, maintained and regularly inspected to ensure their effectiveness • Installation and maintenance of a leachate treatment system	B	2	**L (5)**

Environmental concern	Operational Aspect	Potential Impact	Initial Risk			Management Measure / Controls	Residual Risk		
			Likelihood	Consequence	Risk Score		Likelihood	Consequence	Risk Score
						• Leachate ponds are lined to prevent seepage to groundwater, and covered to prevent surface water infiltration • Emergency backflow infrastructure is installed and working effectively to return leachate from ponds to landfill			
Weeds and Pests	On site operations leading to the introduction and/or spread of weeds	• Introduction of new weeds, and/or the spread of existing weeds within the site • Spread of weeds to surrounding land	C	2	**M (8)**	• Develop and implement a regular vegetation/weed management program that details control measures i.e. seasonal weed spraying, slashing • Develop and implement a rehabilitation and revegetation plan for exposed slopes and disturbed areas	B	2	**L (5)**
	On site operations providing a habitat for pests i.e. vermin, biting insects	• Introduction and/or spread of pests within the site and to the surrounding land	C	2	**M (8)**	• Waste is covered as required i.e. daily covers, temporary covers and/or capping • Regular inspections and clean-up operations are undertaken to prevent wind-blown litter leaving site boundaries • Regular inspections across the site to minimise ponding of water at any area of operations • Installation and maintenance of a boundary fence to prevent access by larger animals	B	2	**L (5)**
Fire	On site handing of flammable and combustible wastes i.e. mulch, hot load	• Uncontrolled fire within the site and/or into the surrounding land resulting in damage to infrastructure and impacts to the community	C	4	**H (18)**	• An Emergency Response Plan has been developed and all personnel and contractors have received training into Emergency Response Procedures • Fire breaks and fuel reduced areas are maintained regularly • NT fire authorities are engaged and involved in any prescribed burning activities • Appropriate firefighting equipment is located throughout the site • Hazardous substances to be stored in appropriately bunded containers or within impervious areas • Waste is covered as required i.e. daily covers, temporary covers and/or capping • Implement a procedure to reduce green waste storage volumes into rows Mulch stockpile heights are limited to prevent excessive piling of mulch materials • Develop and implement a regular vegetation/weed management program that details control measures i.e. seasonal weed spraying, slashing • Implementation and maintenance of 1 m wide path around the edge of any geomembrane	A	4	**M (10)**

Environmental concern	Operational Aspect	Potential Impact	Initial Risk			Management Measure / Controls	Residual Risk		
			Likelihood	Consequence	Risk Score		Likelihood	Consequence	Risk Score
	Undertaking hot works i.e. welding		C	4	**H (18)**	• Implementation of a hot works permit procedure and regular inspections of hot works	A	4	**M (10)**
Heritage Values	On site excavations, earthworks or vehicle movements disturbing a heritage site or artefact	• Damage or disturbance to an unknown heritage site of Aboriginal or European significance	C	3	**H (13)**	• AAPA Certificates have been obtained and all conditions have been adhered to i.e. excluding areas identified in AAPA Certificates from operational works • Develop and implement a Heritage Discovery Procedure, and all personnel and contractors have received training for heritage site identification and protection • Only authorised access tracks are utilised in site operations • Installation and maintenance of a boundary fence to prevent access from the general public	A	3	**L (6)**
Public Safety	On site operations resulting in potential public safety hazards i.e. trip hazards, unauthorised access to hazardous areas, , failure of LTP plant	• Injuries to personnel, contractors and/or the general public	C	3	**H (13)**	• Safety and awareness signage is installed throughout the site • Traffic control signage and devices i.e. boom gates, are installed • All personnel and contractors are to be inducted to the site and provided with clear instructions for each waste disposal area • Personnel and contractors to manage and maintain the Transfer Station i.e. clearing loose rubbish, placing chemicals in hazardous storage cupboards • Waste disposal bays will be closed to the general public when hook bins are full and require emptying • Maintain clear access and sufficient working pad space for vehicles depositing waste at tip face • Regular inspection and monitoring of LTP operational areas of potential hazards, including fire and electrical hazards, test and tagging of electrical devices	A	3	**L (6)**

5 ENVIRONMENTAL MANAGEMENT

5.1 Overview

The following sections provide specific environmental management tables related to identified potentially significant environmental aspects (see Section 4). An environmental aspect is an element of the landfill operation activity that can interact with the environment.

Each environmental management table forms the basis of an environmental inspection and audit to verify compliance with the EMP. Each of the tables shown in the relevant sections below include the following components:

- Environmental objectives – describes the key environmental objectives or goals that the EMP aims to influence for this aspect.
- Mitigation measures – measures that will be implemented with the aim to eliminate, reduce, or control potential adverse environmental impacts and risks resulting from site activities.
- Performance criteria - measurable control indicator that is used to quantify, or evaluate, so as to determine if the performance standard is met.
- Monitoring and Reporting – actions to measure and report compliance against the objectives and performance standards.
- Corrective Action – measure to ensure a non-conformance or non-compliance is corrected.
- Responsibility – overall responsibility to ensure the mitigation measure is implemented and is an effective control. If the task is delegated, the person is still responsible for ensuring implementation.

5.2 General environmental management

The following environmental compliance measures (Table 5-1) to be implemented at the SBWMF are based on EPL conditions and outcomes of the environmental impact and risk assessment (Table 4-4).

Table 5-1. General environmental management

Objective / outcome	To minimise the risk and likelihood of causing harm to the environment
Mitigation / Control	• Ensure the implementation and compliance of this EMP • Annual environmental audit of EPL conditions and EMP • Ensure all personnel working at SBWMF are given an induction detailing environmental risks and mitigation measures in this EMP, as well as emergency response procedures
Target / performance criteria	Impacts/risks to environment are reduced to acceptable levels
Monitoring	• Daily visual site inspection (general parameters) • Monthly environmental inspection against EPL conditions and this EMP, as per site inspection checklist (see Appendix E)
Corrective actions and contingencies	Non-compliance of the EPL and this EMP must have suitable corrective actions with assigned responsibility and date for completion
Responsibility	Site Manager

5.3 Waste acceptance and disposal

Table 5-2 details how environmental aspects related to general and recyclable waste are managed at SBWMF. All listed waste management measures are detailed in Section 5.4.

Table 5-2. General and recyclable waste management

Objective / outcome	• To accept only approved waste for disposal and/or recycling at SBWMF • To ensure no harm is done to the environment as a result of waste disposal • To prevent ground water and surface water contamination • To prevent fires at SBWMF
Mitigation / Control	• Relevant staff are to be trained on the types of waste accepted and pre-approvals required – this will be done through inductions and toolbox talks/staff meetings • Clear signage and communication to make landfill users aware of the types of waste accepted at SBWMF • At the weighbridge – conduct visual inspections of waste loads and question driver regarding types of wastes within the load • If not general waste, seek compliance documentation to verify type of wastes and prior approval if applicable • Any waste not listed in the EPL can only be accepted after special approval from NT EPA • Only clean fill can be accepted for disposal. Soil being brought to SBWMF from potentially contaminated sites will require validation sampling results to be assessed against relevant guidelines as per Section 5.4. • Provide assistance and clear directions on correct waste disposal areas • Clearly labelled signs at transfer stations • Salvage of recyclable materials incorrectly disposed of • Regular clean-up of scattered and inappropriately disposed waste • Apply daily cover, intermediate cover and capping as required • Only domestic users are permitted to use the transfer station unless directed by the weighbridge operator • Accepted wastes are only to be stored within approved areas and storage vessels • All liquid waste (toilets, ablutions etc.) will be disposed of directly into site septic tanks, which will be managed as required • All drivers will be instructed to remain on alert for evidence of hot loads (smoke/fire) and to alert SBWMF staff
Target / performance criteria	• No acceptance of unapproved wastes • No significant impacts or environmental harm • No breach of EPL conditions • All wastes disposed of in accordance with EPL and industry standards
Monitoring	• Visual monitoring of loads to ensure appropriate acceptance of wastes • Water quality monitoring as per EPL • Visual inspections of waste transfer stations and active tip face shall occur at least daily in the dry season and at least twice daily in the wet season
Corrective actions and contingencies	• Ongoing training for relevant staff regarding acceptance of waste procedures • Clearly marked signs stating waste types accepted and not accepted at the entry points to SBWMF for all users to see • Further assistance and instructions from SBWMF staff for users of SBWMF to ensure appropriate disposal of wastes • If waste is found to be incorrectly disposed of, correct if possible • If hazardous waste or unidentified waste is found, identify a licenced specialist for possible disposal and report non-compliance to the NT EPA
Responsibility	Site Manager

5.4 Listed waste

5.4.1 Listed waste objectives and targets

Table 5-3 outlines the listed waste management objectives, targets, and performance measures.

Table 5-3. Listed waste management objectives, targets and performance measures

Objectives	Targets	Performance Measures
• To ensure no environmental harm occurs as a result of waste disposal • To prevent contamination of surface water and groundwater • To ensure no spills of hazardous substances occur • To foster re-use / recycling of listed wastes, where possible	• No significant impacts or environmental harm has occurred • No incident in breach of the EPL conditions causing environmental harm • Re-use / recycling of listed wastes, where possible	• All wastes disposed of in accordance with the conditions of the EPL and good industry practice • Listed waste handling and spill response undertaken in accordance with relevant procedures • Transfer of listed wastes with potential for re-use / recycling

5.4.2 Listed waste tracking

Records of all listed waste being stored or disposed of on-site shall be maintained, and include the following details:

- The date of collection
- The source of the listed waste
- The name of the transport company, if not the licensee
- Vehicle registration
- Listed waste type
- Quantity of listed waste
- Whether the listed waste was stored, treated, recycled or disposed of
- Final destination of the listed waste.

Where domestic users are disposing of listed wastes to the transfer station (i.e. batteries, waste oil, tyres), waste volumes will be tracked when removed from site for recycling or disposal. The records will be reconciled and reported on annually through the EPL Annual Return.

5.4.3 Listed waste management

A Stockpile Management Plan including information about waste received and stockpiled at the SBWMF, quantities, stockpile dimensions, locations and intended use is provided in Appendix D.

As operations of the SBWMF progress, the information provided in the Stockpile Management Plan may change. As such, the management plan, as well as the EMP, will be revised and updated as these changes take place.

5.4.4 Listed waste management measures

The acceptance criteria, storage, disposal, monitoring, corrective actions, and reporting requirements for each listed waste product handled on-site is detailed in Table 5-4 to Table 5-9 below.

Table 5-4. Special waste management

Category	Management measure	Frequency
Special waste acceptance	• The following listed wastes for disposal to landfill must be pre-arranged and approved through completion of a *Special Waste disposal application*: o Animal effluent and residue (including animal carcasses) o Clinical and related wastes	Per load

Category	Management measure	Frequency
	o Sewerage sludge and residues including nightsoil and septic tank sludge	
Special waste disposal	• All approved special waste loads are to be disposed of in a pre-prepared pit excavated within the active tip face. • The waste is to be immediately covered with waste material upon disposal.	Per load
Monitoring	• Inspection of the tip face for correct disposal.	As required
	• Inspection of other tip areas to detect any illegal dumping of special wastes.	Daily
Corrective Actions	• Rectification of any incorrect special waste disposal. • Raising community awareness as required.	As required
Reporting	• Listed waste volumes to be reported in the EPL Annual Return. • Incident reports completed and filed, including any necessary incident notification.	As required

Table 5-5. Contaminated soil management

Category	Management measure	Frequency
Contaminated soil acceptance	• Contaminated soil for disposal to landfill must be pre-arranged and approved through completion of a *Soil disposal application*. • The soil originating location and potential contaminants of concern considered and sampling results requested as required. • Soil results are assessed against relevant guidelines to determine acceptance.	Per load
Contaminated soil disposal	• All soil loads declared as contaminated are to be disposed of in a pre-prepared pit excavated within the active tip face. • The waste is to be immediately covered with waste material upon disposal.	Per load
Monitoring	• Inspection of the tip face for correct disposal.	As required
	• Inspection of other tip areas to detect any illegal dumping of soil material.	Daily
Corrective Actions	• Rectification of any incorrect soil disposal. • Raising community awareness as required.	As required
Reporting	• Listed waste volumes to be reported in the EPL Annual Return. • Incident reports completed and filed, including any necessary incident notification.	As required

Table 5-6. Asbestos and asbestos containing material management

Category	Management measure	Frequency
Asbestos acceptance	• All asbestos loads for disposal must be pre-arranged through completion of an *Asbestos disposal application.* • Approved loads are given a booking time for disposal in order to adequately prepare the disposal area and coordinate loads for maximum use and efficiency of the asbestos cell. • Check compliance of asbestos loads with the *National Occupational Health and Safety Commissions Asbestos Code of Practice and Guidance Notes.*	Per load
Asbestos disposal	• Only correctly wrapped asbestos will be accepted at the SBWMF for disposal - in accordance with Section 4.8 of the *NT Worksafe and Safe Work Australia How to Safely Remove Asbestos Code of Practice.* • Deposited asbestos waste at the asbestos cell area must immediately be covered by suitable material to prevent the release of fibres into the air. • Final cover of the asbestos shall be to a minimum thickness of 3 m in the case of asbestos fibre and dust wastes, and 1 m in the case of stabilised asbestos wastes in a bonded matrix. • Final cover of the asbestos is to incorporate orange marker mesh identifying that asbestos is buried below to the depth required as above. • GPS location and total volume of disposed waste, for each asbestos disposal, will be recorded and maintained in the listed waste tracking register.	Per load
Monitoring	• Inspection of the asbestos cell for correct disposal.	As required
	• Inspection of other tip areas to detect any illegal dumping of asbestos material.	Daily
Corrective Actions	• The licenced waste transporter responsible for any incorrect asbestos disposal is contacted to rectify and place the asbestos in the correct location. • Additional training for staff involved in asbestos acceptance and disposal. • Increased signage	As required
	• Raising community awareness if required.	Regular basis
Reporting	• Listed waste volumes to be reported in the EPL Annual Return. • Incident reports completed and filed, including any necessary incident notification.	As required

Table 5-7. Battery and paint management

Category	Management measure	Frequency
Battery & paint acceptance	• Batteries and paint products only accepted from residential users (i.e. no commercial quantities)	Per load
Battery & paint storage	• Batteries and paint products are to be stored on bunded pallets at the transfer station and protected from rainfall ingress	Per load
Battery & paint disposal	• Batteries and paint products to be removed from site by a licenced waste transporter, for recycling/disposal at an appropriately licenced facility. • Empty, dry and clean paint tins may be disposed of in the scrap metal skip after inspection.	As required
Monitoring	• Inspection of transfer station disposal area for correct disposal.	Daily
Corrective Actions	• Rectification of any incorrect waste disposal. • Increased signage or community awareness if required.	As required
Reporting	• Listed waste volumes to be reported in the EPL Annual Return	As required

Category	Management measure	Frequency
	• Incident reports completed and filed, including any necessary incident notification.	

Table 5-8. Waste tyre management

Category	Management measure	Frequency
Tyre acceptance	• SBWMF accepts both whole and shredded tyres • All tyres for disposal are presented to the weighbridge and relevant charges applied for both domestic and commercial users.	Per load
Tyre disposal	• When landfilling tyres, tyres shall be spread amongst the tip face to minimise movement.	Per load
Monitoring	• Visual inspection of the tyre storage area to identify any ponding water, appropriate fire breaks, appropriate stacking of tyres, etc.	As required
Corrective Actions	• Rectification of any incorrect tyre disposal. • Increased signage or community awareness if required.	Per event
Reporting	• Listed waste volumes to be reported in the EPL Annual Return. • Incident reports completed and filed, including any necessary incident notification.	As required

Table 5-9. Waste oil management

Category	Management measure	Frequency
Waste oil acceptance	• Domestic volumes of waste mineral oil or cooking oil accepted only.	Per load
Waste oil storage	• Storage of fuels and oils must be to Australian Standard 1940-2004 The storage and handling of flammable and combustible liquids (AS 1940), including within a bunded and impervious area. • Any leaks of hazardous materials or chemicals will be treated in accordance with emergency response procedures. • In the event of an oil / fuel spill, the Site Manager will be notified and all persons directed away from the spill area. If safe to do so, contain the spill to prevent further spill from occurring. • If the spill is too large or hazardous to control safely, the fire brigade will be notified by the Supervisor and the appropriate safety precautions taken as deemed necessary (i.e. evacuation). When the fire brigade arrives, the Supervisor will surrender control of the site to the officer on duty. • Disposing of absorbent material used in any clean up shall be done in an appropriate manner with consideration given to any hazardous substances or dangerous goods. • Spill kits and response equipment will be available near the storage areas.	As required
Waste oil disposal	• Waste oil to be removed from site by a licenced waste transporter, for recycling/disposal at an appropriately licenced facility.	As required
Monitoring	• Inspection of waste oil tank and disposal area for correct disposal, and signs of any leaks or spills.	Daily
Corrective Actions	• Rectification of any incorrect waste oil disposal. • Implement appropriate spill clean-up measures. • Increased signage or community awareness if required.	As required
Reporting	• Listed waste volumes to be reported in the EPL Annual Return. • Incident reports completed and filed, including any necessary incident notification.	As required

5.5 Storage and use of hazardous substances

The storage and use of chemicals, oils and fuels is managed as per Table 5-10, which describes the mitigation measures to be implemented to reduce negative impacts and the risk of causing environmental harm from spills leading to the contamination of surface and groundwater. It also details the performance criteria and monitoring measures in place.

Table 5-10. Storage and use of chemicals, oils, and fuels

Objective / outcome	• To prevent spills of hazardous substances • To ensure correct use, handling and storage of hazardous chemicals • To prevent contamination to surface water, ground water and surrounding environment
Mitigation / Control	• Any spills or leaks of hazardous materials will be treated in accordance with the emergency response plan – spill response procedure • All chemicals, oils and fuels will be stored appropriately in locked areas that are bunded, impervious areas in accordance with their safety data sheet (SDS) • SDS will be available in a folder where the chemicals, oils and fuels are stored • Storage of oils and fuels must be in accordance with Australian Standards (AS1940 – The storage and handling of flammable and combustible liquids) • Chemical use will be in accordance with the appropriate SDS • Volumes of stored chemicals, oils and fuels will be kept to a minimum where possible • Spill response kits to be stored and maintained in all storage areas • Site staff to be trained in spill response as part of the induction process
Target / performance criteria	• No spills or leaks of hazardous substances • No breach of EPL • Reporting of spills/leaks to NT EPA
Monitoring	• Daily visual inspections of waste disposal areas to identify any hazards or spills • Monthly site inspection to check correct use and storage of hazardous materials and for signs of any spills or leaks
Corrective actions and contingencies	• Review storage and handling of hazardous materials and provide training where required • Raise concerns at toolbox talks / staff meetings • Ensure staff are trained in spill response procedures
Responsibility	Site Manager

5.6 Water quality

Management of water quality throughout the SBWMF is based on the following objectives in order of preference:

1) No measurable impact on surface water and groundwater quality within the SBWMF operations area:
    - Recognising the historic legacy of water management issues with staged infrastructure upgrades to improve performance.
2) No measurable impacts on aquatic ecosystems and groundwater between the lease area and the SBWMF operations area:
    - Providing a buffer or attenuation zone for the protection of the surrounding environment from the historic legacy related to contamination within the SBWMF.
3) No measurable impacts on aquatic ecosystems and groundwater quality at the edge of the lease area:
    - Reflects the basis for conditions within the EPL.

Water present within the SBWMF is defined into five categories for management purposes which are described in Table 5-4.

Table 5-11. Water categories for management

Water Type	Description	Management Objectives
Clean water	Stormwater runoff that is not impacted by landfilling operations. This may include: • Catchments upstream/outside the operational area • Undisturbed catchments within the operational area • Rehabilitated landfill areas	• Diversion around or away from operational areas and other water types. • Suitable quality for direct release to the environment without active management.
Sediment water	Sediment laden stormwater runoff from erosion of exposed materials within operational areas such as: • Un-vegetated waste cell bunds • Stockpiles of material • Unsealed access tracks and cleared areas	• Minimise the size of disturbed areas. • Progressive rehabilitation of waste cells. • Capture of sediment prior to release of water into the environment.
First flush	Potentially impacted stormwater runoff from lower risk stockpiled resource recovery material such as: • Green waste (tannins & nutrients) • Steel (metals and hydrocarbons) • Concrete (sediment)	• Minimise the size of resource recovery hardstand areas. • Capture first flush water containing contaminants for management through water quality testing and/or treatment prior to release.
Leachate	Water that has been in direct contact with putrescible waste. This can occur through: • Release of stored water from buried waste material. • Surface water infiltration through cover materials into underlying buried waste. • Stormwater runoff contacting uncovered waste.	• Minimising leachate generation through maximising stormwater runoff away from buried waste through small active disposal faces, placement of daily cover and well-shaped landforms. • Progressive rehabilitation of waste cells. • Active collection and management of leachate generation within buried waste materials.
Groundwater	Water flowing through subsurface soils and rock. Groundwater is generally recharged by stormwater within higher elevation catchment areas and discharges into stormwater and waterways within lower catchment areas.	• Containment of buried wastes and leachate and separation from underlying groundwater.

5.6.1 Treatment concepts and principles

As per the adopted stormwater management strategy for SBWMF, a “treatment train” approach has been adopted to manage sediment and first flush water. The train of controls is designed to target capture or attenuation of approximately 80% of the contaminant load in run-off from disturbed or active operational areas (Golder 2020b). The treatment train approach uses a combination of the stormwater controls described in Table 5-12.

Inert waste landfill (Stage 2)

The stormwater management concept design for Stage 2 is comprised of the following elements:

- Two contour banks surrounding the active waste area at the top of the landform that will convey impacted runoff to a chute in the north-west corner
- Runoff from the chute will be conveyed via culverts under the leachate pond access road towards a grassed drain
- Sediment impacted water will be discharged into a sediment basin located within the existing disturbed area north of Stage 3/4 general waste landfill.

General waste landfill (Stage 3 onwards and green waste)

The stormwater concept design for the general waste landfill and green waste areas will be implemented through a staged approach as the landform progresses. Given the larger catchment areas, high rainfall conditions and available land areas, it is proposed to utilise a combination of sediment containment infrastructure as an alternative to large scale sediment basins. This approach is also designed to facilitate nutrient attenuation from the first flush waster. The stormwater management concept for these areas is comprised of the following elements:

- Contour banks surrounding the active waste and along the batters of the landform that will convey impacted runoff to rock-lined chutes down the batters
- Runoff from the chute will be conveyed via toe drains to causeways under the eastern access tracks towards primary coarse sediment traps
- The coarse sediment traps will be designed to slow concentrated flows and settled coarse suspended sediment with rock-lined outlets
- High-flow bypass drains are to be built alongside the sediment traps to convey peak flows
- Design flows from the coarse sediment traps will be conveyed along a bunded, grassed approach drain to a concrete outlet sill level spreader, releasing the concentrated flow as sheet flow onto a stable vegetated area downslope (see Figure 5-1).

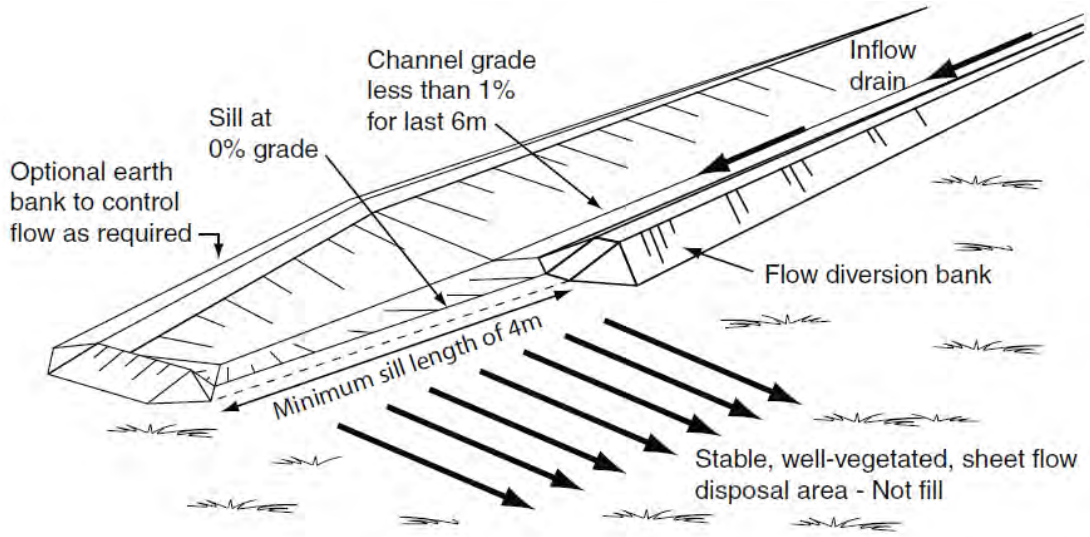
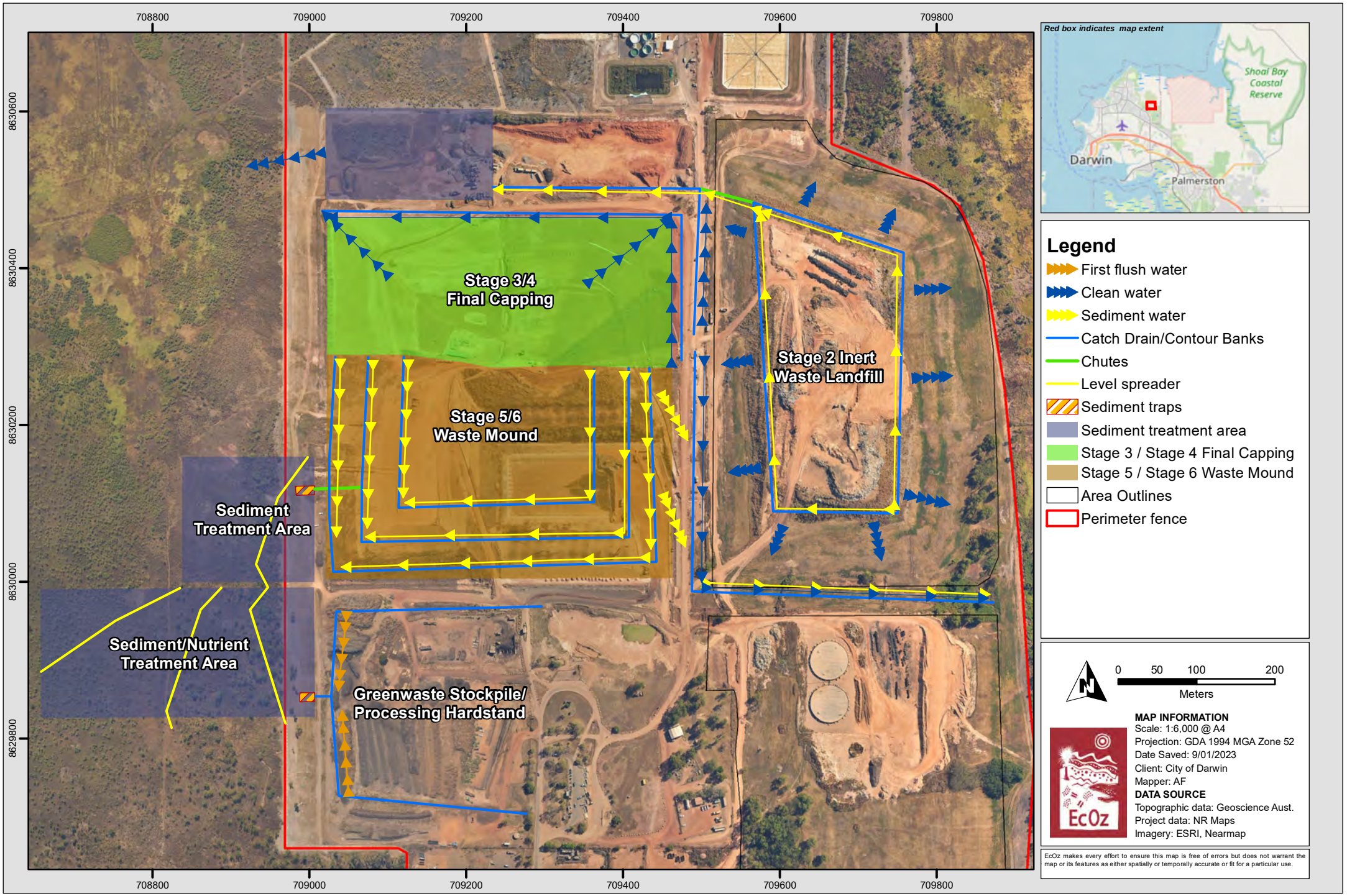


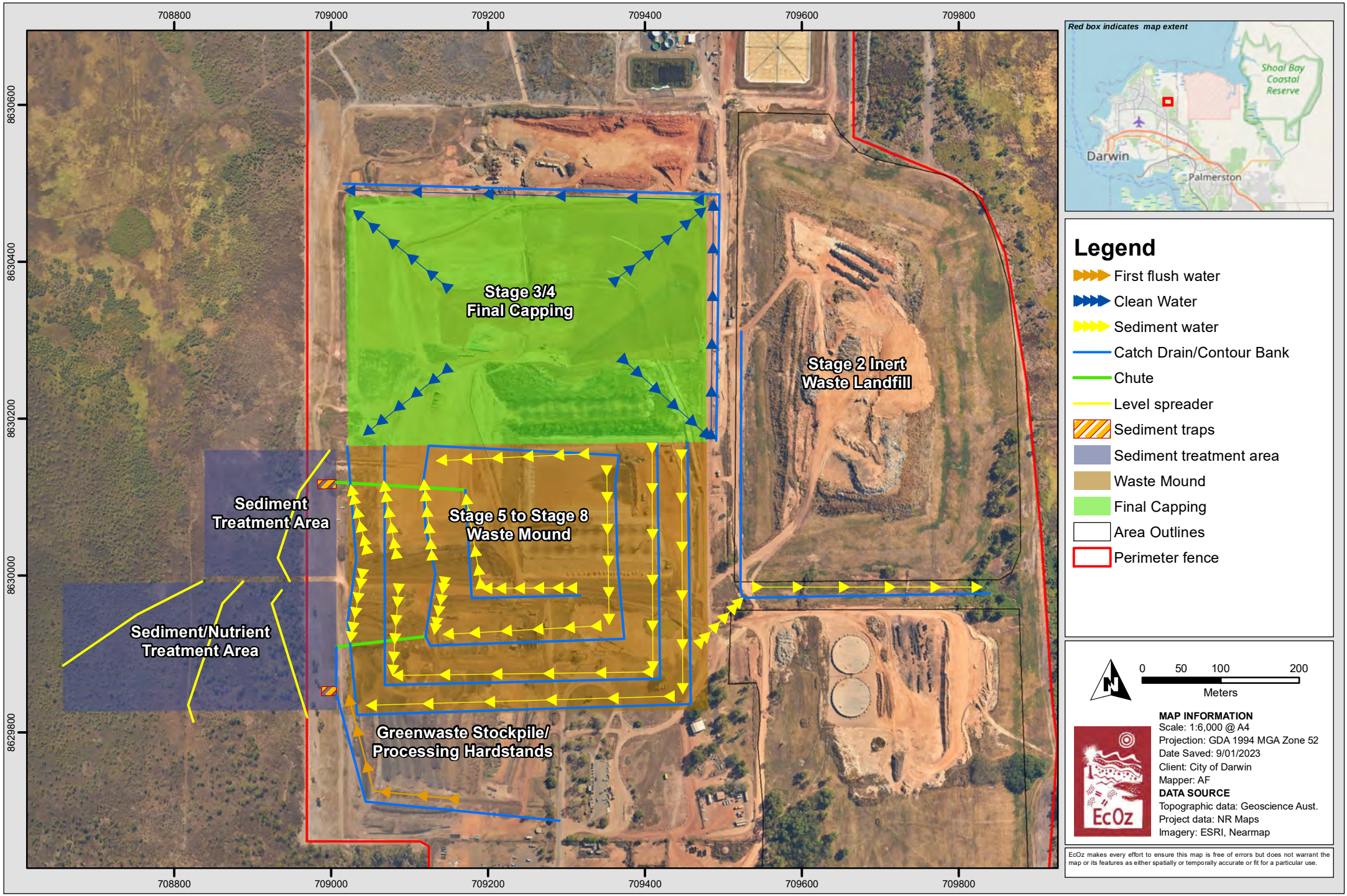
Figure 5-1. Typical layout of a level spreader

The stormwater management concepts outlined above are shown in Figure 5-2 to Figure 5-4, and the nominated controls are summarised in Table 5-12 along with their maintenance triggers and action requirements.



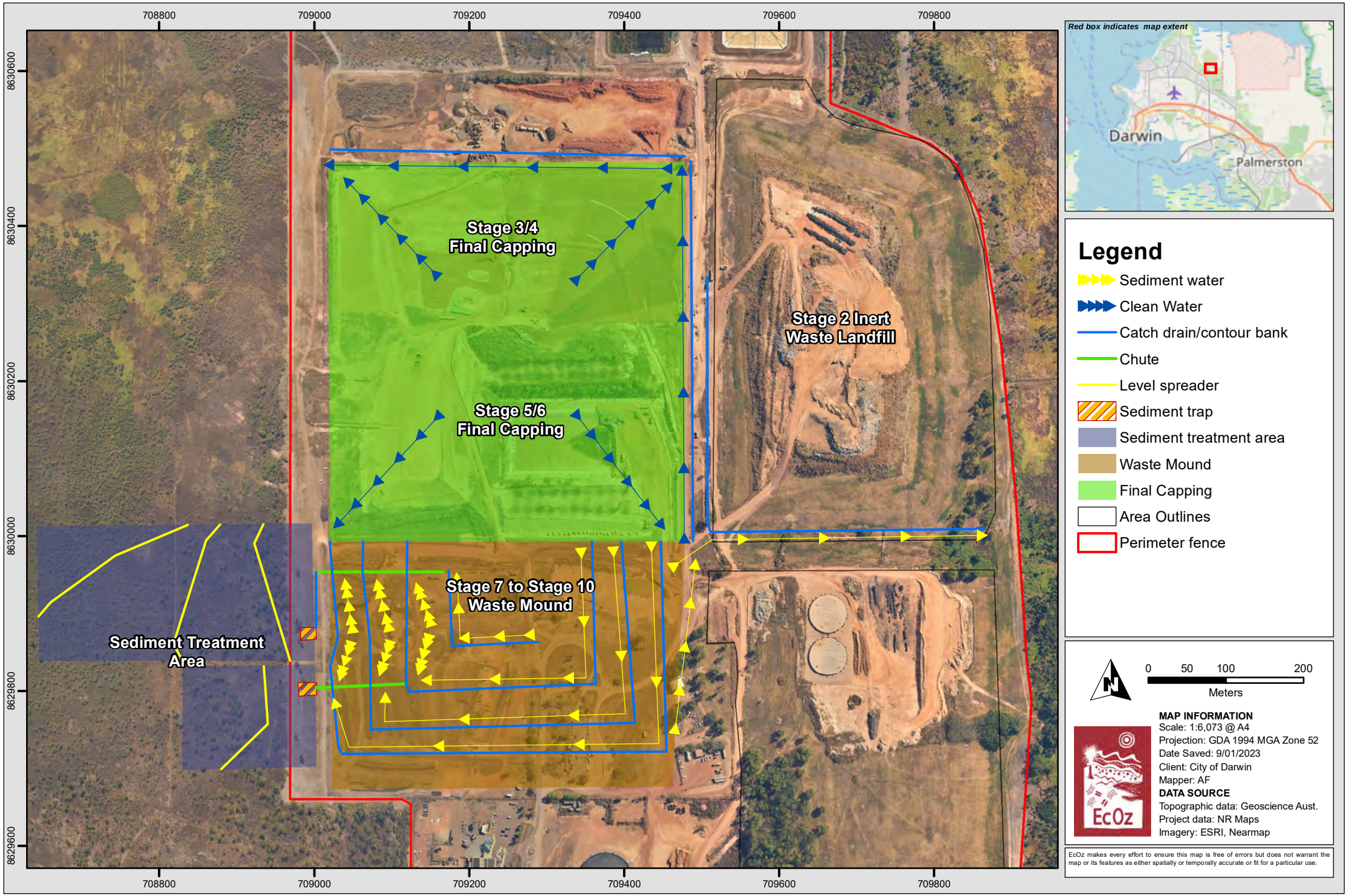
Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Fig X-X. Stage 2-6 stormwater plan.mxd

Figure 5-2. Stormwater management for Stages 2-6 and green waste



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Fig X-X. Stage 7-8 stormwater plan.mxd

Figure 5-3. Stormwater management for Stages 7 to 8 and green waste



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Fig X-X. Stage 9-10 stormwater plan.mxd

Figure 5-4. Stormwater management for Stages 9 to 10

Table 5-12. Proposed controls, maintenance triggers and actions

Control	Description	Maintenance trigger	Maintenance action
Grass-lined contour banks/catch drains	Used to control and direct flows on slopes (i.e. landfill batters) to toe drains or chutes	Evidence of erosion or slumping	Repair/reinstate. Investigate need for additional controls or replace with more effective controls
		Sediment, debris or vegetation blockage	Remove accumulated sediment or debris
		Changes in design slope	Re-profile drain
Rock-lined chutes	Used to convey impacted runoff from the elevated areas of the landfill directly down the batters to toe drains	Displacement of rock or scour	Move rock to original location and consider local placement of larger rock
		Exposed base and/or geotextile	Ensure integrity of base/geotextile and reinstate locally
		Erosion on bunds	Repair/reinstate
Grass-lined drains	Used to convey runoff to treatment areas or to surrounding environment	Vegetation is longer than 250 mm	Grass to be maintained to approximately 100 mm
		Poor vegetation growth	Water if applicable. Consider secured turf or plant tubestock of native grasses/sedges/vetiver
		Evidence of erosion	Repair/reinstate. Consider localised additional controls
Check dams	Rock dams or fibre logs in catch drains used to slow flow velocities and facilitate sediment capture	Damage to dam structure	Reinstate
		Sediment accumulation	Remove any accumulated sediment
		Signs of overtopping/scour	Reduce central height or increase rock armour around edges
		Significant erosion between dams	Install additional dams or install channel liner
Causeway/culvert	Conveys flows across roads/access tracks and maintain trafficability	Evidence of overtopping	Place more rock protection or increase depth
		Evidence or erosion or damage to headwalls or channels	Repair/reinstate. Install extra scour protection
		Blockage, sediment build up	Unblock and/or desilt immediately
Coarse sediment trap	Used to settle out and capture sediment from most flows	Evidence of erosion or damage to structures	Repair/reinstate. Place more rock protection
		Sediment build-up of 30%	Remove sediment and dispose of appropriately
High-flow bypass drain	Grassed trapezoidal drain adjacent to the sediment trap used to convey flows greater than the design event to minimise potential damage to downstream controls	Vegetation is longer than 250 mm	Grass to be maintained to approximately 100 mm
		Poor vegetation growth	Water if applicable. Consider secured turf or plant tubestock of native grasses/sedges/vetiver
		Evidence of erosion	Repair/reinstate. Consider localised additional controls
Level spreader	Grassed and bunded structure to spread and direct flow from the coarse sediment	Evidence of erosion or damage to structures	Repair/reinstate

Control	Description	Maintenance trigger	Maintenance action
	trap to a well vegetated area	Evidence or erosion in vegetation directly below outlet	Consider placing geotextile and rock armour for first 0.5m after outlet or lower inflow level to high-flow bypass
Stiff grass barrier	Vetiver strips (or other suitable vegetation) placed downstream of level spreader discharge or in grassed drains	Evidence of erosion	Repair/reinstate. Consider planting additional strips or alternative species
		Vegetation is longer than 500 mm following wet season	Grass to be cut back to approximately 500 mm
Vegetated extended detention area	Localised bunding in surrounding vegetation to promote increased settling of sediment and uptake of nutrients from green waste area by strategically planted grasses and sedges	Evidence of erosion	Repair/reinstate. Consider planting additional strips or alternative species
Sediment basin	Optional large scale engineered structure (Type C) to capture, treat and store sediment water.	Evidence of erosion or damage to structures	Repair/reinstate. Place more rock protection
		Sediment build-up of 30%	Remove sediment and dispose of appropriately

5.6.2 Water monitoring

Monitoring of groundwater, surface waters and leachate quality is undertaken regularly. Details of the monitoring program, including locations, frequency, parameters measured, analysis and reporting are included in the Site Water Monitoring Plan (SWMP) in Appendix B. The monitoring sites are included Table 5-13 and Table 5-14, below.

As the general waste landform progresses, some of the existing monitoring sites may become redundant. Additional surface water monitoring will be required to determine the effectiveness of the sediment controls and nutrient attenuation within the sediment treatment areas. Monitoring sites shall be established at outfalls from the proposed sediment basin and coarse sediment traps, and within any clean water drains that discharge into the surrounding vegetation. The SWMP will be updated as these changes to the monitoring program occur.

Table 5-13. Leachate monitoring sites and offsite monitoring site details

Site ID	Easting	Northing	Location	Context
Leachate Sites				
DW2	709029	8630459	Deleaching well on southwest corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells
DW3	709038	8630216	Deleaching well on northwest corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells
DW5	709023	8630122	Deleaching well on west side of Stage 5 landfill	Represents leachate from Stage 5 landfill cell
DW6	709041	8630039	Deleaching well on southwest corner of Stage 5 landfill	Represents leachate from Stage 5 landfill cell
DW7	709450	8630121	Deleaching well on east side of Stage 6 landfill	Represents leachate from Stage 6 landfill cell
DW8	709459	8630042	Deleaching well on east side of Stage 6 landfill	Represents leachate from Stage 6 landfill cell
TC Sump	709465	8630233	Sump on southeast corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells
LMP02	709938	8629759	East of Stage 1	Sump that receives leachate from Stage 1 and 2 landfills via an interception trench that runs north-south along the eastern edge of the Stage 1 and 2 landfills.
LP01	709534	8630726	Northern leachate storage pond	Represents leachate in northern storage pond
LP02	709531	8630713	Southern leachate storage pond	Represents leachate in southern storage pond
LP03	TBC	TBC	Pond 3	Represents leachate in pond 3
Treated Leachate Wetland Sites				
LTP wetland	TBC	TBC	Treated leachate wetland (irrigation pump station)	Represents treated leachate water quality prior to irrigation
Offsite Surface Water and Groundwater Sites				

Site ID	Easting	Northing	Location	Context
MC01	TBC	TBC	Mickett Creek downstream near creek mouth	Represents water and sediment quality in tidal zone of Mickett Creek at increasing distance from contamination source ie. To determine any concentration gradients
MC02	TBC	TBC	Mickett Creek halfway between MC01 and MC03	Represents water and sediment quality in tidal zone of Mickett Creek at increasing distance from contamination source ie. To determine any concentration gradients
MC03	TBC	TBC	Mickett Creek as far upstream as accessible by boat	Represents water and sediment quality in tidal zone of Mickett Creek at increasing distance from contamination source i.e. To determine any concentration gradients
MC04	TBC	TBC	Downstream of leachate ponds and north side Stage 2 landfill cell	Represents water and sediment quality in receiving waters immediately offsite and downstream of this infrastructure
MC05	TBC	TBC	In unlined stormwater drain downstream of Stage 2 landfill cell	Represents water and sediment quality in receiving waters immediately offsite and downstream of this infrastructure
MC06	TBC	TBC	Downstream of Stage 1 & Stage 2 landfill cells	Represents water and sediment quality in receiving waters immediately offisite and downstream of this infrastructure
MC07	TBC	TBC	Downstream of Stage 1 and 2 landfill cell	Represents water and sediment quality in receiving waters immediately offisite and downstream of this infrastructure
MC08	TBC	TBC	Downstream of Stage 1	Represents water and sediment quality in receiving waters immediately offisite and downstream of this infrastructure
HJ01	TBC	TBC	Creek that drains Holmes Jungle Reserve	Upstream reference site for comparing with downstream sites
BC01	TBC	TBC	Downstream of Stage 3/4 landfill cells and LTP	Represents water and sediment quality in receiving waters immediately offsite and downstream of this infrastructure
BC02	TBC	TBC	Downstream of green waste area and Stage 5 landfill cell	Represents water and sediment quality in receiving waters immediately offsite and downstream of this infrastructure
BC03	TBC	TBC	Further downstream of green waste, Stage 5 landfill cell	Represents water and sediment quality in receiving waters immediately offsite and downstream of this infrastructure
BC04	TBC	TBC	Stormwater drain that receives runoff from urban areas	Represents water and sediment quality in receiving waters immediately offsite and downstream of this infrastructure
GW19-3	TBC	TBC	North of site	To detect any groundwater impacts migrating to the north
GW19-12	TBC	TBC	North of site	To detect any groundwater impacts migrating to the north
GW20-3	TBC	TBC	West of site	To detect any groundwater impacts migrating to the west of site
GW20-12	TBC	TBC	West of site	To detect any groundwater impacts migrating to the west of site
GW21-3	TBC	TBC	West of site	To detect any groundwater impacts migrating west of site
GW21-12	TBC	TBC	West of site	To detect any groundwater impacts migrating west of site
GW22-3	TBC	TBC	East of site	To detect any groundwater impacts migrating east of site
GW22-12	TBC	TBC	East of site	To detect any groundwater impacts migrating east of site
GW23-3	TBC	TBC	East of site	To detect any groundwater impacts migrating east of site

Site ID	Easting	Northing	Location	Context
GW23-12	TBC	TBC	East of site	To detect any groundwater impacts migrating east of site
GW24-3	TBC	TBC	South of site	Upgradient bore for establishing background groundwater quality
GW24-3	TBC	TBC	South of site	Upgradient bore for establishing background groundwater quality
GW24-3	TBC	TBC	South of site	Upgradient bore for establishing background groundwater quality

Table 5-14. Groundwater monitoring bore details

Bore ID	Easting	Northing	Location	TOC[3] outer elevation mAHD	TOC[2] elevation mAHD	Ground elevation mAHD	Screened interval mBGL	Screened lithology
GW1-3	709564	8631004	On floodplain, 190 m north of leachate storage area	8.71	8.63	8.02	1.5-3	Siltstone
GW1-12	709566	8631004		8.71	8.59	8.00	9-12	Siltstone
GW2-3	709629	8630835	On north-east corner of leachate storage area	8.06	7.94	7.33	1.5-3	Siltstone
GW2-12	709631	8630835		8.08	7.94	7.28	9-12	Siltstone
GW3-3	709652	8630746	East of leachate storage area	9.94	9.80	9.12	1.5-3	Siltstone
GW3-12	709654	8630746		9.87	9.82	9.10	9-12	Siltstone
GW4-3	709775	8630634	On floodplain, north of Stage 2 landfill	5.65	5.49	4.88	1.5-3	Siltstone
GW4-12	709776	8630633		5.61	5.44	5.36	9-12	Siltstone
GW4-30	709777	8630631		5.50	5.20	5.33	15-21	Gravelly sand, Sandstone
GW5-3	709880	8630224	East of Stage 2 landfill	5.51	5.41	4.70	1.5-3	Siltstone
GW5-12	709880	8630226		5.48	5.33	4.70	9-12	Siltstone, Gravelly Clay
GW6-3	709464	8630022	Decommissioned when Stage 6 was constructed	N/A	N/A	N/A	N/A	Gravelly Sandy Silt, Siltstone
GW6-12	709464	8630021		N/A	N/A	N/A	N/A	Siltstone
GW6-30	709464	8630018		N/A	N/A	N/A	N/A	Siltstone, Sandstone
GW7-3	709900	8629992	South-east of Stage 2 and north-east of Stage 1	5.18	5.03	4.33	1.5-3	Siltstone
GW7-12	709900	8629994		5.16	5.08	4.33	9-12	Siltstone, Sandy Silt
GW8-3	709896	8629708	East of Stage 1	5.42	5.28	4.65	1.5-3	Claystone
GW8-12	709896	8629708		5.37	5.22	4.62	9.1-12.1	Claystone, Sandstone
GW9-12	709660	8629469	On southern boundary of SBWMF – up-gradient of all SBWMF operations and infrastructure	16.18	15.93	15.44	9-12	Siltstone
GW10-3	709147	8629507	South of SBWMF – up-gradient of all SBWMF operations and infrastructure	18.12	18.06	17.32	1.5-3	Siltstone
GW10-12	709149	8629507		18.13	17.98	17.37	9.1-12.1	Siltstone
GW11-3	709040	8629671	South-west corner of SBWMF	13.50	13.38	12.72	1.5-3	Siltstone
GW11-12	709042	8629671		13.52	13.38	12.84	9-12	Siltstone, Sandstone
GW12-3	709024	8629881	West of green waste area	12.20	12.07	11.44	1.5-3	Siltstone

Bore ID	Easting	Northing	Location	TOC[3] outer elevation mAHD	TOC[2] elevation mAHD	Ground elevation mAHD	Screened interval mBGL	Screened lithology
GW12-12	709024	8629883		12.22	12.04	11.50	9-12	Siltstone
GW12-30	709024	8629885		12.21	12.05	11.55	24-30	Sandstone
GW13-3	709017	8630175	On south-west corner of Stage 3/4 and north-west corner of Stage 5 landfills	12.93	12.88	12.32	3-4.5	Siltstone
GW13-12	709016	8630174		12.91	12.86	12.25	10-13.5	Siltstone
GW14-3	709013	8630423	West of Stage 4 landfill	6.78	6.73	6.09	1.5-3	Siltstone
GW14-12	709013	8630424		6.77	6.64	6.08	9-12	Siltstone
GW15-3	709230	8630599	North of Stage 3/4 landfill	11.27	11.06	10.44	1.5-3	Siltstone
GW15-12	709233	8630599		11.20	11.04	10.44	9-12	Siltstone
GW16-3	709493	8630030	East of Stage 5/6	14.50	14.55	13.57	1.5-3	Sandy Claystone
GW16-12	709494	8630025	East of Stage 5/6	14.57	14.61	13.65	9-12	Siltstone
GW16-30	709495	8630021	East of Stage 5/6	14.53	14.56	13.2	20-26	Siltstone
GW17-3	709386	8630672	Within the proposed treatment area	11.80	11.83	TBC	0.5-4	Siltstone
GW17-12	709384	8630672	Within the proposed treatment area	11.86	11.80	TBC	8-11	Sandy clay loam
GW17-30	709381	8630672	Within the proposed treatment area	11.90	11.88	TBC	27-30	Fine loamy sand
GW18-3	709464	8630729	Within the proposed treatment area	11.50	11.51	TBC	TBC	TBC
GW18-12	709464	8630728	Within the proposed treatment area	TBC	10.72	TBC	8-12	Sandy clay loam
WW1	709471	8630151	Between Stage 3 and Stage 2 landfills	-	16.60	15.90	0-6.3	-
WW6	709047	8630478	North-west corner of Stage 3/4 landfill	-	7.46	6.76	0-20.4	-
WW9	709016	8630598	North-west corner of SBWMF	-	7.09	6.39	1-9.8	Siltstone
WW13	709457	8630598	On northern boundary of SBWMF	+0.8	+0.7	Not available	1-10	Siltstone

TBC – To be confirmed

5.6.3 Water management

Objective / outcome	• To prevent the contamination of surface water and groundwater due to landfill activities
Mitigation / Control	• Diversion of clean water from operational areas • Minimize the size of disturbed areas • Capture of sediment and first flush water containing contaminants prior to release of water into the environment • Progressive rehabilitation of cells • Active collection and management of leachate generation within buried waste materials • Reduce stormwater runoff from buried waste by keeping small active disposal faces, placing daily cover and maintaining well-shaped landforms • Containment of buried wastes and leachate and separation from underlaying groundwater • Monitoring of groundwater, surface water and leachate in accordance with the SWMP
Target / performance criteria	• Compliance with the *Australian and New Zealand Guidelines for Marine and Freshwater Quality* trigger values for protection of 90% of marine ecosystems
Monitoring	• Ensure water monitoring is undertaken in accordance with the SWMP

Corrective actions and contingencies	• Undertake additional monitoring and analysis to confirm exceedances • Implement changes to management system if required • Raise concern at toolbox talks/staff meetings • Report non compliances of EPL to NT EPA
Responsibility	Site Manager

5.7 Leachate

5.7.1 Leachate overview

Leachate is liquid that passes through the waste facility and collects extracted solutes and suspended solids. Leachate has the potential to pollute the surrounding environment and is of particular concern during the wet season. The current leachate collection systems installed on site are described in Table 5-15 and shown in Figure 5-5.

Table 5-15. Landfill stages and leachate collection systems.
Taken from Golder (2021b)

Stage	Waste Cell	Area (ha)	Leachate Collection System	Condition	Collection Sump	Status
Stage 1	N/A	12.2	Toe pipe and trench	Operational	Sump 1/2	Operational
Stage 2	General Waste	17.6	Toe pipe and trench	Operational	Sump 1/2	Operational
	Inert Waste	7.0	General waste	Unknown	Sump 1/2	Operational
Stage 3	Cell floor	10.5	Pipes and gravel stripes at 50 m spacing	Non-functional	Sump 3	Not Used
	Southern Area	N/A	Pipe and gravel blanket	Operational	Sump 3B	Operational
	Northern Toe	N/A	Toe pipe/aggregate	Operational	Sump 3C/3D	Operational
	Eastern Toe	N/A	Toe pipe/aggregate	Operational	Sump 3E	Operational
Stage 4	Cell floor	2.5	Gravel blanket & pipes	Operational	Sump 4	Operational
Stage 5	Stage 5A	1.9	Gravel blanket & pipes	Operational	Sump 5A	Operational
	Stage 5B	1.75	Gravel blanket & pipes	Operational	Sump 5B	Operational
Stage 6	Stage 6A	1.8	Gravel blanket & pipes	Operational	Sump 6A	Operational
	Stage 6B	1.65	Gravel blanket & pipes	Constructed	Sump 6B	Constructed

Stage 1 & 2

Leachate that moves laterally from Stage 1 and 2 waste cells is recovered using interception trenches along the eastern toe of both stages. A gravity drain transfers the leachate to a single sump (Sump 1/2) that is pumped to an irrigation area over the eastern side of Stage 1. Details for the constructed drainage systems have not been provided by CoD.

Stage 3 to Stage 6

Leachate collection systems were constituted by gravel mound covered drainage pipes located at 50 m spacings; this leachate collection system in Stage 3 is considered to have failed and is no longer in use. An elevated leachate mound is known to be present within the current waste landform.

The installation of final capping for the combined Stage 3/Stage 4 landfill cells was completed in 2022. The capping works include the installation of a new perimeter leachate drain along the northern and eastern toe line of Stage 3 that drain to three new leachate collection sumps (Sump 3x to Sump Z)

Stage 4 to Stage 6 have a constructed composite liner and gravel blanket leachate collection system.

Leachate extraction from Stage 3 to Stage 6 comprise the following:

- Leachate from each sump is pumped through a rising main to three 15 ML covered leachate storage ponds (Northern Pond & Southern Pond)
- Leachate disposal includes (1) leachate treatment plant surface irrigation within a section of the combined plateau areas of Stage 3 / Stage 4 and (2) enhanced evaporation system

The construction of a permanent leachate treatment/disposal system to service SBWMF was completed in late 2022.

Leachate collection volumes

A leachate water balance was undertaken for the site which predicted the leachate collection volumes over ten years. The water balance calculation included an assessment of current leachate volumes and generation rates, based on rainfall and capping stages. Table 5-16 outlines the estimated leachate collection volumes from the putrescible waste cells over ten years based on two rainfall scenarios. This includes estimates from Stage 3 to the proposed Stage 7 landfill cells. An additional 4 to 8 ML of leachate is estimated to be collected from Stage 1 and 2 over this period.

Table 5-16. Estimated leachate collection volume estimates (ML)
Taken from Golder (2020)

Rainfall	2022	2023-27	2028	2029	2030/31
50th percentile	22	16	17	11	13
90th percentile	29	21	24	14	16

The volumes presented in Table 5-16 do not include the planned future drawdown of the existing leachate mound present within Stage 3. Dewatering of the mound is planned to start once the current leachate volumes in the leachate ponds and temporary storage tanks are reduced to manageable levels.

Leachate storage ponds

Three leachate storage ponds fitted with floating covers and a nominal capacity of 45 ML (15 ML each pond) have been installed at the SBWMF. Leachate from the four engineered general waste stages (Stages 3 to Stage 6) is pumped into the storage ponds (Golder 2021a).

Each of the leachate ponds are lined with geosynthetic liners to reduce leakage and covered to prevent rainfall capture. The covers are designed to allow stormwater runoff to be collected and retained over the cover.

Clean water storage on top of the covers assists with mitigating risks of damage to the cover system associated with high wind/cyclone events and bushfire embers.

The leachate storage ponds are also protected by an internal perimeter fence to exclude unauthorised access that may result in exposure to safety risks and protect liner systems from damage by terrestrial fauna.

Three additional temporary leachate storage tanks are located within the SBWMF to support the current storage infrastructure. One of the tanks (leachate storage tank 3), with a nominal capacity of 13000 m^3, is located east of the Gatehouse. The remaining two tanks (leachate storage tank 1 and 2 have a capacity of 3 ML each and are located on stage 1. The location of the tanks is shown in Figure 2-1.

Leachate treatment system

All leachate collected from Stages 1 and 2 is currently collected via a leachate interception trench on the eastern side of Stages 1 & 2, which then overflows off-site into the salt marsh area. Leachate collected from Stages 3 to Stages 6 is pumped via an above ground rising main pipe network to the ponds for management, shown in Figure 5-6 (Golder 2021a).

From the leachate storage ponds, leachate will be pumped to the leachate treatment system designed to treat the leachate to a suitable quality for discharge within the site (i.e. via irrigation). The leachate treatment system includes the following:

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. Irrigation of treated leachate

The treatment system has been sized to treat flows of up to 140 kL/day however is inherently scalable and flexible in nature to manage the fluctuating leachate generation rates outlined in Table 5-16. The storage of treated leachate will be within one of the 15 ML leachate storage ponds .

Approximately 50ML/yr of treated leachate is planned to be irrigated onto 6.5 ha on the landfill capping of Stage 3 and 4. Leachate irrigation will only be undertaken on specifically designed capped landfill cells to reduce the risks of environmental contamination and migration of contaminants off site. The Irrigation Management Plan (IMP) for SBWMF is provided in Appendix G. The EMP for the Leachate treatment and Irrigation at SBWMF (WCG 2020) as well as the Integrated Leachate Management Program (Golder 2021a) should be read in conjunction with this EMP. These reports provide further detail on the treatment methodology, outputs and monitoring requirements, and all the environmental management activities and control measures to be implemented to minimise environmental impacts.

Leachate irrigation and reinjection into the lined cells

During dry season, leachate irrigation will be undertaken to irrigate leachate on the lined landfill cells to reduce leachate volumes through evaporation. In extreme scenarios such as extreme rainfall events where the leachate generation far exceeds the storage capacity, the leachate will be reinjected into the lined landfill cells to reduce the risk of leachate overflow into the environment.



Figure 5-5. SBWMF constructed general waste landfill cells and leachate collection pump locations

Taken from 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, as cited in Golder (2021a)

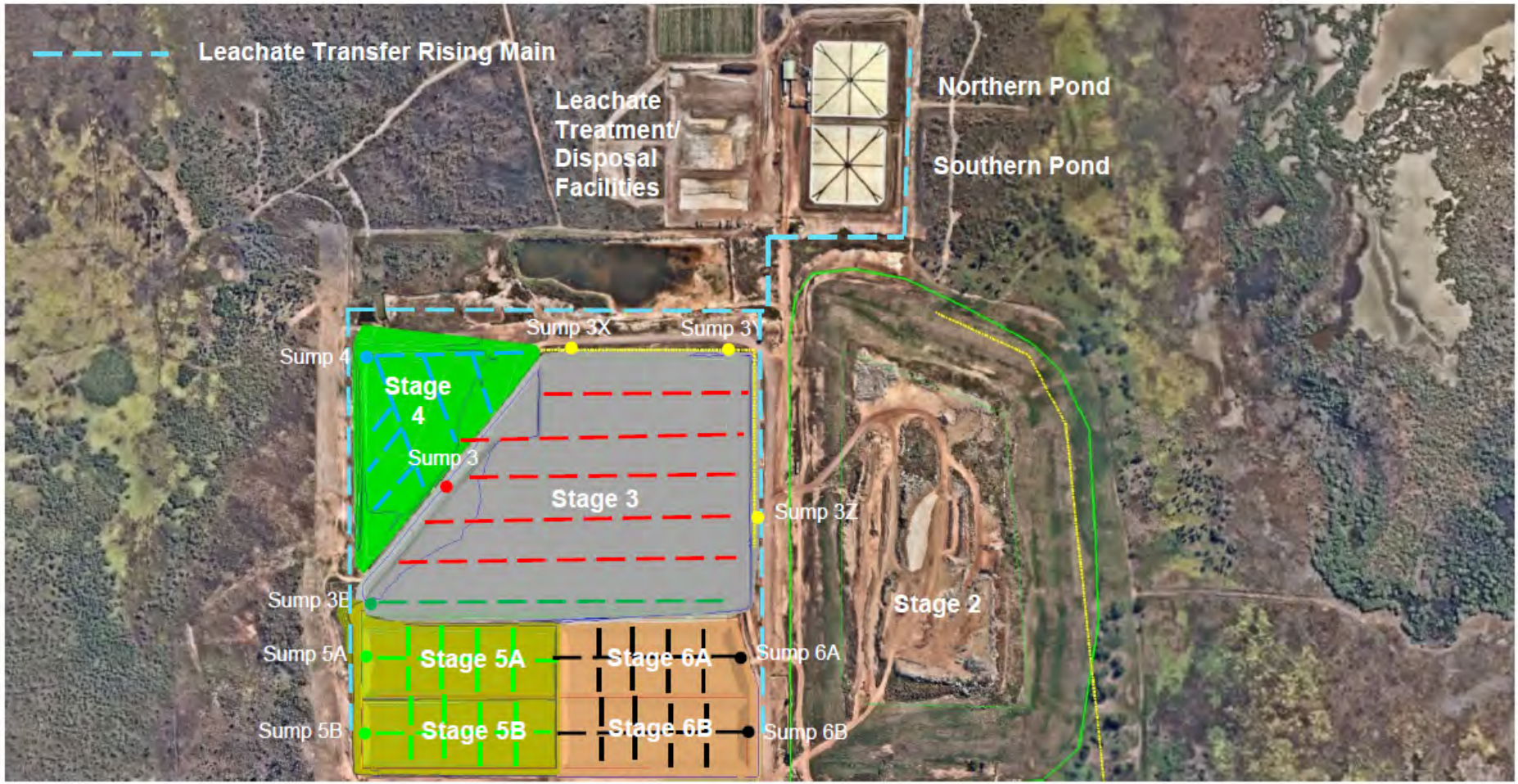


Figure 5-6. SBWMF engineered general waste landfill stages leachate collection systems

Taken from Nearmap Image, June 2021, Council/Defence Lease Plan, Council Stage 4/Stage 5 As-constructed Survey, 2012 & 2016, Golder Design 2019 as cited in Golder (2021a)

5.7.2 Leachate management

Leachate is managed as per Table 5-17 to reduce to risks of leachate generation and contamination from SBWMF.

Table 5-17. Leachate management

Objective / outcome	• To prevent impacts to the surface water, groundwater and surrounding environment due to leachate
Mitigation / Control	*General landfill operations:* • Ensure appropriate disposal of wastes into landfill cells • Use of appropriate cover and capping for landfill cells and installation of interim and final capping as required • Minimise exposed tip face area to reduce rainfall infiltration • Maintain a free-draining landform at all times • Use of diversion bunds or similar where required to direct stormwater runoff around active tip faces • Inspections and installation of additional controls as required for periods of forecast high rainfall (i.e. cyclones or monsoons) • New landfill cells designed to minimise leachate generation (i.e. sub-cells) with early waste placement scheduled during dry periods • All wash down bay water is captured and contained • Irrigation of raw leachate to occur over lined (uncapped) landfill cells only • Monitor all active waste areas following high rainfall events for signs of discoloured runoff / leachate • Where leachate contamination of surface runoff is visible, construct diversions to direct leachate back into landfill or into leachate management structures • Minimise the surface area and volumes of green waste kept on site *Leachate collection and storage:* • Leachate collection systems are installed, maintained and regularly inspected to ensure their effectiveness • Maintain leachate sumps, drains, ponds, pumps and other infrastructure and ensure no new leachate springs occur • Leachate ponds/tanks are lined to prevent seepage to groundwater, and covered to prevent surface water infiltration • Leachate tanks equipped with a leak detection system and pressure/level sensor to monitor leachate levels and promptly identify any leakage from the tanks • The inter-connected leachate lines allow transfer of leachate from one storage to another whenever required • Emergency backflow infrastructure is installed and working effectively to return leachate from ponds to landfill *Leachate treatment* • Installation and maintenance of a leachate treatment system • Undertake daily checks on treatment infrastructure • Ensure leachate is stored within tanks/ponds specifically designed for leachate • Treat leachate to a quality suitable for on-site discharge (sampling of treated leachate prior to discharge) • Development and implementation of an irrigation management plan • Irrigation will be controlled to avoid surface runoff and irrigation will be limited or stopped during rainfall events • Ground saturation to be monitored and logged to avoid overland flow • Implementation of a monitoring program • Flow and volumes will be monitored and recorded daily • • During extreme events of high rainfall, the raw leachate will be reinjected into lined and capped cells to mitigate environmental harm from the release of raw leachate into the environment
Target / performance criteria	• No incidents or monitoring results in breach of the EPL • No detectable leachate flowing from SBWMF operations area

	• No impacts to the surface water or groundwater at SBWMF
Monitoring	• Ensure water quality monitoring is undertaken in accordance with the SWMP • Inspection of waste disposal areas following heavy rainfall events • Conduct site inspections on water quality controls as per the site inspection schedule • • Monthly internal water quality monitoring of treated leachate from LTP
Corrective actions and contingencies	• Implement changes to the leachate management system if required • Raise concerns at toolbox talks / staff meetings • Report non compliances of EPL to NT EPA
Responsibility	Site Manager

5.8 Dust and odour

Table 5-18 describes the complaints management system in place at SBWMF for dust and odour management, and details mitigation measures in place to reduce the occurrence of dust, odour and aesthetic nuisances to the surrounding properties and SBWMF users.

Table 5-18. Dust, odour and aesthetics management

Objective / outcome	• To minimise dust and odour nuisance to SBWMF users, employees and surrounding properties • To minimise dust impacts to the surrounding environment
Mitigation / Control	• Dust suppression through the use of a water cart/truck will be undertaken when necessary • Speed limits on site will be enforced to reduce the amount of dust Progressive revegetation of disturbed areas will be undertaken to reduce generation of dust • Appropriate use of daily cover to minimise odour from the tip face • Immediate cover of odorous wastes, such as animal effluent and residues • Transfer station skip bins will be emptied when full and at least at the close of each working day • Skip bins used at the transfer station are to be cleaned at least monthly to prevent build-up of odours
Target / performance criteria	• No complaints received from SBWMF users, employees and surrounding land owners/users relating to dust or odour.
Monitoring	• Regular inspections of tip face throughout the day to manage odour or windblown waste • Daily site inspection to include visual checks of cleanliness and tidiness • Visual monitoring for excessive dust generation • Ensure that all the LTP processes for nutrient removal are working effectively to reduce odour
Corrective actions and contingencies	• Training of staff regarding dust suppression, tidiness and cleanliness • Training staff in complaints handling • Raise concerns at toolbox talks / staff meetings • All complaints received will be logged in a complaints register • All complaints shall be responded to within 48 hours, with documentation added to the complaints register
Responsibility	Site Manager

5.9 Landfill gas

5.9.1 Overview

Active landfill gas system

Landfill gas emissions at the SBWMF are primarily controlled via a landfill gas extraction system, which was commissioned in 2005, and is owned and operated by a private company, LMS Energy.

As shown in Figure 5-7 landfill gas is extracted via a network of wells and pipelines located across all landfill stages (i.e. Stages 1 to 5). The gas extracted is conveyed to an on-site 1.1 MW power station, where it is used to generate electricity. A flare is also part of the landfill gas system on site.

Condensate is generated in the landfill gas extraction system as the gas cools. The condensate is collected and transferred to the leachate collection and treatment system.

Passive landfill gas system

A passive gas collection system uses extraction wells to collect landfill gas which is sent into the atmosphere or a control system. At the SBWMF, a passive gas collection system will be installed as part of their closure plan for management of landfill gas generated at low rates.

The current design of the passive gas collection system is only available for Stage 3 and Stage 4. The system involves a passive gas capture system located under the geosynthetic clay liner (GCL) layer and five vertical vents along the cover soil placement and final profile (refer to Shoal Bay Waste Management Facility Stage 3/ Stage 4 Capping Project design drawing 7). Installation of the passive gas collection system is in place for the Stage 3 and 4 capping works (see Appendix F).

The design and installation of the passive gas system are done as part of the capping works, which are progressively undertaken, so they meet current standards and technologies. Therefore, as operations of the SBWMF progress and other Stages are filled, information about the passive landfill gas system will change; this EMP will be revised and updated as these changes occur.

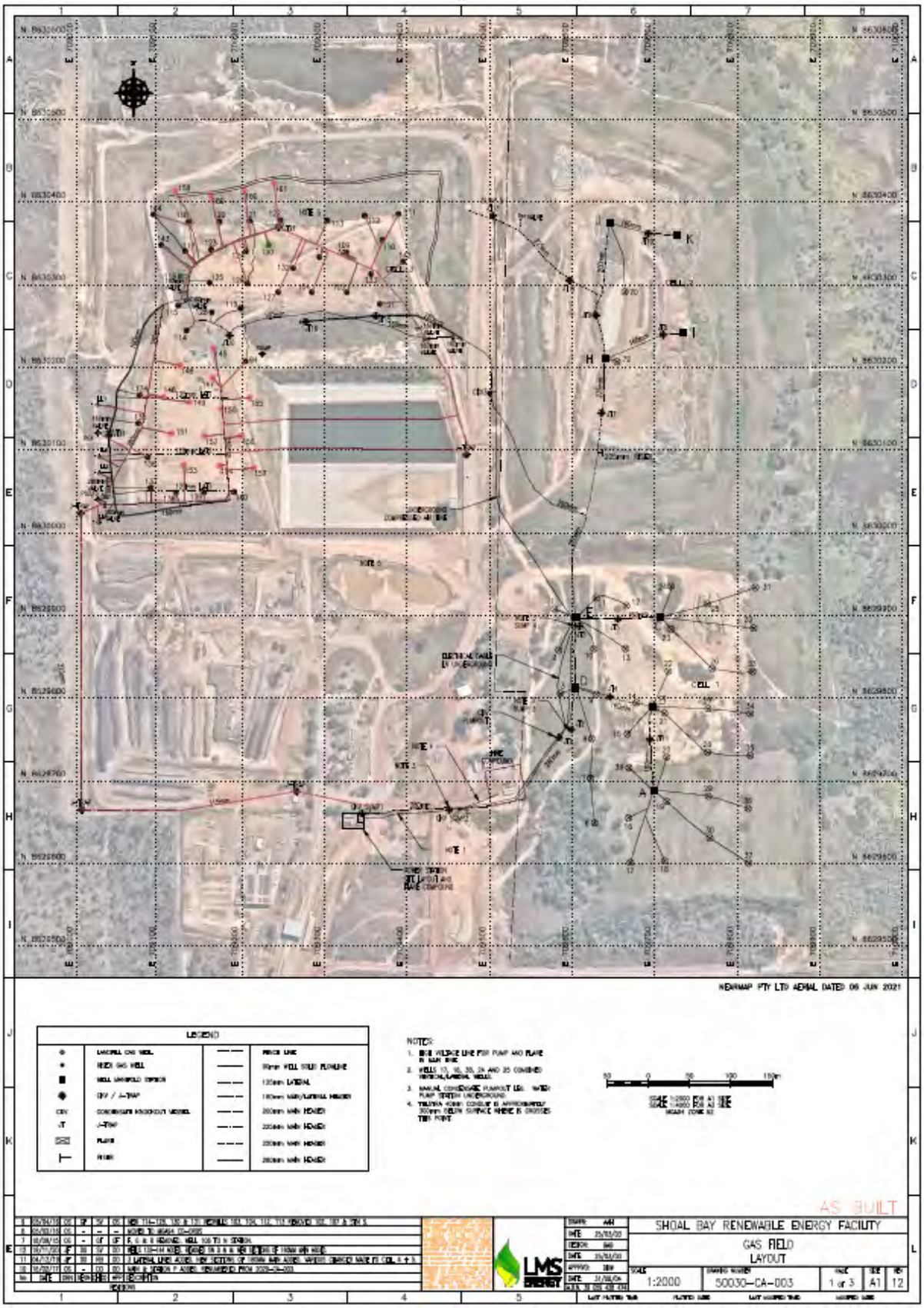


Figure 5-7. Active Landfill Gas System at SBWMF
Black and red wells are current.

5.9.2 Management

Landfill gas is managed as per Table 5-19 to reduce the risks of landfill gas (LFG) emissions from SBWMF.

Table 5-19. Landfill gas management

Objective / outcome	• To minimise the fugitive loss of greenhouse gas (methane) emissions to atmosphere
Mitigation / Control	• A LFG collection system is installed on site • Ensure regular maintenance of gas infrastructure including raising of gas wells in line with current fill plans
Target / performance criteria	• No significant loss of greenhouse gas (methane) emissions to atmosphere
Monitoring	• Undertake LFG monitoring as per monitoring schedule • Conduct inspections on gas infrastructure to identify any leaks or defects
Corrective actions and contingencies	• Rectify any leaks or defects in the system immediately • Consider installation of additional wells if there is sufficient capacity
Responsibility	Site Manager

5.9.3 Monitoring

Monitoring of LFG at surface, sub-surface and in buildings and subsurface pits will be undertaken quarterly. Details of the monitoring program, which include locations, frequency, parameters measured and assessment criteria, are provided in the Landfill Gas Monitoring Plan (LGMP) in Appendix C.

As the monitoring progresses, new monitoring sites around the SBWMF may be identified as requiring sampling and adding to the monitoring program. In addition, some of the current sampling sites may be removed as the monitoring and the waste landform progress. Monitoring frequency may also be subject to modifications; as such, the LGMP will be updated as these changes to the monitoring program occur.

5.10 Noise

Table 5-20 describes the complaints management system in place at SBWMF for noise management, and details mitigation measures in place to reduce the occurrence of noise nuisances to the surrounding properties and SBWMF users.

Table 5-20. Noise management

Objective / outcome	• To minimise noise nuisance to SBWMF users, employees and surrounding properties • To minimise noise impacts to the surrounding environment
Mitigation / Control	• Maintain all equipment and machinery to manufacturers standards • Conduct all operations during standard work hours
Target / performance criteria	• No complaints received from SBWMF users, employees and surrounding land owners/users relating to noise
Monitoring	• If noise outside of what is considered normal operational noise is to occur, notification and details will be given to the public and surrounding land owners via newspapers and letter drops • Noise monitoring will be undertaken in the event of a complaint
Corrective actions and contingencies	• Train staff in complaints handling • Raise concerns at toolbox talks / staff meetings • All complaints received will be logged in a complaints register • All complaints shall be responded to within 48 hours, with documentation added to the complaints register
Responsibility	Site Manager

5.11 Litter

Table 5-21 describes the complaints management system in place at SBWMF for litter management, and details mitigation measures in place to reduce the occurrence of litter nuisances to the surrounding properties.

Table 5-21. Litter management

Objective / outcome	• To ensure no litter nuisance to SBWMF users, employees and surrounding land owners/users • To minimise litter impacts to the surrounding environment
Mitigation / Control	• Litter will be regularly cleaned up and disposed of appropriately by SBWMF staff • The perimeter fence is designed to reduce wind-blown litter leaving the SBWMF. This fence will be maintained. • Additional litter fencing should be installed around active tip faces where required.
Target / performance criteria	• No complaints received from SBWMF users, employees and surrounding land owners/users relating to litter
Monitoring	• Daily site inspections to include a visual check for litter • Monthly formal site inspection including inspection of litter and litter controls
Corrective actions and contingencies	• Training staff in complaints handling • Raise concerns at toolbox talks / staff meetings • All complaints received will be logged in a complaints register • All complaints shall be responded to within 48 hours, with documentation added to the complaints register
Responsibility	Site Manager

5.12 Flora and fauna

Table 5-22 details the management and mitigation measures to reduce the risks to flora and fauna.

Table 5-22. Flora and fauna management

Objective / outcome	• To minimise impacts on flora and fauna at SBWMF and in the surrounding environment
Mitigation / Control	• All clearing at SBWMF will have the required approvals undertaken by CoD • Any sightings of threatened fauna species are to be reported to the Site Manager to determine whether the animal is at risk and requires relocation • Report any injured fauna to the Site Manager • No pets / domestic animals allowed to be brought onto SBWMF • Speed limits will be enforced to minimise potential for fauna impact • Disturbed areas will be progressively rehabilitated, and done so with species local to the surrounding environment • Perimeter fencing around the landfill site to prevent large fauna entering the site
Target / performance criteria	• No significant impacts to flora and fauna • No injured fauna as a result of SBWMF activities • Disturbed areas progressively rehabilitated with local native species, and achieving a minimum 80% groundcover within the first year
Monitoring	• Monthly site inspections to check for signs of impacted flora and fauna • Monitoring of rehabilitation areas will be undertaken to ensure it is to an acceptable standard (i.e. a minimum 80% groundcover within the first year)
Corrective actions and contingencies	• Training of staff regarding potentially significant fauna on site • Ensure clear signage of speed limits for users of SBWMF • Raise concerns at toolbox talks or staff meetings • Further rehabilitation works if found to be to in-effective
Responsibility	Site Manager

5.13 Pests and weeds

Table 5-23 details mitigation measures to reduce the likelihood of infestations, introduction and spread of pests and weeds.

Table 5-23. Pest and weed management

Objective / outcome	• To reduce the likelihood of weed infestations at SBWMF • To reduce the spread of weeds at SBWMF • To minimise the numbers of feral / pest species and mosquitos at SBWMF
Mitigation / Control	• Declared weeds are not to be disposed of at SBWMF without prior approval from CoD and the NT EPA • Weed management to be undertaken in accordance with the *NT Weed Management Handbook* depending on weeds present • Regular pest control activities to be undertaken at SBWMF, including use of bait stations etc. • Where an infestation has been identified, a qualified, licensed pest control contractor will be called in to control the infestation • Boundary fence to be regularly inspected and maintained to prevent access to animals • The pooling of water will be prevented where possible, to decrease the breeding grounds for mosquitos
Target / performance criteria	• No declared weeds or introduction of noxious weeds at SBWMF • No spread of weeds from SBWMF to surrounding environment • No introduction of feral / pest species at SBWMF • No feral / pest / vector infestations at SBWMF
Monitoring	• A weed survey is to be undertaken at least annually • Monthly site inspection to check for presence of pests and weeds in operational areas
Corrective actions and contingencies	• Seek advice from the NT Weeds Management Branch if required • Seek advice from the NT Department of Health if mosquito eradication is required • Implement more rigorous monitoring routines for pests and weeds as required • Ensure clear signage for SBWMF users so they know what declared weeds are • Training for staff regarding weed identification and management of weeds at SBWMF • Raise concerns at toolbox talks or staff meetings
Responsibility	Site Manager

5.14 Fire prevention

Fire prevention management is detailed in Table 5-24 which includes mitigation measures relating to risks such as fires within the landfill and bushfires.

Table 5-24. Fire prevention management

Objective / outcome	• To minimise the risk of fire from and to the landfill
Mitigation / Control	• Appropriate management of waste disposal into landfill cells to ensure no hot loads or smoking loads • Ensure a clean and tidy operations area to minimise ignition sources • Appropriate hot works procedures – no hot works undertaken during fire bans or near flammable materials • Maintain fire-fighting equipment including extinguishers in date and accessible water cart. • Smoking only to occur in designated smoking areas • Maintain a 4 m wide fire break around the perimeter of the SBWMF, around buildings and operational areas • Ensure refuelling of diesel is in well-ventilated area (BeneTerra, 2022)

Target / performance criteria	• Fire risk from and to the SBWMF is reduced • No fires started at SBWMF
Monitoring	• Visual monitoring of loads going to landfill cells for evidence of smoking or hot loads • Site inspections to include checks for firefighting equipment and fire risks such as site tidiness, appropriate hot works permits etc. • Regular inspection and monitoring of all electrical devices/equipment
Corrective actions and contingencies	• Training for staff regarding fire risks and emergency response plan • Raise concerns at toolbox talks or staff meetings
Responsibility	Site Manager

6 COMMUNICATION AND CONSULTATION

6.1 Inductions and training

All project personnel, subcontractors and consultants will be required to undertake a site induction which will, as a minimum, address the following environmental topics:

- Details of the EPL and conditions and consequences of non-compliance with the EPL;
- The significant environmental risks and details of this EMP;
- Location of significant environmental sensitive areas; and
- Incident management procedures (e.g. the action to be taken in emergencies, communication lines and contact details for emergency services and site representatives).

Personnel performing tasks that can cause significant environmental impacts shall be competent on the basis of appropriate education, training and/or experience. Training related to emergency response is outlined in Section 8.5.

6.2 Stakeholders

The key stakeholders of the landfill facility include:

- Commonwealth Department of Defence;
- Northern Territory Environmental Protection Agency;
- Northern Territory Government agencies / departments;
- SBWMF operations contractor;
- Adjacent properties to landfill site;
- Local environmental / conservation groups;
- Local community organisations;
- Local indigenous parties / groups;
- Domestic and commercial users; and
- Darwin community / public.

6.3 Communication and consultation

Communication and consultation will be undertaken in accordance with the SBWMF Communication and Consultation Procedure and this EMP.

6.3.1 Internal communication

Activities, changes or incidents relevant to SBWMF will be communicated to staff through different means such as meetings, toolbox talks, emails and flyers. Site specific environmental information and lessons learnt will be disseminated through to site based teams through the use of pre-start messages and toolbox talks to ensure all parties are kept informed.

6.3.2 Awareness

Ongoing environmental awareness will be maintained through the use of visual aids and signage so as to be visible to the general public and users of SBWMF. The CoD website will be maintained with current and relevant information on the facility. Information may also be disseminated through CoD social media pages and media releases.

6.3.3 Community consultation

In accordance with the CoD's Community Consultation Policy (Policy No 025), CoD has a standing commitment to effectively consult with the community through communication, awareness, participation and inclusion. CoD is committed to open, accountable and responsive decision making, which is informed by effective communication and consultation between CoD and the community. The Community Consultation Policy specifies three levels designated to suit all consultation requirements, ranging from the most basic public notification, to seeking input on an issue or communitywide significance.

Should a change arise at the SBWMF that involves community consultation, prescribed statutory requirements and the Community Consultation Policy will be followed. The Community Consultation Policy is available for public viewing on the CoD website or in hard copy at the Civic Centre customer service desk.

6.3.4 External stakeholders

Where a site activity or issue is of concern or interest to any external stakeholders such as regulatory authorities or the land owner, the respective parties will be notified by verbal or written communication as deemed appropriate by CoD or as detailed in the EPL. Any communications with external stakeholders will be documented and recorded in a communication / consultation register detailing contact details, time / date, location, any issues raised, responses given and actions (who, what, when and how), each issue will be addressed.

6.4 Complaint management

Complaints handling will be undertaken in accordance with the CoD's Complaints Handling and Review of Decisions Policy (Policy No 026). Complaints may be made in person, in writing, by telephone, by facsimile transmission or by email. Complaints may be lodged directly to CoD, to an Elected Member, or through the Ombudsman, Commissioner for Public Disclosure or other external agency.

A complaints and enquiry handling system will be implemented and managed through CoD's electronic document register. This will require the following records to be kept:

- Date, time and nature of the complaint or inquiry;
- Type of communication (telephone, letter, meeting etc.);
- Name, address, contact number;
- Nature of complaint; and
- Response details.

All complaints shall be treated as an environmental incident and logged in a complaints register including details of the complaint, issue and time / date. Verification of the incident shall be reviewed and if justified an action to address the issue assigned. All complaints shall be responded to within 48 hours, with documentation added to the register.

Following a complaint, ensure all employees and sub-contractors are aware of the potential environmental nuisance issues and controls through inductions, toolbox and pre-start meetings

7 AUDITS AND REPORTING

7.1 Audits

CoD will commission an audit to be conducted by an independent and suitably qualified person on an annual basis to evaluate the extent to which compliance has been achieved with this EMP, the EPL, the *WMPC Act* and the *Water Act*. A written report must be prepared and signed by the qualified person who conducted the audit. The written report must be provided in full to the NT EPA within ten business days of being signed.

7.2 Non-conformance and corrective actions

Any non-conformance, corrective or preventative actions identified during an inspection or audit will be recorded in an action register and issued to the relevant party for rectification. The action register will detail the non-conformance, identified actions, responsible persons and due date for completion.

Any non-compliance with the EPL will be managed as an incident and any corrective or preventative actions will be detailed in the action register.

7.3 Incident management

All environmental incidents, near-misses or EPL non-compliances must be reported to CoD as soon as practicable. Reports can be made verbally but must be followed up in writing using the approved Incident Reporting Form.

Incident reports must have the following information, including the:

- Date, time and circumstance under which the incident became known;
- Known or estimated dates and times at which the incident commenced and ended;
- Details of the person initially reporting the incident;
- Actual and potential causes and contributing factors to the incident;
- Risk of environmental harm arising from the incident;
- Action(s) that have or will be undertaken to mitigate any environmental harm;
- Corrective actions that have or will be undertaken to prevent a reoccurrence; and
- If no action was taken, why no action was taken.

A record of all environmental incidents, near-misses and EPL non-compliances will be maintained in an environmental incident register.

7.4 Reporting

CoD will ensure all non-compliances with the EPL are reported to the NT EPA, as soon as practicable after (and in any case within 24 hours after) first becoming aware of the non-compliance.

CoD will prepare and submit an Annual Return to the NT EPA, outlining compliance with the EPL conditions in the preceding 12-month period. The Annual Return will be submitted within 10 business days after the EPL commencement date anniversary each year.

CoD will prepare and submit an Annual Monitoring Report to the NT EPA, outlining the results of monitoring over the preceding 12-month period and will be submitted within 20 business days after the EPL commencement date anniversary each year. In accordance with the EPL, the Monitoring Report must include a data analysis and interpretation as well an assessment of environmental impact, and leachate levels in various landfill cells

7.5 Reviews

The EMP will be reviewed every 12-months to ensure that it adequately addresses the identified issues and the activities being undertaken during the operation of SBWMF.

The review will consider as a minimum of:

- NT EPA comments or recommendations;
- Audit findings;
- Environmental monitoring outcomes;
- Incidents and non-conformances;
- Changes in organisational structure and responsibilities; and
- Changes in standards and legislation.

7.6 Document control

CoD is required by the *Information Act* to ensure that complete and accurate records of the business of CoD 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 CoD's Record and Information Management Policy (Policy No 057), which applies to all CoD staff and to records of all business activities performed by or on behalf of CoD.

All environmental documentation, plans, procedures, reports, data and records will be uploaded onto the CoD electronic document and records management system. Records of quantities and source of waste, including listed waste, received at SBWMF will be maintained through CoD's electronic weighbridge reporting system.

All records will be held for at least 10-years and will be accessible to the regulatory authorities as required.

8 EMERGENCY RESPONSE PLAN

This Emergency Response Plan (ERP) identifies potential incidents and emergencies at SBWMF that may present environmental risks. It also outlines CoD's emergency preparedness, mitigation measures, and reporting requirements, relating to these risks.

8.1 Potential emergency incidents

Emergency incidents that may occur at SBWMF include:

- **Extreme weather events** (e.g. cyclones, storms, intense and prolonged rainfall) resulting in damage to facilities, flooding and/or excessive landfill leachate generation that could lead to uncontrolled discharges to the surrounding environment
- **Lightning strike** that may disrupt power sources and impact on operations
- **Fuel, chemical or leachate spills** that may contaminate water or soils
- **Fire** as a result of bushfire or accidental fire as a result of operations.

8.2 Emergency contacts

The Site Manager is the contact person for all emergencies and environmental incidents. All incidents which cause or have the potential to cause material or serious environmental harm, will be reported to NT EPA as soon as the Site Manager becomes aware of the incident, or in any case within 24 hours as required under Section 14 of the NT *Waste Management and Pollution Control Act*.

The details of the designated contact persons responsible for on-site environmental management are provided below in Table 8-1. Also included are emergency contacts for reporting pollution incidents (including non-urgent problems such as dust/noise) and contacts for provision of advice.

Table 8-1. Emergency contact details

Contact	Details
Team Leader Waste	City of Darwin Ph: 08 8930 0300 E: darwin@darwin.nt.gov.au
Site Manager SBWMF	Nick Walker Veolia Ph: 08 8947 8947
NT EPA Pollution Hotline / Pollution Reporting	GPO Box 3675, Darwin NT, 0801 Pollution Hotline: 1800 064 567 pollution@nt.gov.au
Emergency Services (police, fire, ambulance)	000
NT Police (non-emergency)	131 444

Environmental conditions are monitored by the Site Manager through the Bureau of Meteorology website, NT Police, Fire and Emergency Services announcements, media, and local radio emergency broadcasts.

8.3 Objectives, targets, and indicators of the ERP

The objectives, targets and indicators of this ERP are summarised in Table 8-2.

Table 8-2. Emergency objectives, targets and indicators summary

Objectives	Targets	Indicators
• Protect people, property and the environment	• No incidents of harm to people, property or the environment from activities associated with an environmental emergency	• Number of incidents recorded
• Identify potential environmental emergency risks	• All risks identified and management controls are in place	• Audits and inspection findings
• Identify and implement management and mitigation controls to reduce the residual risk		
• Ensure emergency response equipment requirements are able to be identified and are available	• All risks are identified, and management controls are in place. • Emergency response scenarios have been identified	• Audits and inspection findings
• Ensure a high level of preparedness is maintained		
• Facilitate efficient response to emergencies to limit the impacts to the environment		
• Ensure emergency response training is relevant for the types of emergencies that SBWMF may experience	• Training for all employees	• Training records

8.4 Emergency response procedures

8.4.1 General emergency preparedness

SBWMF commit to continuous emergency preparedness through the following actions:

- Ensure that all personnel, including management, have received a site induction that specifically covers emergency response procedures (refer to Appendix H)
- The Site Manager will regularly liaise with staff to ensure that they are competent in responding to emergencies
- Conduct regular inspections on all emergency response equipment and ensure that all equipment is in good working order
- Following an emergency event, undertake an incident debrief and provide all staff with training into improved emergency response procedures or actions.

When advice is issued by authorities (e.g. cyclone watch, cyclone warning, evacuation order), the Site Manager will ensure that the following steps will be undertaken:

- All employees and contractors will report to the designated evacuation point (front gate), and receive further instructions regarding preparations for the emergency or evacuation.
- Where there is sufficient preparation time (i.e. in the event of a cyclone watch issued by the Bureau of Meteorology),
    - All essential vehicles will be fuelled, if required to evacuate employees, and non-essential vehicles will be parked and secured.
    - All potentially mobile items will be secured, tied down and/or stored and locked in the site buildings.

8.4.2 Fire

There are many different situations on-site where fire may result, such as landfill fire, fire in a waste haulage vehicle, office/building fire, transfer station fire, plant and equipment fire or bushfire.

In response to discovery of a fire, the following general steps must be undertaken:

- Notify the Site Manager immediately, with the location, type of fire, and details of any potential injuries or hazards. If necessary, the Site Manager will notify emergency services.
- Any plant or equipment in the vicinity of the fire should be moved to a suitable location or shutdown if safe to do so
- If evacuation of the site is necessary, all employees and contractors will report to the designated evacuation point, and receive further instructions regarding the emergency or evacuation.
- The affected area is not to be re-entered until the Site Manager deems the area safe
- All fire-fighting water is to be treated as leachate and must be managed accordingly.

Landfill fire

- Landfill fires can be managed by attempting to smother the fire with inert soil or similar material, or using a water cart
- Power supply and gas lines should be switched off only if there is ensuing risk.

Fire in waste haulage vehicle

- In the event of fire within a waste haulage vehicle, the vehicle must stop on a hardstand, vegetation free area (where possible and safe to do so) where the load can be extinguished (i.e. wash-down bay).
- If possible, the driver should exit the vehicle and remain at a safe distance whilst the fire is being extinguished by water or smothering

8.4.3 Spills

In the case of any spills, the following procedure is to be implemented:

- Locate the source to identify volume and type of spill
- Assess the risk to workers and environment to ensure appropriate PPE and measures to be implemented
- Control and contain the spill by isolating or removing source
- Clean the spill using spill kit and absorbent material or installing bunds
- Appropriate disposal of any material that was used to control and clean up the spill
- Repair any damaged plant or infrastructure associated with the spill
- Report significant spills or spills that have entered stormwater to NT EPA Pollution Hotline (1800 064 567).

Spill containment equipment kits will be available in all relevant works areas and their condition regularly checked and kept fully stocked. All personnel on site will be trained in how to use these spill kits.

8.4.4 Leachate breakouts

In the event of a leachate breakout from the landfill, storage, or treatment area the following measures are to be undertaken:

- Undertake measures to protect downstream receiving waters (e.g. block drainage lines)
- Isolate the area with appropriate bunding and remove excess leachate i.e. pump to storage ponds, recirculate through lined landfill cell or pump to an emergency leachate storage
- Excavate the breakout area (if within landfill) to remove any obstructions and encourage downward flow of leachate towards liner
- Re-compact waste layer and apply intermediate cover or capping as required
- Excavate any contaminated material from surface as a result of breakout and dispose of within the landfill cell.

8.4.5 Storm surge or flooding

In the event of a storm surge or forecast high rainfall event that may lead to some localised flooding, the following response measures shall be implemented:

- Move machinery, equipment and any fuel or chemical stores to high ground
- Ensure instruments or equipment that are to remain in-situ are well secured
- Switch off electric power to any low-lying appliances
- Empty any stormwater or sediment ponds to ensure sufficient capacity to attenuate stormwater flows
- Check all flow paths including open drains, ponds and culverts
- Confirm availability of pumping equipment for any potential dewatering
- Ensure appropriate cover over active waste management areas.

Following a flooding event, the following clean-up measures shall be undertaken:

- Inspect the landfill for instability and leachate breakouts
- Isolate any water that could be contaminated
- Inspect the site for any breaches of ponds or drains
- Clear any debris from drainage lines or structures that may have collected.

8.4.6 Environmental incidents

In accordance with the conditions of the EPL, the NT EPA will be notified in the event of an incident causing or with the potential to cause environmental harm, including but not limited to the following:

- Fire
- Spills involving waste/leachate which can result in environmental harm
- Release of potentially contaminated leachate or stormwater to receiving environment
- Exceedance of monitoring parameters
- Incidents which may have public health consequences or cause nuisance.

Environmental incidents can also occur as a result of illegal waste being delivered to the landfill. This can occur where the illegal waste is not discovered at the weighbridge because it is mixed in with other waste material. Where an employee becomes aware of such an incident, the Site Manager must be notified and the waste identified.

The Site Manager will be responsible for seeking advice on how to manage the situation.

8.4.7 Medical emergencies

In the event of a medical emergency, where possible the First Aid Officer will administer assistance to their level of training and competence. Where required, emergency services will be contacted immediately.

8.5 Emergency Training

All employees must be trained in the contents of this ERP, including the location of the designated evacuation point, emergency contact details and incident notification during the induction process.

Specific training will be provided for appropriate persons in the following:

- First Aid
- Spill response
- Evacuation drill
- Fire extinguishers
- Any other training identified for the purposes of emergency response.

An annual emergency drill shall be undertaken to evaluate compliance with this ERP and identify areas for further training or updates to the ERP as required.

8.6 Equipment

All emergency response equipment will be serviced and maintained in accordance with relevant Australian Standards and/or manufacturer's instructions.

Regular training will be carried out to ensure that designated/appropriate employees can operate the equipment as required.

The equipment will include as a minimum:

- Fire extinguishers, appropriate to materials on site
- Fire hose, pump, and water tank
- Operational machinery such as loader and water cart
- Appropriate spill kits and clean-up material.

9 CLOSURE

Complementary plans have been developed to support the progressive capping and closure of the SBWMF. These plans have been developed in accordance with the requirements of the EPL and NT EPA *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites in the Northern Territory* (2013).

These plans that reference the closure planning include:

- Water Balance Model, Leachate and Stormwater Management Strategies (Golder 2021b)
- Integrated Leachate Management Program (Golder 2021a)
- Shoal Bay Landfill Stage 6 Detailed Design Report (Golder 2019)
- Shoal Bay Waste Disposal Facility Stage 3 / Stage 4 Capping Project, Technical Specification (Golder 2020a)

The following sections provide a summary of the proposed closure plan for SBWMF.

9.1 Closure objectives

The main closure and rehabilitation objectives for SBWMF include:

- Final landform designed and rehabilitated to ensure structural stability, revegetation success and containment of wastes
- Final landform is maintained in a manner that minimises leachate generation
- Final landform is safe and non-polluting
- Rehabilitation aspects are conducive to post-closure land use and are compatible with surrounding and future land uses.

9.2 Closure considerations

Prior to closure of the SBWMF, appropriate environmental management strategies are required to be established and operational in order to manage any potential environmental risks once operations cease. Such management strategies include:

- An established and functioning leachate collection and treatment system with the capacity to manage the predicted volumes of leachate to be generated during the post-closure period
- Stormwater management infrastructure with erosion and sediment considerations to appropriately manage site runoff water
- A groundwater monitoring network to identify any potential risks to groundwater during the post-closure period
- A landfill gas extraction and management system capable of managing the predicted gas generation during the post-closure period
- Designated site access points to allow for ongoing maintenance and monitoring throughout the post-closure period
- The removal of redundant facilities and infrastructure i.e. buildings, laydowns, storage areas.

9.3 Final landform

The final landform will reach a maximum elevation of 70 m AHD with external batter gradients of 3W:1H pre-settlement (see Figure 9-2). Post-closure, waste settlement can result in a reduction of total waste thickness of up to 25%. The final landform post settlement is expected to result in a final elevation of 54.90 m AHD and batter slopes closer to 4W:1H (see Figure 9-3).

9.4 Capping

A final capping layer is required over the landfill to ensure the final surface provides an appropriate barrier to water infiltration, controls emissions to water and air, promotes sound land management and conservation, prevents hazards and protects amenity (NT EPA, 2013). Progressive capping of the final landform is to occur as per the LDP, whilst the facility remains operational (see Figure 9-4). This staged approach is recommended to reduce long-term leachate generation rates.

A detailed capping design is being undertaken; however, the final capping system proposed for SBWMF includes the following layers (Golder 2016b):

- Revegetation layer (approximately 1 m thick) including top soil to suit root depths of proposed revegetation species.
- Geocomposite drainage layer – this is a geosynthetic drainage layer encased in a filtration geotextile, with typical thickness in the order of 30 mm. This is thinner than the 0.3 m thick drainage layer of sandy soil or gravel indicated in the NT EPA Guidelines. Detailed design will need to consider anticipated flow rates for selection of an appropriately sized geocomposite drainage material.
- Liner low density polyethylene (LLDPE) geomembrane – LLDPE materials have higher strain tolerance compared to high density polyethylene (HDPE) geomembrane materials; LLDPE materials are considered favourable for geomembrane liners in landfill caps due to their capacity to withstand differential settlement of the underlying waste. The NT EPA Guidelines also include a geomembrane layer.
- Geosynthetic clay liner (GCL). Detailed design should consider whether a GCL is required underneath the geomembrane to achieve the NT EPA Guideline requirement that final capping be designed such that infiltration through the cap does not exceed the calculated seepage rate through the landfill liner. If a GCL is required, there may be value in considering a combined coated product to replace the geomembrane that provides protection against wetting and drying cycles and root penetration.
- Gas collection system. Detailed design should consider inclusion of a gas collection system incorporating passive gas relief strips (e.g. geocomposite drainage material) underneath the geosynthetic liner elements, connected to gas vents. This system would be intended to provide a means of passive gas management to be used when active gas collection is no longer commercially viable.
- Intermediate cover layer (300 mm).

9.4.1 Stage 3 / Stage 4

The final capping profile of Stages 3 and 4 is shown in Figure 9-1. Another two profiles are shown in Figure 9-1, given that the final capping of these Stages integrate an irrigation system, as well as access tracks and mid-slope benches. The final capping designs for Stage 3 and 4 are included in Appendix F. Details about the materials used for capping of these Stages are provided in *Shoal Bay Waste Disposal Facility Stage 3 / Stage 4 Capping Project, Technical Specification* by Golder (2020).

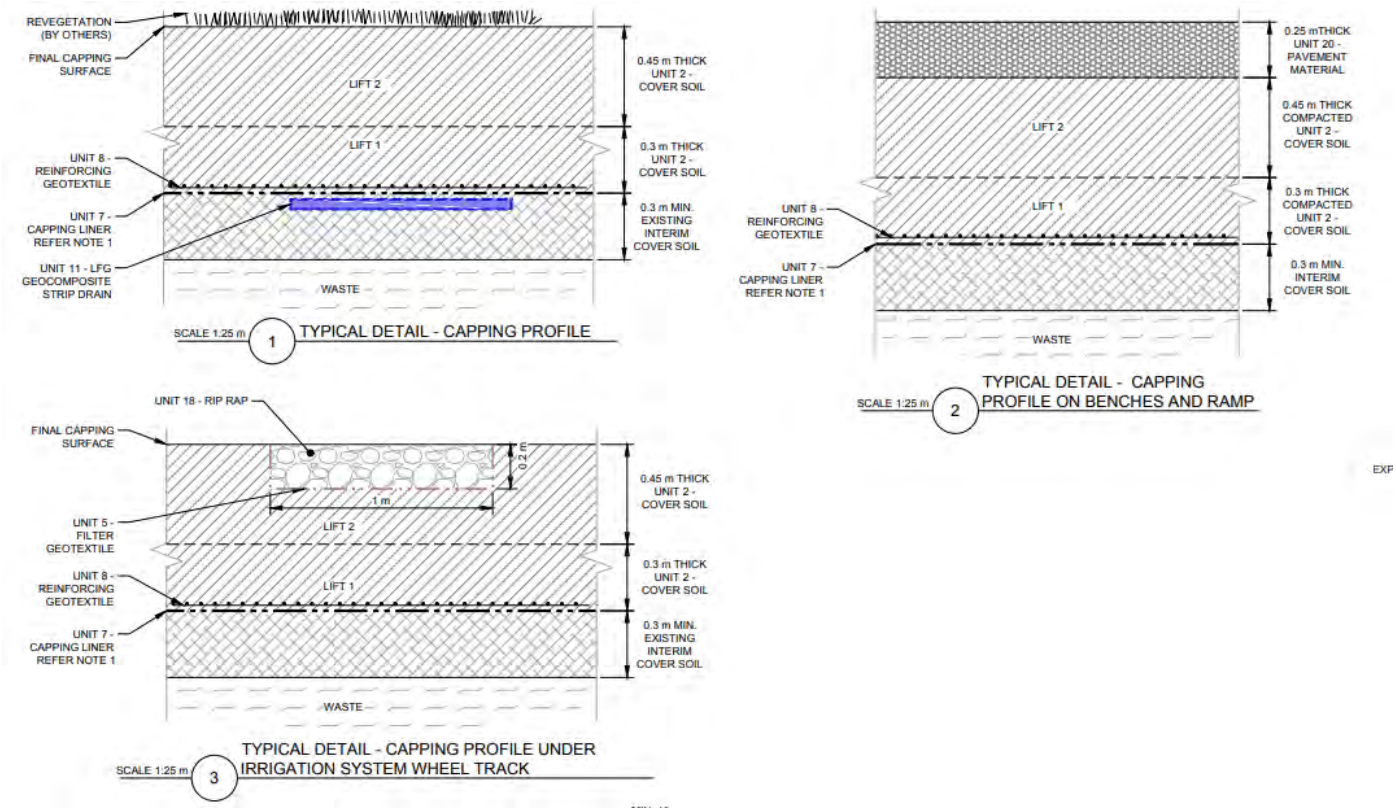


Figure 9-1. Capping profile of Stage 3 / Stage 4
Taken from Golder (2020a)

9.5 Revegetation

Revegetation will be undertaken progressively as the final capping layer is completed for each cell. The purpose of the vegetation is to establish quickly and provide a long-term vegetative cover to improve resistance to erosion. The vegetation must be shallow rooted to maintain the cover system.

Prior to direct seeding, weed control will be undertaken (if necessary) and the topsoil will be ripped along contours to a depth of at least 500mm to reduce erosion and improve vegetation recruitment. Native vegetation will then be established via hydroseeding. The seed mix will comprise of native grass species that occur in region. However, because the end landform is steeply sloped – in contrast to the surrounding landforms – further investigation is required to identify suitable native grasses which can grow on a slope and are compatible with the characteristics of the topsoil that is being used. Use of supplementary tubestock may be required. Active, ongoing management of the landfill site will necessary to ensure adequate groundcover and to avoid colonisation by native or introduced plant species with deep roots.

Where the final capped cell has alternative uses identified (i.e. treated leachate irrigation), revegetation will include tubestock planting of specific plants for the intended use – e.g. vetiver grass. In other areas of rehabilitation (i.e. decommissioned and removed facilities), a combination of seeding, planting and natural regeneration will be used to reflect the surrounding undisturbed vegetation areas.

9.6 Final land use

There is currently no proposed future land use for the SBWMF site. The site will be rehabilitated and revegetated to a condition reflective of the surrounding areas. As the site is leased, the land will be returned to the Commonwealth Government in an acceptable condition agreed by all parties.

9.7 Landfill gas

During operations, landfill gas collection and treatment infrastructure is managed by a third-party contractor. A monitoring plan has been developed (Landfill Gas Monitoring Plan developed by EcOz in 2021), which details the monitoring procedures applicable for Stages 1-5 of the SBWMF. Following closure, it is anticipated that gas extraction for the renewable energy facility will continue until such time where insufficient gas is being generated to operate the facility. Draft designs of a passive landfill gas system has been proposed by Golder Associates in 2021 (refer to Appendix F). This EMP will be required to be updated as the progressive landfill gas plans for the SBWMF are developed and approved.

9.8 Leachate

The generation of leachate within the landfill cells will continue for some time after closure of the facility. The leachate collection system will continue to extract leachate from the cells and direct it to the LTP for treatment. These operations will continue until monitoring of the leachate indicates that the generation of leachate has reached a sustainable level and the quality of the leachate is no longer considered a contamination risk.

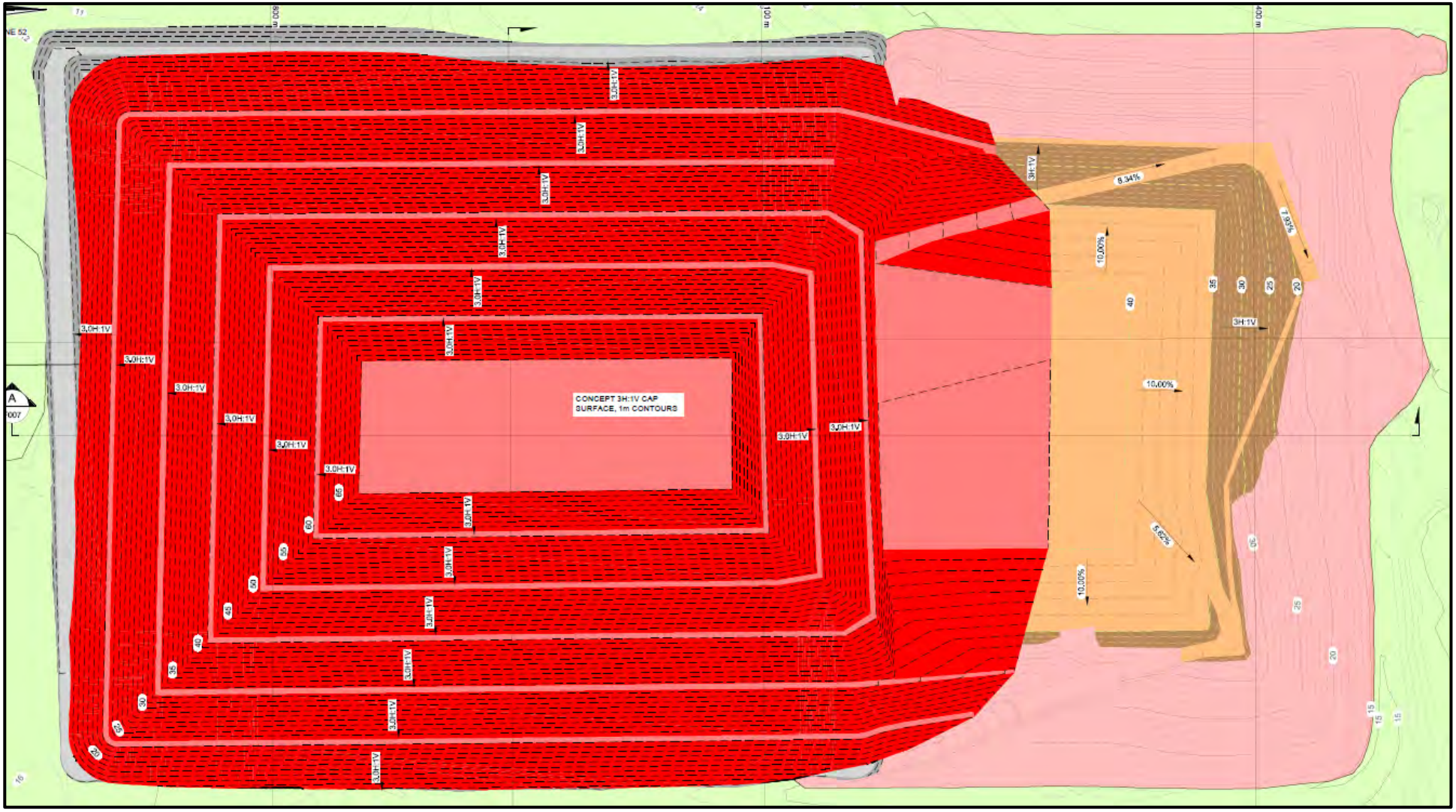


Figure 9-2. Pre-settlement landform
Taken from Golder (2016a)

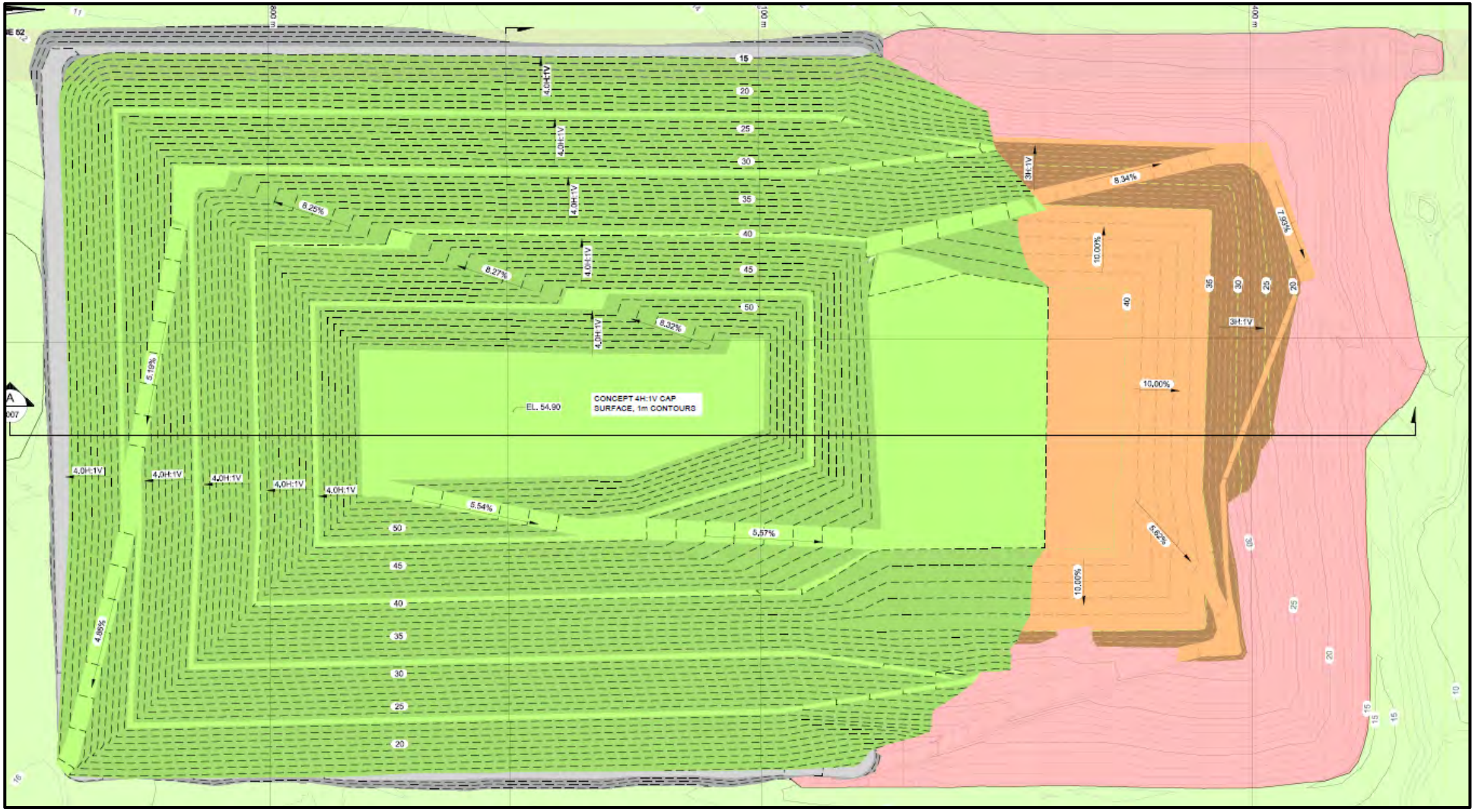


Figure 9-3. Post-settlement landform
Taken from Golder (2016a)

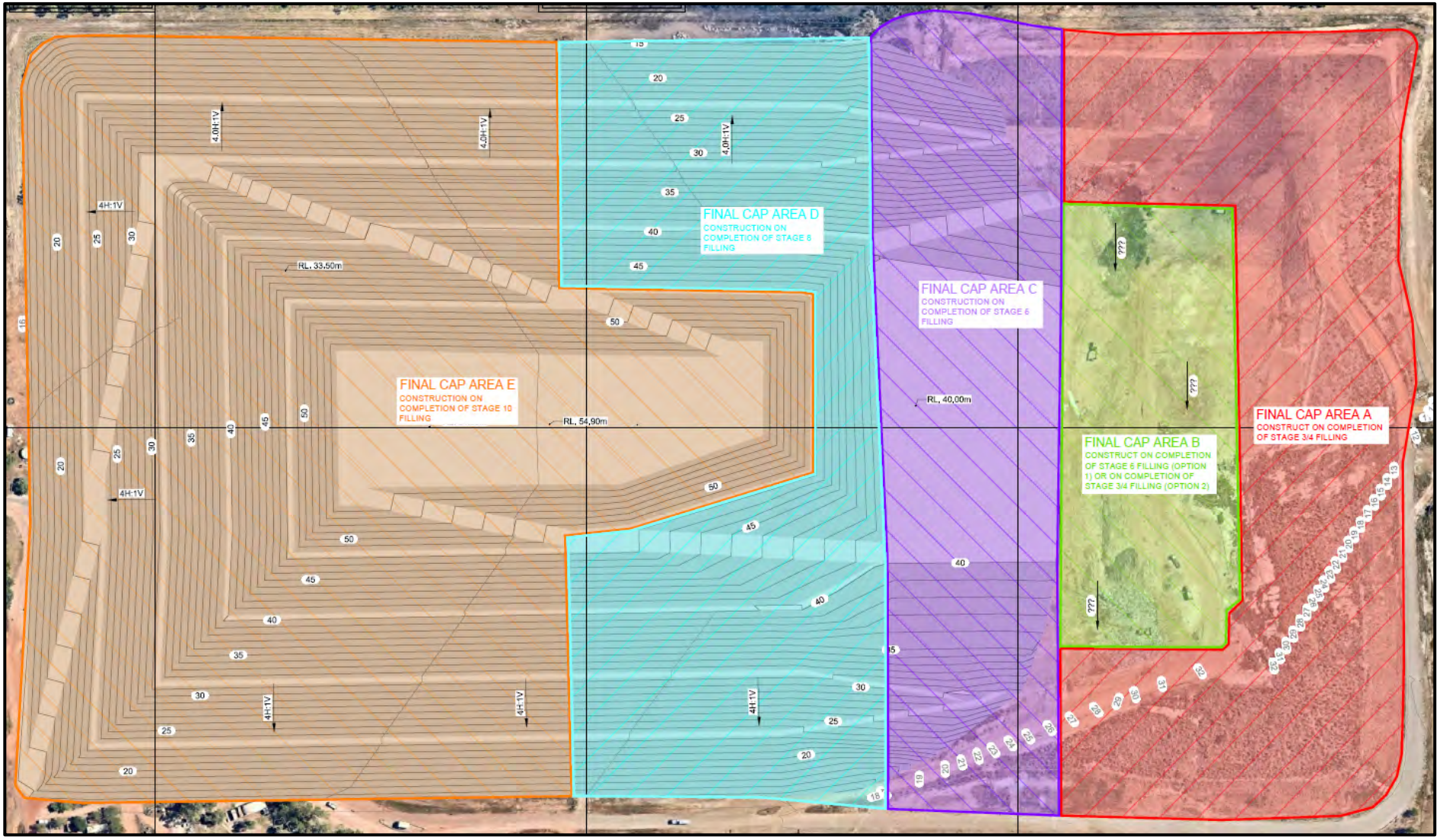


Figure 9-4. Final capping plan
Taken from Golder (2016b)

10 POST CLOSURE

Closed landfills require extensive monitoring and maintenance for up to 30 years' post-closure to ensure there are no ongoing environmental impacts on receiving environments.

10.1 Monitoring

An environmental monitoring program is required to assess potential impacts of the landfill on the receiving environment as it matures. The monitoring program should include any elements potentially at risk or posing a risk to the environment, including groundwater, surface water, landfill gas and leachate. The post-closure monitoring program is detailed in Table 10-1.

Table 10-1. Post-closure environmental monitoring program

Aspect	Parameters measured	Locations	Frequency	Duration
Groundwater	Analytes listed in WQMP at the time of closure	All active bores	Quarterly	First 2 years
			Biannually	Following 3 years (provided existing data supports a reduced frequency)
			Annually	Following 25 years
Surface water	Analytes listed in WQMP at the time of closure	All surface water discharge points	Biannually (during wet season)	5 years
Leachate	Analytes listed in LTP at the time of closure	Leachate treatment outputs	As per LTP at time of closure	Whilst leachate treatment plant is in operation
	Levels	Landfill cells	Quarterly	First 2 years
			Annually	Following 28 years
Landfill gas	Concentrations	Monitoring risers	As required by gas management operations	Whilst gas management system is in operation
		Gas monitoring bores and final cap areas	Annually	30 years

10.2 Settlement

Following capping and rehabilitation works on each cell, site walkovers to inspect the integrity of the cap should be conducted twice annually and following severe weather events (i.e. cyclones or monsoons) for a 15 year period.

Topographical surveys to measure the settlement should be undertaken annually in the first two years and then reduced to every two years for the following 13 years unless the settlement rate indicates that more frequent surveys are required. Following this it is anticipated that settlement will be very minor, therefore surveys should be reduced to every five years or until settlement has stabilised.

10.3 Maintenance

Maintenance planning shall take into consideration maintenance aspects associated with the landfill cap, leachate collection and treatment systems and landfill gas management system. Maintenance requirements for the facility may also include:

- Maintenance and repairs of site infrastructure such as fencing, buildings, security features etc.
- Mowing schedules or other landscaping requirements
- Weed and pest management
- Stormwater control and collection infrastructure.

Leachate collection and treatment systems

Maintenance and operation of leachate collection and treatment system shall continue as per the operational stage to prevent potential leachate contamination and allow effective extraction of landfill gas. Regular inspections of the leachate collection and treatment infrastructure is required and maintenance undertaken as per manufacturers recommendations or as identified by the operator.

Landfill gas management system

Maintenance and operation of landfill gas extraction system are required to ensure effective gas extraction and reduce the risk of fugitive emissions. Below is a list of considerations for post-closure LFG management:

- Well condition and pipework inspections
- Gas treatment plant capacity considerations, electrical interconnection and flaring requirements
- Provision of spare parts and repair response times
- Gas treatment plant maintenance and inspection schedule
- Condensate management.

Revegetation

All revegetation works will include a two-year maintenance period to ensure effective ground cover has been achieved. Where revegetation areas have not achieved at least 70% ground cover, maintenance measures will be implement (e.g. seeding, fertiliser application, compost application etc.). If any tubestock planting was undertaken and was unsuccessful, the plants will be replaced.

Weed inspections will be undertaken annually and appropriate weed control measures will be implemented for at least 5 years' post-closure.

11 REFERENCES

Ahmad, M and Muson TJ. (2013). Chapter 40: Money Shoal Basin. pp. 40-1 – 40-19 In *Geology and minerals resources of the Northern Territory*. Darwin, NT.: NTG.

BeneTerra. (2020) *Shoal Bay Waste Management Facility – Environmental Management Plan – BeneVap*. Prepared for City of Darwin by BeneTerra.

Bureau of Meteorology (2022). *Climate Data Online*. [online] Available at: http://www.bom.gov.au/climate/data/ [Accessed 11 November 2021]

Cardno (2022). *Annual Monitoring Review – Shoal Bay Waste Management Facility, Soil and Water Monitoring Program*. [online] Available at https://ntepa.nt.gov.au/__data/assets/pdf_file/0013/1124050/epl188-monitoring-report-2022.pdf [Accessed 04 August 2022]

CDM Smith Australia Pty Ltd (2019). *Shoal Bay Waste Management Facility – Environmental Protection Licence 188 Audit Report 2019*. [Unpublished].

EPA Victoria (2018). *Closed Landfill Guidelines,* Publication 1490.1, January 2018, Carlton VIC.

GHD Pty Ltd (2014). *Northern Territory Storm Surge Mapping Darwin Area Storm Inundation for 2100.* Prepared for Northern Territory Government by GHD Pty Ltd, November 2014.

GHD Pty Ltd (2021a) *Shoal Bay Waste Disposal Site – Stage 2 Expansion Concept Design Report*. Report prepared by GHD Pty Ltd for City of Darwin, March 2021.

GHD Pty Ltd (2021b) Shoal Bay Waste Management Facility – Emergency Waste Holding and Processing Area Options Assessment. Report prepared by GHD Pty Ltd for City of Darwin, April 2021

Golder Associates Pty Ltd (2016a). *Final Landform Geometry Options Review, Future Landfill Stages 5 to 10, Shoal Bay Waste Management Facility.* Letter prepared by Golder Associates Pty Ltd for City of Darwin, May 2016.

Golder Associates Pty Ltd (2016b). *Landfill Development Plan, Stage 5 to Stage 10 General Waste Cells, Shoal Bay Waste Management Facility, Darwin.* Report prepared by Golder Associates Pty Ltd for City of Darwin, August 2016.

Golder Associates Pty Ltd (2019). *Shoal Bay Waste Disposal Facility, Stage 6 Detailed Design Report, Darwin*. Report prepared by Golder Associates Pty Ltd for City of Darwin, February 2019.

Golder Associates Pty Ltd (2020a). Shoal Bay Waste Disposal Facility Stage 3/ Stage 4 Capping Project, Technical Specification. Report by Golder Associates Pty Ltd for City of Darwin, December 2020.

Golder Associates Pty Ltd (2020b). *Water Balance, Leachate and Stormwater Management Strategies Shoal Bay Landfill, Darwin*. Report prepared by Golder Associates Pty Ltd for City of Darwin, July 2020.
Golder Associates Pty Ltd (2021a). *Integrated Leachate Management Program, Shoal Bay Waste Management Facility, Darwin*. Report prepared by Golder Associates Pty Ltd for City of Darwin, October 2021

Golder Associates Pty Ltd (2021b). *Water Balance Model, Leachate and Stormwater Management Strategies, Shoal Bay Waste Management Facility, Darwin*. Report prepared by Golder Associates Pty Ltd for City of Darwin, October 2021.

NRETA 2008, *Groundwater Supply Prospects and Hydrogeology of the Cox Peninsula Region* map

NT EPA (2013), *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites in the Northern Territory*, Darwin NT

NT EPA (2020), Annual Return, Environmental Protection Licence 188 (EPL188). Provided by City of Darwin to the NT EPA 02/07/2026.

NT EPA (2022). Annual Return 2021 to 2022 Reporting Period. [online] Available at: https://ntepa.nt.gov.au/__data/assets/pdf_file/0019/1123057/epl188-city-of-darwin-annual-return2022.pdf [Accessed 04 August 2022]

URS (2015), *Shoal Bay Waste Disposal Site, Hydrogeological Investigation*, Report prepared by URS Australia Pty Ltd for John Holland Pty Ltd, November 2015.

URS (2016). *Shoal Bay Waste Disposal Site, Conceptual Site Model*, Report prepared by URS Australia Pty Ltd for John Holland Pty Ltd, February 2016.

Water and Carbon Group Pty Ltd (WCG) (2020). *Shoal Bay Waste Management Facility Environmental Management Plan Leachate Treatment and Irrigation.* Prepared by WCG for City of Darwin, July 2020.

APPENDIX A CITY OF DARWIN ENVIRONMENTAL POLICY

ENVIRONMENT

1 PURPOSE

This policy addresses environmental matters associated with Council operations including energy, waste and water management and will allow council to understand, manage and where possible eliminate environmental risks.

City of Darwin is committed to implementing best practice and advocating for improved sustainability and the protection of our environment. Council values biodiversity and the natural environment as important parts of the city. Council will strive to continually improve on its environmental performance and to foster a culture of environmental awareness and sustainability among its staff and the community.

2 SCOPE

Through the implementation of this policy, Council aims to be a leader and champion of sustainability and environmental best practice.

City of Darwin has a commitment to reducing energy and water consumption, improving resource recovery and enhancing the Darwin environment.

The Darwin community will be well informed of Council initiatives and strategies that protect the environment and will be engaged to understand and implement environmental strategies in their own lives.

Council will resource the implementation of this policy and monitor its environmental performance.

3 POLICY STATEMENT

The City of Darwin will encourage a culture of environmental responsibility at work and in the community and promote sustainable practices such as waste minimisation, and sustainable transport.

To lead and advocate for environmental sustainability, the City of Darwin will:

- Comply with and where possible, exceed the requirements of relevant legislation, regulation, policy and standards to continually improve its environmental performance.
- Work with the Darwin community to enhance the city's environmental sustainability, while respecting cultural, social and economic values.
- Enhance and protect Darwin's urban forest and local natural ecosystems.
- Regularly assess and audit its environmental performance and the effectiveness of its environmental management systems.

A COOL, CLEAN AND GREEN CITY

CITY FOR PEOPLE. CITY OF COLOUR.

- Improve its environmental performance through setting measurable targets and key performance indicators.
- Ensure its employees, suppliers and contractors are aware of and able to respond to their environmental responsibilities.
- Reduce resource consumption, including energy and water use.
- Consider environmental and social sustainability in all procurement.
- Recognise interconnections between people, livelihoods, lifestyle, economy and the natural environment, and ensure this approach is included in management planning and project delivery.
- Use an evidence-based approach to managing the environment and adapt appropriately as new information arises regarding environmental matters.
- Apply the precautionary approach to environmental decision making where there is uncertainty, to avoid or minimise harm.
- Working in partnership with government, organisations and the community to promote the ecological, social and economic sustainability of the city.
- Will empower individuals and groups to take an active role in managing their environmental sustainability.

4 DEFINITIONS

Sustainability - Meeting current needs of a population by responsibly utilising resources (economic, social and environmental) without jeopardizing the ability for future generations to meet their needs.

5 LEGISLATIVE REFERENCES

Northern Territory Environmental Protection Act 2019

Environment Protection Regulations 2020

Northern Territory Water Act 1992

Weeds Management Act 001

Environment Protection (Beverage Containers and Plastic Bags) Act

Environmental Assessment Act 2011

Environmental Offences and Penalties Act 1996

Waste Management and Pollution Control Act 1998

Environment Protection and Biodiversity Conservation Act 1999

National Environment Protection Measures (Implementation) Act 1998

A COOL, CLEAN AND GREEN CITY

CITY FOR PEOPLE. CITY OF COLOUR.

6 PROCEDURES / RELATED DOCUMENTS

Policy No. 059 - Climate Change
Policy No. 054 - Waste Management
Policy No. 068 - Green Fleet
Policy No. 077 - Green Information Technology
Procedure No. 009 - Domestic Waste Reporting

7 RESPONSIBILITY / APPLICATION

Each employee will be responsible for implementing relevant actions related to this policy in their own work area. Support is available through the Engineering and City Services.

On-going evaluation of environmental performance will be part of the Environmental Management System audit processes and annual reporting coordinated through the Engineering and City Services Climate Change & Environment team.

A COOL, CLEAN AND GREEN CITY
CITY FOR PEOPLE. CITY OF COLOUR.

APPENDIX B WATER QUALITY MONITORING PLAN

Water Quality Monitoring Plan

Shoal Bay Waste Management Facility

City of Darwin



www.ecoz.com.au

DOCUMENT CONTROL RECORD

Job	EZ22109
Document ID	217509-20
Author(s)	Jack Dymalla, Paula Martinez

DOCUMENT HISTORY

Rev	Reviewed by	Approved by	Issued to	Date
1	Emma Lewis	Emma Lewis	City of Darwin	11/08/2020
2	Emma Lewis	Emma Lewis	City of Darwin	11/08/2022
3	City of Darwin	City of Darwin	City of Darwin	11/01/2023
4	Adele Faraone	Pema Dorji (City of Darwin)	City of Darwin	17/07/2023

Recipients are responsible for eliminating all superseded documents in their possession.

EcOz Pty Ltd.
ABN: 81 143 989 039
Level 1, 70 Cavenagh Street
DARWIN NT 0800
GPO Box 381, Darwin NT 0800

Telephone: +61 8 8981 1100
Email: ecoz@ecoz.com.au
Internet: www.ecoz.com.au

RELIANCE, USES and LIMITATIONS

This report is copyright and is to be used only for its intended purpose by the intended recipient, and is not to be copied or used in any other way. The report may be relied upon for its intended purpose within the limits of the following disclaimer.

This study, report and analyses have been based on the information available to EcOz Environmental Consultants at the time of preparation. EcOz Environmental Consultants accepts responsibility for the report and its conclusions to the extent that the information was sufficient and accurate at the time of preparation. EcOz Environmental Consultants does not take responsibility for errors and omissions due to incorrect information or information not available to EcOz Environmental Consultants at the time of preparation of the study, report or analyses.

TABLE OF CONTENTS

1 INTRODUCTION 1

1.1 Scope 1

1.2 Amendments 1

2 MONITORING PROGRAM 2

2.1 Monitoring Objectives 2

2.2 Monitoring Sites 2

2.2.1 Groundwater Monitoring Bores 2

2.2.2 -Leachate Sites 2

2.2.3 Offsite surface and groundwater monitoring sites 2

2.3 Analytes and Frequency of Sampling 9

3 SAMPLING METHODOLOGY 11

3.1 Groundwater sampling 11

3.2 Surface water and leachate sampling 11

3.3 Quality Assurance / Quality Control 12

4 REPORTING 13

4.1 Exceedance Notification 13

4.2 Annual Reporting 13

5 REFERENCES 14

Tables

Table 2-1 Groundwater monitoring bore details. 5

Table 2-2. Leachate monitoring sites and offsite monitoring site details. 7

Table 2-3. Monitoring program sampling frequency and analytes for groundwater 9

Table 2-4. Monitoring program sampling frequency and analytes for offsite monitoring sites 9

Table 2-5. Monitoring program sampling frequency and analytes for leachate 10

Table 2-6. Monitoring program sampling frequency and analytes for the lined treated leachate wetland 10

Figures

Figure 2-1. Map of SBWMF layout and monitoring site locations 3

Figure 2-2. Offsite monitoring stations 4

ACRONYMS AND ABBREVIATIONS

BTEXN	benzene, toluene, ethylbenzene, xylene, naphthalene
CoD	City of Darwin
COD	chemical oxygen demand
DO	dissolved oxygen
EC	electrical conductivity
EcOz	EcOz Environmental Consultants
EPA	Environment Protection Authority
EPL	Environment Protection License
LTP	leachate treatment plant
mBTOC	metres below top of casing
mBGL	metres below ground level
NH_4	ammonium ion
NH_3	ammonia ion
NO_2	nitrite
NO_3	nitrate
NO_x	nitrate NO_3 + nitrite NO_2
NT	Northern Territory
PFAS	per and poly-fluoroalkyl substances
SBWMF	Shoal Bay Waste Management Facility
SWL	standing water level
TDS	total dissolved solids
TN	total nitrogen
TP	total phosphorus
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TRH	total recoverable hydrocarbons NEMP 2013 fractions
WQMP	Water Quality Monitoring Plan

1 INTRODUCTION

EcOz Environmental Consultants (EcOz) was engaged by City of Darwin (CoD) to develop a Water Quality Monitoring Plan (WQMP) for the Shoal Bay Waste Management Facility (SBWMF) as required by the Northern Territory (NT) Environment Protection Authority (EPA), 2013. *Guidelines for the Sitting, Design and Management of Solid Waste Disposal Sites in the Northern Territory*, and pursuant to Environment Protection Licence (EPL) EPL188-03 issued by the NT EPA.

CoD operate the SBWMF located 13 km north-east of Darwin City within Lot 3952, Town of Sanderson, in the suburb of Holmes. This facility is the main municipal waste resource recovery and disposal site servicing domestic and commercial customers in the Darwin area.

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 800 m to the south-west with a bushland buffer in between.

Water quality monitoring is undertaken on a regular basis at the SBWMF, to detect if contaminants from the landfills, or associated operations, are present in groundwater and/or surface water.

1.1 Scope

This WQMP includes:

- Monitoring objectives
- Details of monitoring sites
- List of analytes
- Frequency of sampling
- Sampling methodology
- Quality assurance/Quality Control requirements
- Analysis and reporting requirements

1.2 Amendments

This WQMP has been prepared as an update to the previous Shoal Bay Water Monitoring Plan (URS 2016). Changes to this WQMP as compared to the URS 2016 plan comprise;

- Amended site information to reflect current site conditions
- Amended monitoring sites to remove old sites and add new sites
- Updated monitoring map
- Revised monitoring parameters and frequency as per recommendations in the EcOz historic data review (EcOz 2020).
- Amended surface water, leachate, and groundwater monitoring sites to reflect current site conditions and requirements of EPL188-03. This includes sites relevant to the recently completed leachate treatment plant (LTP) and planned Leachate Storage Pond 3.

2 MONITORING PROGRAM

2.1 Monitoring Objectives

In accordance with the NT EPA Guidelines this WQMP has the following objectives;

- To monitor leachate production and composition
- To determine the effects on the environment due to landfill on groundwater and surface water.
- To check compliance with regulatory requirements
- To identify the need for remedial/mitigation measures

To achieve these objectives, this WQMP incorporates water quality monitoring for groundwater, surface water and leachate.

2.2 Monitoring Sites

Monitoring sites include 44 groundwater bores, 11 surface water sites and 12 leachate sites. Figure 2-1 shows monitoring site locations.

2.2.1 Groundwater Monitoring Bores

The 44 groundwater monitoring bores are detailed in Table 2-1. This bore network aims to allow detection of landfill leachate, or other contaminants, migrating from the site in groundwater to areas down-gradient. Groundwater monitoring bores surround the entire site; both up-gradient (south) and down-gradient (west, north, and east). There are also some bores centrally located within the site. Most bore locations include a shallow bore, screened between 1.5 and 3 m below ground level (mBGL), and a deeper bore, screened between 9 and 12 mBGL. Some sites also include a deep bore up to 30 m deep.

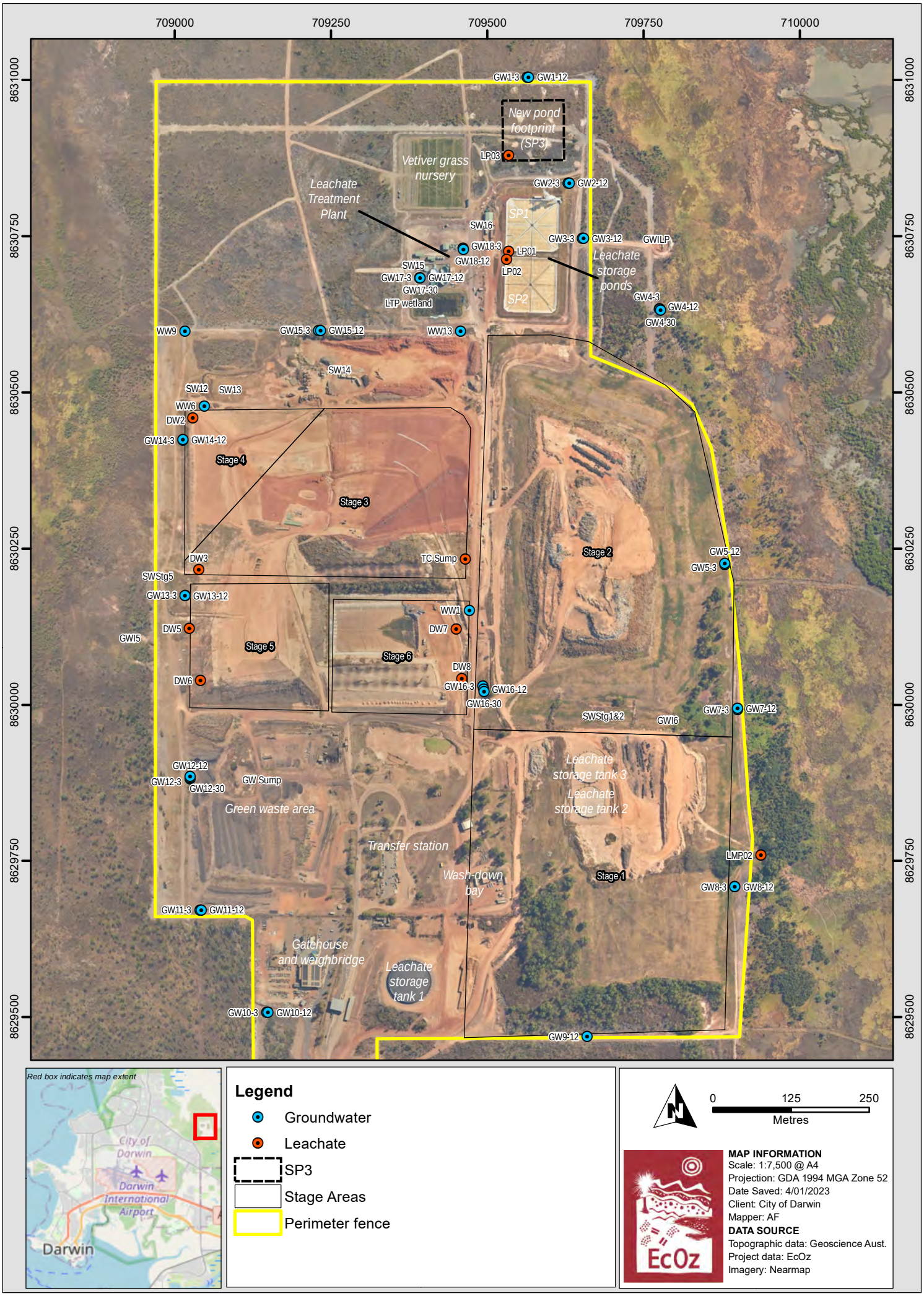
2.2.2 Table 2-2Leachate Sites

Leachate sampling aims to allow the characterisation of contaminant concentrations in leachate for comparison with groundwater and surface water results. Leachate monitoring site details are provided in Table 2-2.

Sampling of the treated leachate in the LTP lined wetland is also undertaken.

2.2.3 Offsite surface and groundwater monitoring sites

As part of the s48 Audit monthly offsite surface water monitoring commenced since April 2023 to continue for 12 months. The offsite ground water monitoring stations will be finalised during the hydrogeological assessment for the site, which will be conducted as part of the s48 Audit. This assessment will also provide an input in determining suitable surface water monitoring sites for SBWMF. The tentative details of the offsite surface water and groundwater monitoring sites are provided in Table 22.



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

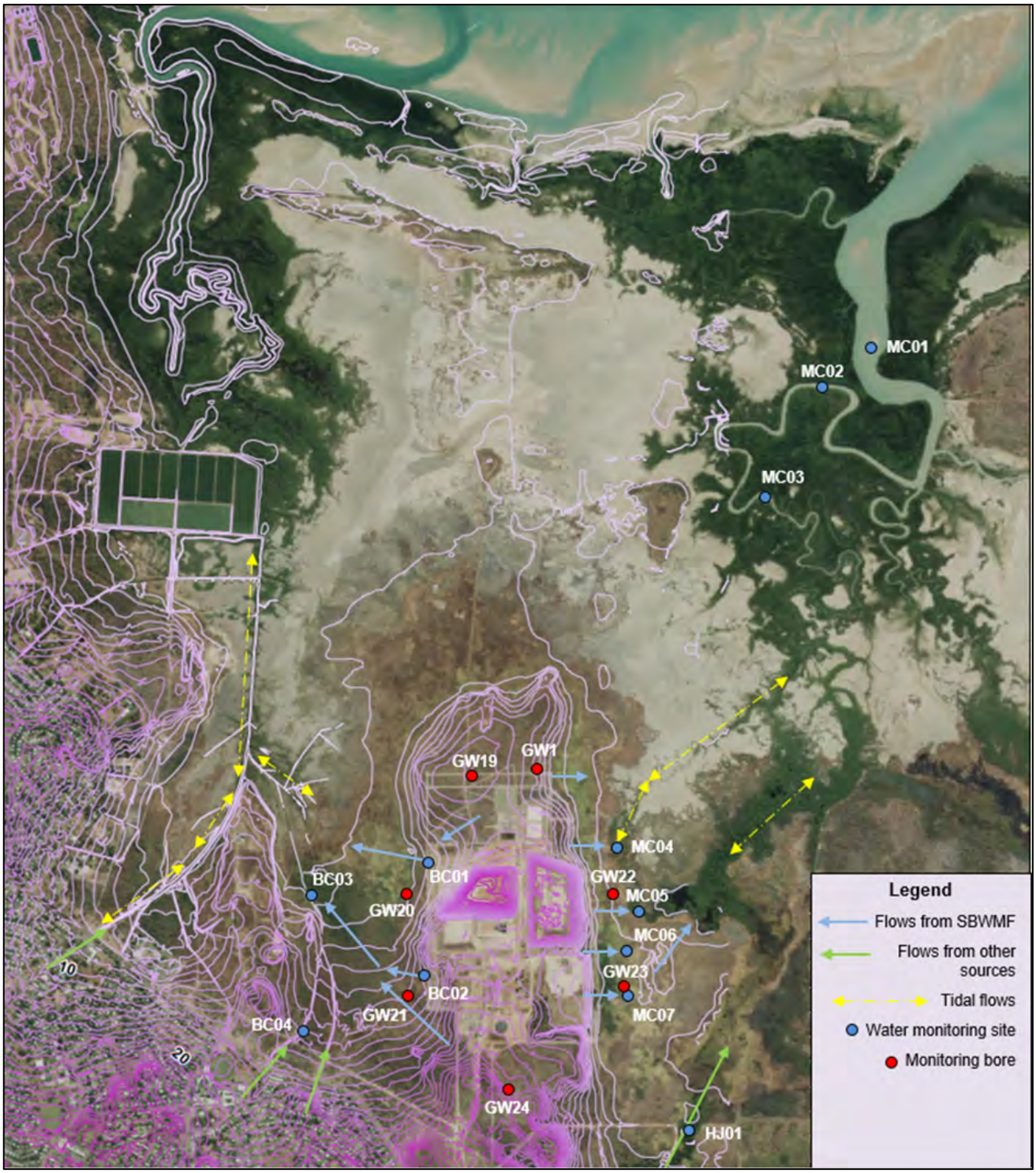


Figure 2-2. Offsite monitoring stations

Table 2-1 Groundwater monitoring bore details.

Bore ID	Easting	Northing	Location	TOC[3] outer elevation mAHD	TOC[2] elevation mAHD	Ground elevation mAHD	Screened interval mBGL	Screened lithology
GW1-3	709564	8631004	On floodplain, 190 m north of leachate storage area	8.71	8.63	8.02	1.5-3	Siltstone
GW1-12	709566	8631004		8.71	8.59	8.00	9-12	Siltstone
GW2-3	709629	8630835	On north-east corner of leachate storage area	8.06	7.94	7.33	1.5-3	Siltstone
GW2-12	709631	8630835		8.08	7.94	7.28	9-12	Siltstone
GW3-3	709652	8630746	East of leachate storage area	9.94	9.80	9.12	1.5-3	Siltstone
GW3-12	709654	8630746		9.87	9.82	9.10	9-12	Siltstone
GW4-3	709775	8630634	On floodplain, north of Stage 2 landfill	5.65	5.49	4.88	1.5-3	Siltstone
GW4-12	709776	8630633		5.61	5.44	5.36	9-12	Siltstone
GW4-30	709777	8630631		5.50	5.20	5.33	15-21	Gravelly sand, Sandstone
GW5-3	709880	8630224	East of Stage 2 landfill	5.51	5.41	4.70	1.5-3	Siltstone
GW5-12	709880	8630226		5.48	5.33	4.70	9-12	Siltstone, Gravelly Clay
GW6-3	709464	8630022	Decommissioned when Stage 6 was constructed	N/A	N/A	N/A	N/A	Gravelly Sandy Silt, Siltstone
GW6-12	709464	8630021		N/A	N/A	N/A	N/A	Siltstone
GW6-30	709464	8630018		N/A	N/A	N/A	N/A	Siltstone, Sandstone
GW7-3	709900	8629992	South-east of Stage 2 and north-east of Stage 1	5.18	5.03	4.33	1.5-3	Siltstone
GW7-12	709900	8629994		5.16	5.08	4.33	9-12	Siltstone, Sandy Silt
GW8-3	709896	8629708	East of Stage 1	5.42	5.28	4.65	1.5-3	Claystone
GW8-12	709896	8629708		5.37	5.22	4.62	9.1-12.1	Claystone, Sandstone
GW9-12	709660	8629469	On southern boundary of SBWMF – up-gradient of all SBWMF operations and infrastructure	16.18	15.93	15.44	9-12	Siltstone
GW10-3	709147	8629507	South of SBWMF – up-gradient of all SBWMF operations and infrastructure	18.12	18.06	17.32	1.5-3	Siltstone
GW10-12	709149	8629507		18.13	17.98	17.37	9.1-12.1	Siltstone
GW11-3	709040	8629671	South-west corner of SBWMF	13.50	13.38	12.72	1.5-3	Siltstone
GW11-12	709042	8629671		13.52	13.38	12.84	9-12	Siltstone, Sandstone
GW12-3	709024	8629881	West of green waste area	12.20	12.07	11.44	1.5-3	Siltstone
GW12-12	709024	8629883		12.22	12.04	11.50	9-12	Siltstone
GW12-30	709024	8629885		12.21	12.05	11.55	24-30	Sandstone
GW13-3	709017	8630175	On south-west corner of Stage 3/4 and north-west corner of Stage 5 landfills	12.93	12.88	12.32	3-4.5	Siltstone
GW13-12	709016	8630174		12.91	12.86	12.25	10-13.5	Siltstone
GW14-3	709013	8630423	West of Stage 4 landfill	6.78	6.73	6.09	1.5-3	Siltstone
GW14-12	709013	8630424		6.77	6.64	6.08	9-12	Siltstone
GW15-3	709230	8630599	North of Stage 3/4 landfill	11.27	11.06	10.44	1.5-3	Siltstone
GW15-12	709233	8630599		11.20	11.04	10.44	9-12	Siltstone
GW16-3	709493	8630030	East of Stage 5/6	14.50	14.55	13.57	1.5-3	Sandy Claystone
GW16-12	709494	8630025	East of Stage 5/6	14.57	14.61	13.65	9-12	Siltstone

Bore ID	Easting	Northing	Location	TOC[3] outer elevation mAHD	TOC[2] elevation mAHD	Ground elevation mAHD	Screened interval mBGL	Screened lithology
GW16-30	709495	8630021	East of Stage 5/6	14.53	14.56	13.2	20-26	Siltstone
GW17-3	709386	8630672	Within the proposed treatment area	11.80	11.83	TBC	0.5-4	Siltstone
GW17-12	709384	8630672	Within the proposed treatment area	11.86	11.80	TBC	8-11	Sandy clay loam
GW17-30	709381	8630672	Within the proposed treatment area	11.90	11.88	TBC	27-30	Fine loamy sand
GW18-3	709464	8630729	Within the proposed treatment area	11.50	11.51	TBC	TBC	TBC
GW18-12	709464	8630728	Within the proposed treatment area	TBC	10.72	TBC	8-12	Sandy clay loam
WW1	709471	8630151	Between Stage 3 and Stage 2 landfills	-	16.60	15.90	0-6.3	-
WW6	709047	8630478	North-west corner of Stage 3/4 landfill	-	7.46	6.76	0-20.4	-
WW9	709016	8630598	North-west corner of SBWMF	-	7.09	6.39	1-9.8	Siltstone
WW13	709457	8630598	On northern boundary of SBWMF	+0.8	+0.7	Not available	1-10	Siltstone

TBC – To be confirmed

Table 2-2. Leachate monitoring sites and offsite monitoring site details.

Site ID	Easting	Northing	Location	Context
Leachate Sites				
DW2	709029	8630459	Deleaching well on southwest corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells
DW3	709038	8630216	Deleaching well on northwest corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells
DW5	709023	8630122	Deleaching well on west side of Stage 5 landfill	Represents leachate from Stage 5 landfill cell
DW6	709041	8630039	Deleaching well on southwest corner of Stage 5 landfill	Represents leachate from Stage 5 landfill cell
DW7	709450	8630121	Deleaching well on east side of Stage 6 landfill	Represents leachate from Stage 6 landfill cell
DW8	709459	8630042	Deleaching well on east side of Stage 6 landfill	Represents leachate from Stage 6 landfill cell
TC Sump	709465	8630233	Sump on southeast corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells
LMP02	709938	8629759	East of Stage 1	Sump that receives leachate from Stage 1 and 2 landfills via an interception trench that runs north-south along the eastern edge of the Stage 1 and 2 landfills.
LP01	709534	8630726	Northern leachate storage pond	Represents leachate in northern storage pond
LP02	709531	8630713	Southern leachate storage pond	Represents leachate in southern storage pond
LP03	TBC	TBC	Pond 3	Represents leachate in pond 3
Treated Leachate Wetland Sites				
LTP wetland	TBC	TBC	Treated leachate wetland (irrigation pump station)	Represents treated leachate water quality prior to irrigation
Offsite Surface Water and Groundwater Sites				
MC01	TBC	TBC	Mickett Creek downstream near creek mouth	Represents water and sediment quality in tidal zone of Mickett Creek at increasing distance from contamination source ie. To determine any concentration gradients
MC02	TBC	TBC	Mickett Creek halfway between MC01 and MC03	Represents water and sediment quality in tidal zone of Mickett Creek at increasing distance from contamination source ie. To determine any concentration gradients
MC03	TBC	TBC	Mickett Creek as far upstream as accessible by boat	Represents water and sediment quality in tidal zone of Mickett Creek at increasing distance from contamination source i.e. To determine any concentration gradients
MC04	TBC	TBC	Downstream of leachate ponds and north side Stage 2 landfill cell	Represents water and sediment quality in receiving waters immediately offsite and downstream of this infrastructure
MC05	TBC	TBC	In unlined stormwater drain downstream of Stage 2 landfill cell	Represents water and sediment quality in receiving waters immediately offsite and downstream of this infrastructure
MC06	TBC	TBC	Downstream of Stage 1 & Stage 2 landfill cells	Represents water and sediment quality in receiving waters immediately offisite and downstream of this infrastructure
MC07	TBC	TBC	Downstream of Stage 1 and 2 landfill cell	Represents water and sediment quality in receiving waters immediately offisite and downstream of this infrastructure
MC08	TBC	TBC	Downstream of Stage 1	Represents water and sediment quality in receiving waters immediately offisite and downstream of this infrastructure
HJ01	TBC	TBC	Creek that drains Holmes Jungle Reserve	Upstream reference site for comparing with downstream sites
BC01	TBC	TBC	Downstream of Stage 3/4 landfill cells and LTP	Represents water and sediment quality in receiving waters immediately offsite and downstream of this infrastructure
BC02	TBC	TBC	Downstream of green waste area and Stage 5 landfill cell	Represents water and sediment quality in receiving waters immediately offsite and downstream of this infrastructure

Site ID	Easting	Northing	Location	Context
BC03	TBC	TBC	Further downstream of green waste, Stage 5 landfill cell	Represents water and sediment quality in receiving waters immediately offsite and downstream of this infrastructure
BC04	TBC	TBC	Stormwater drain that receives runoff from urban areas	Represents water and sediment quality in receiving waters immediately offsite and downstream of this infrastructure
GW19-3	TBC	TBC	North of site	To detect any groundwater impacts migrating to the north
GW19-12	TBC	TBC	North of site	To detect any groundwater impacts migrating to the north
GW20-3	TBC	TBC	West of site	To detect any groundwater impacts migrating to the west of site
GW20-12	TBC	TBC	West of site	To detect any groundwater impacts migrating to the west of site
GW21-3	TBC	TBC	West of site	To detect any groundwater impacts migrating west of site
GW21-12	TBC	TBC	West of site	To detect any groundwater impacts migrating west of site
GW22-3	TBC	TBC	East of site	To detect any groundwater impacts migrating east of site
GW22-12	TBC	TBC	East of site	To detect any groundwater impacts migrating east of site
GW23-3	TBC	TBC	East of site	To detect any groundwater impacts migrating east of site
GW23-12	TBC	TBC	East of site	To detect any groundwater impacts migrating east of site
GW24-3	TBC	TBC	South of site	Upgradient bore for establishing background groundwater quality
GW24-3	TBC	TBC	South of site	Upgradient bore for establishing background groundwater quality
GW24-3	TBC	TBC	South of site	Upgradient bore for establishing background groundwater quality

2.3 Analytes and Frequency of Sampling

The frequency of sampling in the Wet season and the Dry season are outlined in Table 2-3 to Table 2-6, along with details of the standard suite of analytes used across all sites.

Table 2-3. Monitoring program sampling frequency and analytes for groundwater

Analytes	Frequency (all monitoring bores)
Flow	M
Standing water level (SWL)	M
Field measurements (pH, EC, DO, temperature, REDOX) **Dissolved metals** (only boron, chromium, copper, lead, nickel, zinc) **Major ions** (CO_3, HCO_3, Ca, Mg, K, Na, Cl, SO_4) **Nutrients** (NH_3 as N, NO_3, NO_2, NO_X, TN, TP and FRP) **Other** (TOC, COD, TDS)	Q
Dissolved metals (only arsenic, cadmium, cobalt, lithium, vanadium) **Hydrocarbons** (TRH, BTEXN) **PFAS** (PFOS, PFOA) **Other** (organophosphate pesticides, organochlorine pesticides, polychlorinated biphenyls, tributyltin oxide, phenols, *E. Coli*, enterococci)	A

M – Monthly, Q-Quarterly (January, April, July and October), A-Annually

Table 2-4. Monitoring program sampling frequency and analytes for offsite monitoring sites

Analytes	Frequency												
	MC01	MC02	MC02	MC02	MC02	MC02	MC02	MC02	HJ01	BC01	BC02	BC03	BC04
Flow	-	-	-	-	-	-	-	-	-	-	-	-	-
Water level	M	M	M	M	M	M	M	M	M	M	M	M	M
Field measurements (flow, water level, pH, EC, DO, temperature, turbidity)	M	M	M	M	M	M	M	M	M	M	M	M	M
Dissolved and total metals/metalloids (only boron, chromium, copper, lead, nickel, zinc) **Other** (TOC, COD, TSS, TDS) **Major ions** (CO_3, HCO_3, Ca, Mg, K, Na, Cl, SO_4) **Nutrients** (NH_3 as N, NO_3, NO_2, NO_X, TN, TP and FRP)	M[2]	M[2]	M[2]	M[2]	M[2]	M[2]	M[2]	M[2]	M[2]	M[2]	M[2]	M[2]	M[2]
Dissolved and total (cadmium, cobalt) **Hydrocarbons** (TRH, BTEXN) **PFAS** (PFOS, PFOA)	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]

M – Monthly, C- Continuous, Q-Quarterly (January, April, July and October), A-Annually
[1]Using a flow meter
[2]Only between October to April

Table 2-5. Monitoring program sampling frequency and analytes for leachate

Analytes	Frequency										
	LP01	LP02	LP03	DW2	DW3	DW5	DW6	DW7	DW8	TC Sump	LMP02
Flow	-	-	-		C[1]	C[1]	C[1]	C[1]	C[1]	C[1]	C[1]
Water level	M	M	M	M	M	M	M	M	M	M	M
Field measurements (flow, water level, pH, EC, DO, temperature, turbidity) **Dissolved and total metals/metalloids** (aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, nickel, selenium, vanadium, zinc) **Major ions** (CO_3, HCO_3, Ca, Mg, K, Na, Cl, SO_4) **Nutrients** (NH_3, NH_4, NO_3, NO_2, NO_X, TN, TP and FRP) **Hydrocarbons** (TRH, BTEXN) **PFAS** (PFOS, PFOA) **Other** (TOC, COD, TSS, TDS)	Q	Q	Q	B	B	B	B	B	B	B	B
Other (organophosphate pesticides, organochlorine pesticides, polychlorinated biphenyls, tributyltin oxide, phenols, *E. Coli*, enterococci)	A	A	A	-	-	-	-	-	-	-	-

M – Monthly, C- Continuous, Q-Quarterly (January, April, July and October), A-Annually
[1]Using a flow meter
[2]Only between October to April

Table 2-6. Monitoring program sampling frequency and analytes for the lined treated leachate wetland

Analytes	Frequency
	LTP wetland
Dissolved and total metals/metalloids (aluminium, arsenic, beryllium, boron, cadmium, chromium, cobalt, copper, fluoride, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, uranium, vanadium, zinc) **Other** (E.coli, electrical conductivity) **PFAS** (PFOS, PFOA) **Nutrients** (total nitrogen, total phosphorous, NH_3 as N, NO_3, NO_2, NO_X, TN, TP and FRP)	Q

Q-Quarterly (January, April, July and October)

3 SAMPLING METHODOLOGY

All sampling will comply with the Australian/New Zealand Standard on Water Quality Sampling - Part 1: *Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples* (AS/NZS 5667.1:1998).

Samples will be immediately chilled in eskies with ice bricks and delivered to a National Association of Testing Authorities (NATA) accredited laboratory each day.

3.1 Groundwater sampling

Groundwater sampling methods will comply with the Australian/New Zealand Standard on Water Quality Sampling – Part 11: *Guidance on sampling of groundwater* (AS/NZS 5667.11:1998). Groundwater sampling involves:

- The measurement of physical parameters (pH, temperature, EC, DO, REDOX) in groundwater using hand-held field water quality meters calibrated immediately prior to mobilisation to site, and
- The collection of groundwater into laboratory-supplied sample bottles for sending to the laboratory for analysis.

Samples will be collected from groundwater bodies using a micropurge/low-flow bladder pump in the first instance, or with manual bailers if groundwater yields are insufficient to allow pumping. The micropurge/low-flow sampling set up is proven for minimal effect on water chemistry and obtaining representative samples (Sundaram 2009). If manual bailing is required, disposable Clear-View PVC bailers will be used; a new bailer for each bore.

In order to gain a representative sample of the surrounding groundwater aquifer quality and not stagnant water contained within the bore, the pump is lowered to within the screened interval, and the rate of pumping matched to the groundwater recharge rate; confirmed by constant monitoring of the standing water level (SWL), which must remain stable. Water quality parameters (pH, temperature, EC, DO, ORP) are constantly monitored in the groundwater as it is pumped from the bore using water quality meters that have been calibrated immediately prior to mobilisation to site. Pumping is continued until readings stabilise i.e. until three consecutive readings of all parameters measured at 5 minute intervals stabilise to within 5% of each other. This usually takes at least 30 minutes of pumping. Low dissolved oxygen (DO) and negative oxidation reduction potential (ORP) are also indicators of fresh groundwater, and not water from within the bore casing which is in contact with the air. Once stable readings are achieved, samples for laboratory analysis are collected directly into laboratory-supplied bottles.

When using manual bailers, a dedicated bailer is used for each bore, and the bore is purged until dry and then sampled once the bore has recharged and SWL has returned to its original level. If recharge in the bore means it doesn't completely empty, then three times volumes worth of standing water in the bore must be removed and the original standing water level allowed to return prior to sampling.

Samples for metals analysis will be field-filtered using a new disposable syringe and filter (0.45 µm) for each sample.

3.2 Surface water and leachate sampling

Surface water and leachate sampling methods will comply with the Australian/New Zealand Standard on Water Quality Sampling - Part 6: *Guidance on sampling of rivers and streams* (AS/NZS 5667.6:1998), Part 4: *Guidance on sampling from lakes, natural and man-made* (AS/NZS 5667.4:1998), and Part 10: *Guidance on sampling of waste waters* (AN/NZS 5667.10:1998).

Surface water and leachate sampling involves:

- The measurement of physical parameters (pH, temperature, EC, DO, turbidity) using hand-held field water quality meters calibrated immediately prior to mobilisation to site, and
- The collection of water into laboratory-supplied sample bottles for sending to the laboratory for analysis.

The specific method of sampling differs depending on the water source. The five different types of water sources and corresponding sampling methods are:

- Surface water bodies, ponds, and drains with safe direct access – will be sampled directly by placing field water quality meters into the water body for physical parameters, and collecting water samples for laboratory analysis directly into the laboratory-supplied sample bottles (note for bottles with preservative, sample will be decanted into the bottle from one of the unpreserved laboratory-supplied bottles to prevent loss of preservative).
- Surface water bodies, ponds, and drains without safe direct access – will be sampled using a clean, decontaminated jug on a pole, and the physical parameters measured immediately from within the jug. The jug on a pole will then be rinsed in the sample water several times prior to collecting sample for decanting into the laboratory-supplied sample containers for lab analysis.
- Sumps without a pump – will be sampled using a clean, decontaminated jug on a pole (as explained above) or a dedicated bailer. When using a bailer, the sample is decanted into a clean, decontaminated jug for measuring physical parameters and the sample poured directly into laboratory-supplied sample containers for laboratory analysis.
- Sumps with a pump – will be sampled by turning the tap on and the sample going into a clean, decontaminated jug for measuring physical parameters and then poured directly from the tap into laboratory-supplied sample containers for laboratory analysis.
- Leachate risers – will be sampled using a submersible pump lowered into the riser with the sample going from the hose into a clean, decontaminated jug for measuring physical parameters and then directly from the hose into laboratory-supplied sample containers for laboratory analysis.

For surface water bodies and sumps sampled either directly or using a sample pole or bailer, samples will be collected approximately 0.3 m below the water surface. When collecting samples from flowing water bodies, the sample must be collected a reasonable distance from the water's edge and facing into the flow direction, keeping hands and sampler equipment downstream to prevent contamination.

Samples for metals analysis (both surface water and leachate) will be field-filtered using a new disposable syringe and filter (0.45 µm) for each sample.

3.3 Quality Assurance / Quality Control

QA/QC samples will comprise:

- Field duplicate samples at 1 per 10 water samples per monitoring event, to identify the variation in analyte concentrations between samples collected from the same location and/or the repeatability of laboratory analysis.
- Field triplicate (split) samples at 1 per 20 water samples per monitoring event, analysed by a second laboratory, to verify the analytical proficiency of the primary laboratory.

Samples will be analysed by a NATA accredited laboratory and laboratory certificates will be NATA endorsed reports. Upon receipt of the laboratory analytical results, the following elements will be assessed to ensure QA/QC of samples;

- Laboratory, field duplicates, and trip blanks
- Laboratory internal standards, calibration blanks, method blanks, matrix spike, duplicate and surrogate spikes etc
- The occurrence of apparent unusual or anomalous results, e.g. laboratory results that appear to be inconsistent with field observations or measurements.

4 REPORTING

The Australian and New Zealand Environment Conservation Council (ANZECC 2000) *Australian and New Zealand Guidelines for Marine and Freshwater Quality* trigger values for protection of 90 % of marine species have been adopted for reference when assessing the sample analytical results.

All electronic and hard copy files will be maintained electronically and/or in hardcopy to enable timely access. This includes all reports, laboratory analysis results, sampling documentation, chain of custody records, cad, GIS or surfer data and associated correspondence.

4.1 Exceedance Notification

The NT EPA will be notified in writing as soon as practicable (and in any case within 24 hrs) after becoming aware, when the guideline specified trigger values are exceeded;

- on three consecutive sampling occasions; or
- at greater than or equal to two times the trigger value; or
- at a median value for six consecutive monitoring results.

This notification should include as a minimum;

- when the exceedance was detected and by whom;
- the date and time of the exceedance;
- the actual and potential causes and contributing factors to the exceedance;
- the risk of environmental harm arising from the exceedance assessed in accordance with relevant standards as listed in the WQMP;
- the action(s) that have or will be undertaken to address the exceedance and/or environmental harm;
- if no action was taken, why no action was taken; and
- a date when an incident investigation report will be submitted to the NT EPA.

4.2 Annual Reporting

A completed Annual Return will be submitted via NT EPA Online within 10 business days after each anniversary date of EPL 188, which relates to the preceding 12 month period.

A completed Monitoring Report will be provided to the NT EPA, as prescribed by EPL 188, within 20 business days after each anniversary date of EPL 188.

This Monitoring Report should;

- be prepared in accordance with the requirements of the NT EPA *'Guideline for Reporting on Environmental Monitoring*';
- include tabulation of all monitoring data required as a condition of EPL 188;
- include long term trend analysis of monitoring data to demonstrate any environmental impact associated with the activity over a minimum period of three years (where the data is available); and
- include an assessment of environmental impact from the activity.

5 REFERENCES

ANZECC & AMRCANZ 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), Canberra.

ANZECC & AMRCANZ 2000, *Australian Guidelines for Water Quality Monitoring and Reporting*, National Water Quality Management Strategy Paper No 7, Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), Canberra.

Australian/New Zealand Standard on Water Quality Sampling - Part 1: *Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples* (AS/NZS 5667.1:1998), Standards Australia, New South Wales.

Australian Standard on Water Quality Sampling - Part 4: *Guidance on sampling from lakes, natural and man-made* (AS/NZS 5667.4:1998), Standards Australia, New South Wales.

Australian/New Zealand Standard on Water Quality Sampling - Part 6: *Guidance on sampling of rivers and streams* (AS/NZS 5667.6:1998), Standards Australia, New South Wales.

Australian Standard on Water Quality Sampling – Part 10: *Guidance on sampling of waste waters* (AN/NZS 5667.10:1998), Standards Australia, New South Wales.

Australian/New Zealand Standard on Water Quality Sampling – Part 11: *Guidance on sampling of groundwater* (AS/NZS 5667.11:1998), Standards Australia, New South Wales.

Cardno (2022). *Annual Monitoring Review – Shoal Bay Waste Management Facility, Soil and Water Monitoring Program*. [online] Available at https://ntepa.nt.gov.au/__data/assets/pdf_file/0013/1124050/epl188-monitoring-report-2022.pdf [Accessed 04 August 2022]

EcOz 2020, *Shoal Bay Waste Management Facility Water quality monitoring data review 2016 – 2020*, Report prepared for City of Darwin by EcOz Environmental Consultants, August 2020, Darwin

NT EPA 2021, *Environment Protection Licence EPL188-03*, Issued 2 July 2021, Expires 1 July 2026, Northern Territory Environment Protection Authority (NT EPA), Darwin, NT.

NT EPA 2013, *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites in the Northern Territory*, Northern Territory Environment Protection Authority (NT EPA), Darwin, NT.

Sundaram, B., Feitz, A., Caritat, P. de, Plazinska, A., Brodie, R., Coram, J. and Ransley, T., 2009. *Groundwater Sampling and Analysis – A Field Guide*. Geoscience Australia, Record 2009/27 95 pp.

Work Health and Safety (National Uniform Legislation) Act, and Work Health and Safety (National Uniform Legislation) Regulations, NT Government.

URS 2016, *Shoal Bay Waste Disposal Site Water Monitoring Plan*, March 2016, Report prepared for John Holland Pty Ltd, URS Australia, Darwin, NT.

EcOz Environmental Consultants

EcOz Pty Ltd.
ABN 81 143 989 039

Level 1, 70 Cavenagh St,
GPO Box 381,
Darwin, NT 0801

T: +61 8 8981 1100
E: ecoz@ecoz.com.au

www.ecoz.com.au

APPROVED COMPANY ISO 14001 Environmental Management Systems
QMS Certification Services

APPROVED COMPANY AS/NZS 4801 Occupational Health & Safety Management Systems
QMS Certification Services

APPROVED COMPANY ISO 9001 Quality Management Systems
QMS Certification Services

APPENDIX C LANDFILL GAS MONITORING PLAN

Landfill Gas Monitoring Plan

Shoal Bay Waste Management Facility

City of Darwin



www.ecoz.com.au

DOCUMENT CONTROL RECORD

Job	EZ21181
Document ID	206427
Author(s)	Paula Martinez, Emma Smith

DOCUMENT HISTORY

Rev	Reviewed by	Date
1	Andrew Balch - Director at Air Environment, Certified Air Quality Professional	9/11/2021

Rev	Approved by	Issued to	Date
1	Emma Smith	City of Darwin	9/11/2021
2	Emma Smith after Andrew Balch and City of Darwin review	City of Darwin	15/11/2021

Recipients are responsible for eliminating all superseded documents in their possession.

EcOz Pty Ltd.
ABN: 81 143 989 039
Level 1, 70 Cavenagh Street
DARWIN NT 0800
GPO Box 381, Darwin NT 0800

Telephone: +61 8 8981 1100
Email: ecoz@ecoz.com.au
Internet: www.ecoz.com.au

RELIANCE, USES and LIMITATIONS

This report is copyright and is to be used only for its intended purpose by the intended recipient, and is not to be copied or used in any other way. The report may be relied upon for its intended purpose within the limits of the following disclaimer.

This study, report and analyses have been based on the information available to EcOz Environmental Consultants at the time of preparation. EcOz Environmental Consultants accepts responsibility for the report and its conclusions to the extent that the information was sufficient and accurate at the time of preparation. EcOz Environmental Consultants does not take responsibility for errors and omissions due to incorrect information or information not available to EcOz Environmental Consultants at the time of preparation of the study, report or analyses.

TABLE OF CONTENTS

1 INTRODUCTION 1

1.1 Purpose 1

1.2 Scope 3

1.3 Review 3

2 ABOUT LANDFILL GAS 4

3 SBWMF OPERATIONS OVERVIEW 5

3.1 Land tenue and location 5

3.2 Infrastructure and layout 5

3.3 Landfilling method 5

3.4 Site development 10

3.5 Landfill gas extraction system 14

3.6 Other landfill gas control measures 14

3.7 Leachate collection and treatment system 14

3.8 Underground services 15

4 ENVIRONMENTAL SETTING 17

4.1 Surrounding land-use 17

4.2 Climate 17

4.2.1 Temperature and rainfall 17

4.2.2 Atmospheric pressure 18

4.2.3 Wind direction and strength 18

4.3 Hydrogeology 20

4.4 Surface water 20

5 CONCEPTUAL SITE MODEL 21

5.1 Contaminants of concern 21

5.2 Sources 21

5.3 Migration pathways 21

5.4 Potential receptors 21

5.5 Preliminary risk assessment 22

6 LANDFILL GAS MONITORING PROGRAM 23

6.1 Design rationale 23

6.2 Monitoring frequency, methods, and sites 23

6.2.1 Surface transects 24

6.2.2 Subsurface monitoring 25

6.2.3 Buildings and subsurface pits 26

6.3 Health and safety during monitoring 29

7 ASSESSMENT CRITERIA 30

7.1 Assessment criteria and notification 30

8 RECORD-KEEPING AND REPORTING 31
8.1 Database 31
8.2 Reporting 31
8.3 Monitoring review 31
9 REFERENCES 32
Monitoring Instruments 34
Monitoring Procedures 34

Tables

Table 3-1. SBWMF facilities 6
Table 3-2. Summary of landfill stage lifespans 10
Table 3-3. Summary of future development precincts 10
Table 4-1. Land uses surrounding the SBWMF 17
Table 4-2. Darwin Airport wet season wind rose 19
Table 4-3. Darwin Airport dry season wind rose 19
Table 6-1. Number of transects required across each landfill stage based on estimated landfill area 24
Table 6-2. Details of subsurface, building and pit monitoring locations 25
Table 7-1. Landfill gas assessment criteria 30

Figures

Figure 1-1. Map of SBWMF location 2
Figure 3-1. Map of SBWMF operational area and uncleared UXO area 8
Figure 3-2. SBWMF site layout 9
Figure 3-3. Landfill cell staging 12
Figure 3-4. Future development precincts 13
Figure 3-5. Map of main underground services present at the SBWMF 16
Figure 4-1. Graph of mean temperature and rainfall at Darwin Airport (Station no. 014015) 18
Figure 6-1. Map of surface transects 27
Figure 6-2. Map of monitoring wells, buildings and subsurface monitoring sites 28

Appendices

Appendix A Groundwater levels and flows taken from EcOz 2020
Appendix B Monitoring Proceedures
Appendix C Landfill gas subsurface monitoring data sheet
Appendix D Independent Expert Review

ACRONYMS AND ABBREVIATIONS

BOM	Bureau of Meteorology
CH_4	methane
CO_2	carbon dioxide
CoD	City of Darwin
CSM	conceptual site model
EMP	Environmental Management Plan
EPL	Environment Protection Licence
LGMP	Landfill Gas Monitoring Plan
mAHD	metres Australian Height Datum
mBGL	metres below ground level
NT	Northern Territory
NT EPA	Northern Territory Environment Protection Authority
SBWMF	Shoal Bay Waste Management Facility
SWL	standing water level
UXO	unexploded ordinance

1 INTRODUCTION

The City of Darwin (CoD), Shoal Bay Waste Management Facility (SBWMF) is a municipal waste resource recovery and disposal site servicing both domestic and commercial customers in the Darwin area. The SBWMF is located 13 km north-east of Darwin City, within Lot 3952, Town of Sanderson, in the suburb of Holmes (see Figure 1-1).

This Landfill Gas Monitoring Plan (LGMP) details the rationale and design of landfill gas monitoring to be undertaken at the SBWMF. The SBWMF currently has an active gas extraction system, which is operated by a private company (LMS Energy). To date, no landfill gas monitoring has been undertaken at the site other than that by LMS Energy of landfill gas collected by their extraction system. This LGMP aims to monitor fugitive landfill gas emissions and migration to inform effective management of on-site and off-site landfill gas-related human health and/or the environmental risks.

Landfill gas management practices adopted at SBWMF are required to:

- Minimise emissions of untreated landfill gas to air and through sub-surface strata and services
- Minimise greenhouse gas emissions (in particular, methane)
- Minimise emissions of offensive odour
- Minimise the explosive risk to humans from gas build-up in confined spaces
- Ensure that, wherever feasible, landfill gas is sustainably utilised for energy recovery
- Minimise emissions of air pollutants from the combustion of landfill gas in flaring or electricity-generating equipment.

The data collected as part of this LGMP, once established, can be used to measure the effectiveness of these measures, and identify where improvements can be made. As monitoring results are obtained, they will also be used to review and update this LGMP on an annual basis at minimum. This may involve adjusting the location of sampling sites, sampling frequency and sampling methods.

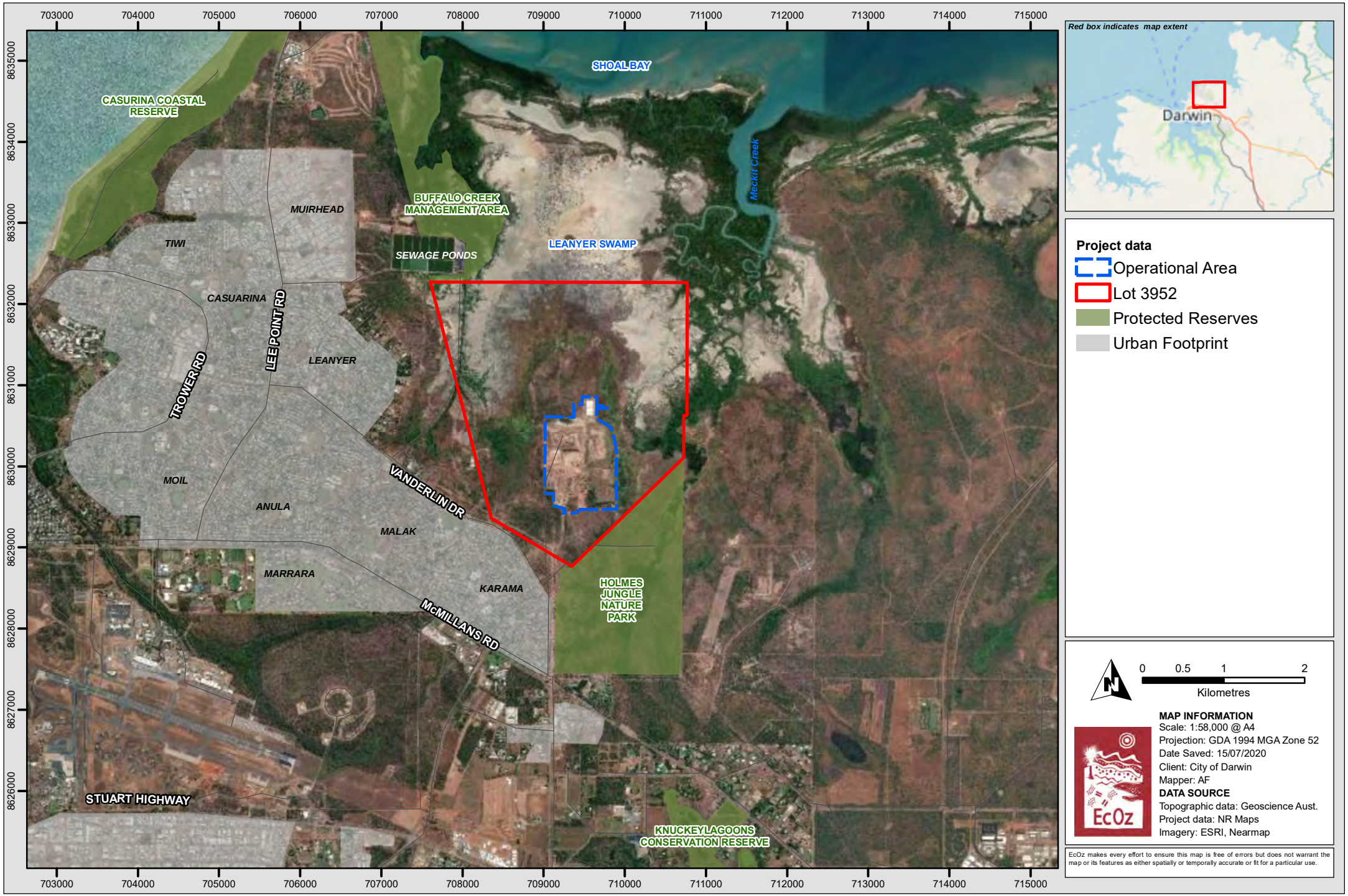
1.1 Purpose

The surface and sub-surface gas monitoring results collected as part of this LGMP will provide information on the effectiveness of the landfill gas extraction system, as well as other control measures implemented by the landfill operators. The results provided by this LGMP aim to inform the:

- Effectiveness of landfill gas control measures and identify any requirements for modification
- Fine-tuning of the gas field to provide optimum gas control
- Identification of migration pathways and the extent of landfill gas migration off-site
- Assessment of risks to potential on-site and off-site human health and/or environmental receptors
- Assessment of fire risk from landfill gas both within and outside landfill cells
- Continued compliance of landfill gas emissions with regulatory requirements

Pursuant to Section 30, Part 2 of Schedule 2 of the *Waste Management and Pollution Control Act*, a landfill servicing the waste disposal requirements of more than 1,000 persons requires an Environment Protection Licence (EPL). CoD hold EPL188, covering the SBWMF, issued by the Northern Territory Environment Protection Authority (NT EPA). This licence also allows for the storage, treatment, recycling, and disposal of 'listed wastes' prescribed under the *Act*; see EPL188 for the specific listed waste types authorised at the SBWMF, as well as the operational, monitoring and reporting requirements CoD must comply with.

This LGMP assists CoD in meeting several EPL188 conditions. It also assists in implementing and assessing the effectiveness of the landfill gas environmental management measures prescribed in the *SBWMF Environmental Management Plan* (EMP).



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Fig 1-1. SBWMF location.mxd

Figure 1-1. Map of SBWMF location

1.2 Scope

This LGMP has been prepared in accordance with the *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites in the Northern Territory* (NT EPA 2013) and the *Landfill gas fugitive emissions monitoring guideline* (EPA Victoria 2018) and includes the following:

- An outline of SBWMF operational aspects that relate to landfill gas generation and potential migration, including details of historic, current, and future-planned landfill cells, the LMS Energy landfill gas extraction system[1], and the location of underground services
- Description of the environmental setting (climate, landform, hydrogeology, surface water flows etc) and surrounding land uses of the SBWMF, that may influence the generation and migration of landfill gas, and also the human health and/or environmental receptors at risk from landfill gas
- Development of a conceptual site model (CSM) that identifies the contaminants of concern, and their potential sources, migration pathways and receptors
- A preliminary risk assessment based on the CSM
- Monitoring plan outlining the sampling sites, sampling frequency, analytical parameters, and sampling methods – informed by the CSM, risk assessment and EPA Victoria (2018) methods
- Outline of required data recording and record-keeping, data analysis, assessment criteria and reporting
- Detailed monitoring procedures (Appendix B and C)

Note that this LGMP focuses on the monitoring and assessment of fugitive landfill gas emissions and migration. Specific details on the operation, maintenance and internal monitoring of the landfill gas extraction system are not presented here. These details must be obtained directly from LMS Energy. Also, for details on the specific landfill gas management measures and their implementation, see the SBWMF EMP.

1.3 Review

This LGMP has been reviewed by a specialist in air monitoring, Andrew Balch, who is a Certified Air Quality Professional, and Director of Air Environment, an environmental consulting and research company specialising in air quality, odour, meteorology, and climatology.

Andrew's review comments are provided at Appendix D. Most review comments have been incorporated into this LGMP version (Revision 2). A detailed operating procedure for conducting monitoring surveys and using the instrumentation will be incorporated into the next revision of this LGMP (i.e. comments 5 and 7 in Andrew's letter). The next revision will also include a more detailed description of how the monitoring results are to be analysed, presented, and reported.

[1] Note the details of this system are commercial in confidence and only generalised information can be provided in this LGMP.

2 ABOUT LANDFILL GAS

Landfill gas is generated as a by-product of microbial decomposition of putrescible waste and the composition of gases emitted will vary according to the dominant phase of microbiological breakdown occurring within the site at the time i.e. aerobic versus anaerobic decomposition. Methane (CH_4) and carbon dioxide (CO_2) are the main gases produced; however, other gases (e.g. hydrogen sulfide, various volatile organic compounds) can also be produced.

During the initial aerobic (in the presence of oxygen) phase of decomposition, the gas is predominantly carbon dioxide. Once all oxygen has been depleted, anaerobic microbial decomposition commences, and the resulting gas has a relatively high methane content. This anaerobic phase has the greatest potential contribution to greenhouse gases.

With daily compaction and covering of waste, the available oxygen is quickly depleted; however, the evolution of significant quantities of methane may take from three months to more than a year to start, and can continue for well in excess of 15 years (NT EPA 2013).

The migration of landfill gas can present an environmental and safety risk. Potential problems as a result of landfill gas include:

- Contribution to greenhouse gas emissions
- Detrimental effects on soils and vegetation within the completed landfill and adjacent sites
- Risks to human health (on-site and off-site)
- Risks of explosions or fires due to gas migrating and collecting in confined spaces such as manholes and chambers and poorly ventilated areas of buildings on or adjacent to the site
- Odour nuisance
- Ignition of landfill gas upon release through cracks and fissures at the surface
- Asphyxiation of personnel entering trenches, manholes or buildings on or near the landfill site

The rate of landfill gas generation, and proportion of different gases emitted (i.e. methane, carbon dioxide, hydrogen sulfide and various volatile organic compounds) is controlled by factors such as moisture, temperature, the rate of landfilling, and the landfill cell design (e.g. type of impermeable liner, cover/capping). The composition of the waste and its degree of fineness and compaction will also have an influence. The removal of landfill leachate, and its associated high nutrient and organic content, and high oxygen demand, can reduce gas production.

A landfill will generally be stratified in a way that results in horizontal gas flow within the layers. These pathways should be considered in a landfill gas monitoring plan. They should also be intercepted by the gas collection system, including horizontal collectors, vertical extraction wells, or cut-off trenches if migration is severe. Care should be taken to ensure that no unintentional gas routes (for example service trenches) result in uncontrolled gas migration.

Gas will build up under the finished landfill final cover system. Gas migration or emission is likely if measures are not taken to prevent pressure build up and maintain the integrity of the cover system. This can be particularly important in times of very dry weather if the final cover system is susceptible to cracking. Other factors to be taken into account from an operational perspective include the effect of a change in atmospheric pressure on gas migration patterns.

Landfill gas-extraction and control needs to continue well after the landfill is closed and capped, and until landfill gas generation has reduced to a level unlikely to have an adverse effect on the environment. As such, monitoring of landfill gas needs to continue until this is conclusively demonstrated; likely to be at least 30 to 50 years.

3 SBWMF OPERATIONS OVERVIEW

This section outlines the infrastructure and operations at the SBWMF, with particular focus on aspects relevant to landfill gas generation, migration, and potential risks.

3.1 Land tenue and location

CoD lease the property (Lot 3952) from the Commonwealth Department of Defence. Under the lease agreement, only a portion of the property is designated as a Waste Management Project Area in which CoD is authorised to conduct waste management and ancillary activities. The rest of the property remains uncleared of unexploded ordinance (UXO) and cannot be utilised at present; see Figure 3-1.

The SBWMF operational area lies within the central-southern part of the property (Figure 3-1). This operational area is bound to the north and east by floodplains, wetlands, and mangroves of the 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, approximately 800 m to the south-west, with a bushland buffer in between.

3.2 Infrastructure and layout

Table 3-1 outlines the SBWMF infrastructure, with comment regarding landfill gas risks. Figure 3-2 shows the general site layout and location of this infrastructure. The landfill gas monitoring program outlined in Section 6 below includes sampling across all historic (capped) landfills and currently active landfills, and also within enclosed buildings and subsurface pits for underground services.

3.3 Landfilling method

SBWMF utilises the 'area method' of landfilling (see NT EPA 2013), whereby waste is disposed of at an active tip face and is then compacted in a mound above-ground (as opposed to trench filling below ground).

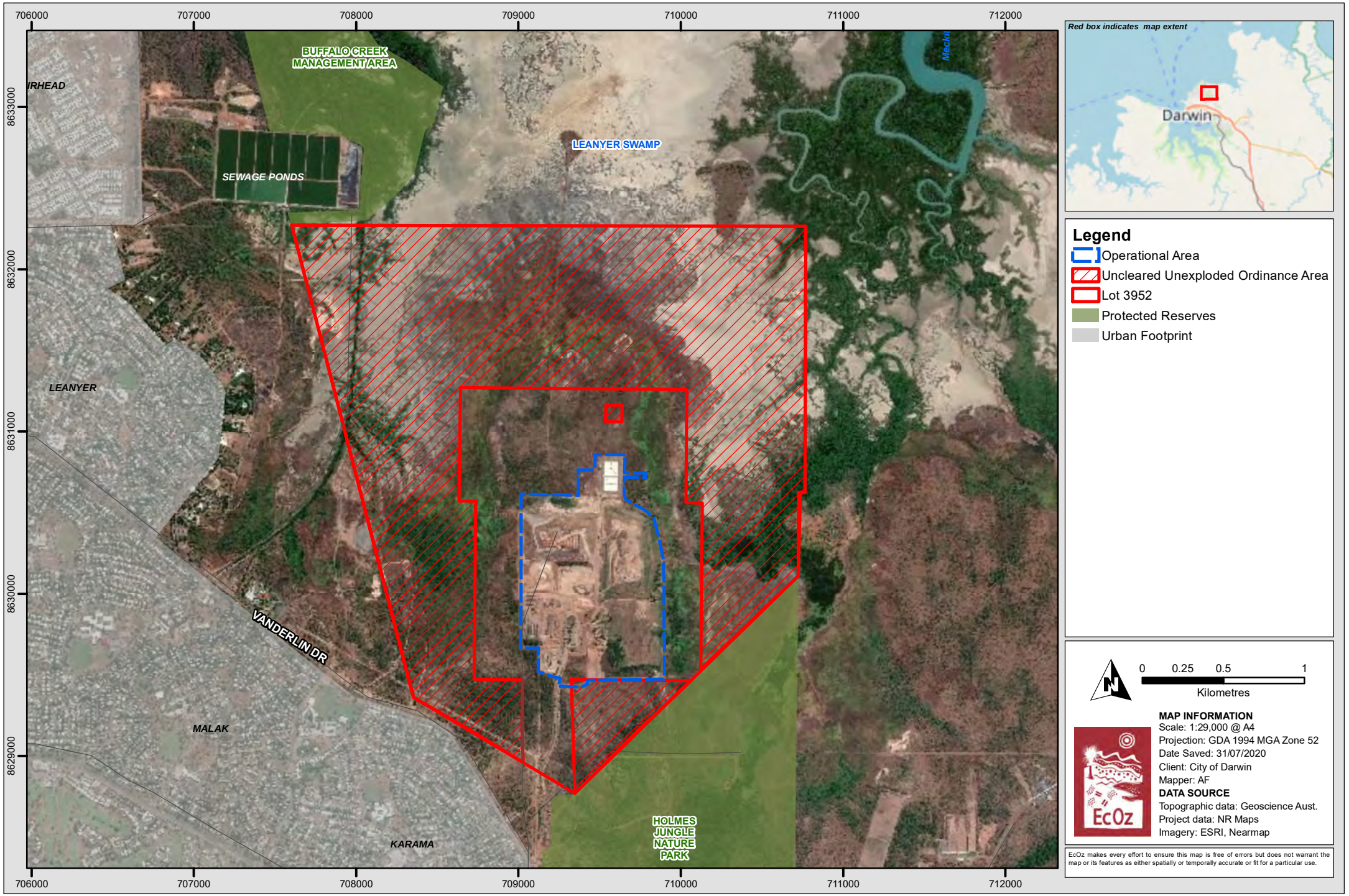
Each day, the waste is covered with a heavy-duty tarp using a deployment system attached to standard landfill machinery. The tarp system is a widely accepted form of landfill daily cover and can be quickly deployed over the tip face. Other alternative methods of daily cover accepted at the site include mulch (during dry periods only) or clean fill (year-round). Material for cover is sourced from clean fill material accepted at the facility or imported as required. Daily cover is applied at a minimum thickness of 150 mm, most of which can be retrieved on the following day prior to new waste disposal.

As the active tip area moves progressively along the length of the cell (building up the height), the waste disposal areas are covered with a 300 mm intermediate layer of cover material to minimise rainfall infiltration. Intermediate layers are sloped and graded to prevent ponding of water. As the landform progresses in height, intermediate cover is removed or penetrated as much as possible prior to waste placement to prevent impermeable layers potentially leading to perched leachate.

Table 3-1. SBWMF facilities

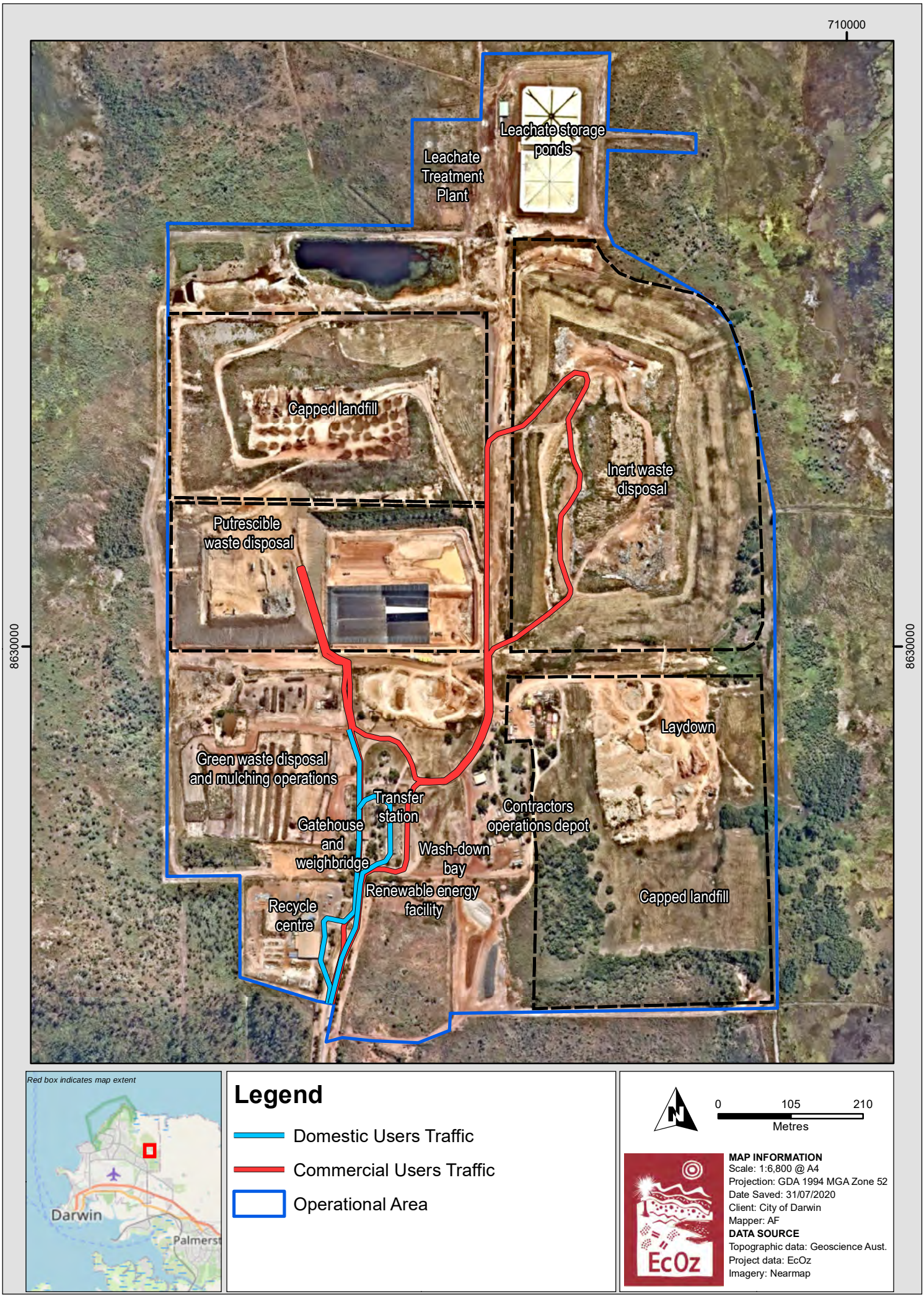
Infrastructure	Description	Landfill gas relevance
Recycle centre	A facility where users can drop off unwanted goods to be recycled, repurposed, or resold to other users. The facility accepts a wide range of goods, including building materials, furniture, electronics, and bric-a-brac.	The facility does not generate putrescible waste that goes to landfill. The building housing this facility, however, is a potential area where landfill gas could accumulate and present a human health risk.
Gatehouse and weighbridge	Located at the entrance to the site, the gatehouse includes office space and amenities for staff and a dual weighbridge system to allow for tracking of incoming and outgoing materials.	The gatehouse building is a potential area where landfill gas could accumulate and present a human health risk.
Transfer station	The transfer station is primarily for domestic users to drop off household waste for recycling, landfill, or disposal off-site to a licenced facility. The transfer station allows for segregation of general, recyclable, and domestic quantities of listed wastes. Users access the facility directly with their vehicles to unload.	A proportion of waste from this facility goes to the putrescible waste landfill.
Inert waste disposal	All inert waste loads are directed to the inert waste disposal cell. Where possible, recyclable materials such as steel and concrete are salvaged from the tip face prior to burial. The inert cell also caters for the disposal of asbestos products and asbestos containing material.	Inert wastes are wastes that are non-biodegradable, non-flammable, non-chemically reactive and have no potentially hazardous content once landfilled. As such, provided only inert waste is placed in this area, it is unlikely to generate landfill gas. The inert waste landfill, however, is located on top of a former putrescible waste landfill (Stage 2), which still potentially generates landfill gas.
Putrescible waste disposal	All putrescible waste loads and listed wastes licenced for burial are directed to the active lined landfill cell for disposal.	All past and present putrescible waste landfills are a source of landfill gas. This comprises the historic landfills Stages 1 to 4, and the current active landfill, Stage 5.
Green waste disposal and mulching operations	All green waste loads are directed to the green waste disposal area for stockpiling. The green waste is then processed into mulch products for reuse on site or resold as a commercial product.	The green waste operations are not a significant source of landfill gas relative to the putrescible waste landfills. The waste remains mostly aerobic and is resold and taken offsite. The diversion of green waste for reuse rather than going to landfill reduces landfill gas production.
Renewable energy facility	Landfill gas is harvested from the landfill by a third-party contractor and directed to an on-site gas processing facility. The facility consists of a 1.1 MW engine, which converts the gas to electrical power for supply back into the grid.	This system extracts landfill gas from the landfills, reducing greenhouse gas emissions and the risk of fire/explosion, accumulation of landfill gas in onsite buildings and underground pits, and the offsite migration to sensitive areas.

Infrastructure	Description	Landfill gas relevance
Leachate collection system and storage ponds	Leachate collection systems extract leachate from the Stage 3/4 landfill and Stage 5 landfill. Leachate is then pumped to 2 x 15 ML storage ponds, which are located at the northern end of the site. The leachate storage ponds are lined and covered.	Well-managed leachate collection and treatment can reduce landfill gas emissions by removing nutrients and organic matter from the landfill that fuel biodegradation and reduce oxygen levels.
Leachate treatment plant	A leachate treatment plant is currently being constructed on a site directly west of the leachate storage ponds that will treat leachate to reduce contaminant levels and allow greater flexibility in its disposal on-site and reduce environmental impacts.	As above, well-managed leachate collection and treatment can reduce landfill gas emissions. Confined spaces within the buildings and structures of the plant are a potential area where landfill gas could accumulate and present a human health risk.
Wash-down bay	A wash-down bay is located near the site exit for use by commercial users after disposing of waste to landfill. The wash-down water is collected in a sump, processed through an oily-water separator, and then irrigated as required over an existing landfill area.	Not a source of landfill gas.
Contractors' operations depot	A hardstand compound located at the southern end of site adjacent to Stage 1. The compound area is comprised of a series of demountable buildings and sheds and a workshop area for minor servicing of plant and equipment.	Buildings within this area are a potential space where landfill gas could accumulate and present a human health risk.
Underground services: water, electricity, communications, and sewerage	Underground services are located throughout the SBWMF, providing water, electricity, communications and sewerage services to the buildings and operational area where it is required. See Figure 3-5 below.	Access pits for undertaking inspections and maintenance of underground services can accumulate landfill gas and present a health risk to workers accessing these pits.



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Fig 1-2. Uncleared Unexploded ordinance Area.mxd

Figure 3-1. Map of SBWMF operational area and uncleared UXO area



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Figure 2-1. SBWMF site facilities and access routes.mxd

Figure 3-2. SBWMF site layout

3.4 Site development

Waste disposal and landfilling activities have been occurring at the site since the 1980's. The initial Stages 1 and 2 are located on the eastern side of the operational area (see Figure 3-2) and are unlined cells that previously accepted all waste types. Stage 3 was constructed between 2001 and 2007, with a geomembrane liner and was progressively filled with general putrescible waste during this time. In 2013, Stage 4 was constructed on the north-west corner of Stage 3 by tying in the new geomembrane liner with existing infrastructure. Filling activities in Stage 3 & 4 ceased in 2018.

Stage 5 and all future landfill cells consist of a composite liner system built to best-practice standards, including leachate collection systems. All new cells and liner designs are subject to an Environment Protection Approval regulated by the NT EPA.

CoD have developed a landfill filling plan that shows the sequence and timing for Stages 5 to 10 to be constructed south of Stage 3. Figure 3-3 shows the current and future staged landfill cells, which is estimated to manage average waste disposal volumes over the next 15 to 20 years. Landfill cell development (including the current Stage 5) volumes and associated lifespan estimates are outlined in Table 3-2below.

Table 3-2. Summary of landfill stage lifespans

Stage	Estimated airspace (m^3)	Lower range filling rate lifespan	Upper range filling rate lifespan
Stage 5	510,000	35 months	27 months
Stage 6	950,000	65 months	50 months
Stage 7	450,000	31 months	23 months
Stage 8	1,220,000	83 months	64 months
Stage 9	525,000	36 months	28 months
Stage 10	1,180,000	81 months	62 months
Totals	**4,835,000**	**331 months**	**254 months**

As the landform progresses, the current site layout of the SBWMF is required to change in order to accommodate the new cells whilst ensuring continuation of ancillary site activities. The site Master Development Plan details the future development plans for the facility. The plan identifies 13 future development precinct areas and three stormwater management areas which are summarised in Table 3-3 and shown in Figure 3-4. These precincts have been identified as a part of a master-planning exercise, therefore it is recognised that many of the future proposed land uses are still subject to the appropriate design and approvals prior to implementation.

This LGMP will need to be regularly reviewed and adjusted to incorporate site changes and new landfill stages.

Table 3-3. Summary of future development precincts

Precinct	Area (ha)	Current use/constraints	Future proposed land use
1	12.2	Stage 1/vacant laydown	Green waste management
2	18.1	Stage 2/inert landfill	Unchanged
2A	5.7	Stage 2/inert landfill	Unchanged, concrete/steel management
3	20.2	Stages 3 to 6/landfill	Unchanged
4	14.1	Green waste and transfer station	Stages 7 to 10 putrescible landfill
5	3.0	Leachate storage ponds	Unchanged

Precinct	Area (ha)	Current use/constraints	Future proposed land use
6	2.5	Recycle shop/vacant	Unchanged, commercial waste operation
7	1.0	Renewable energy facility/vacant	Transfer Station
8	0.5	Vacant	Renewable energy facility
9	1.0	Landfill operations	Unchanged
10	2.6	Vacant	Alternative waste processing facility
11	16.6	Vacant/UXO	Disaster waste management, commercial waste operation
12	31.1	Vacant/UXO	Disaster waste management, commercial waste operation
13	26.4	Vacant	Future landfill, leachate treatment
Stormwater Area A	6.6	Vacant/stormwater	Stage 2 inert landfill stormwater management
Stormwater Area B	7.0	Vacant/UXO	Future green waste stormwater management
Stormwater Area C	31.1	Vacant/UXO	Landfill, waste processing stormwater management



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Figure 2-3. Future general waste stage layout plan.mxd

Figure 3-3. Landfill cell staging



Figure 3-4. Future development precincts

3.5 Landfill gas extraction system

Landfill gas emissions at the SBWMF are primarily controlled via a landfill gas extraction system, which was commissioned in 2005, and is owned and operated by a private company, LMS Energy. Landfill gas extracted by this system is conveyed to an on-site 1.1 MW power station (location shown in Figure 3-2 *Renewable energy facility*), where it is used to generate electricity.

Landfill gas is extracted via a network of wells and pipelines located across all landfill stages (i.e. Stages 1 to 5), although most gas is currently extracted from the more recent landfills, Stage 3, 4, and 5. Over time, the locations and depths of wells has been adjusted depending on well performance and as the active landfill cell is progressed. Over the past 12 months (October 2020 to September 2021), around 5,119,962 m^3 of gas was extracted; all of this from the Stages 3, 4 and 5 landfills.

The power station compound also has a flare, although it is unknown to EcOz the volume of gas that is combusted annually.

Condensate is generated in the landfill gas extraction system as the gas cools. This condensate is collected and transferred to the leachate collection and treatment system; see Section 3.7 below.

Further detail on the management and maintenance of the landfill gas extraction system must be obtained through LMS Energy.

3.6 Other landfill gas control measures

In addition to the landfill gas extraction system, other measures that also control landfill gas implemented at the SBWMF include the use of daily and intermediate cover to prevent gas emissions. Also, the extraction of leachate can assist in controlling landfill gas given leachate can be a source of nutrients and organic matter to fuel gas generation; see Section 3.7 below.

Final capping of landfill cells also reduces long-term landfill gas emissions by preventing the infiltration of stormwater and generation of leachate, as well as preventing landfill gas escaping through the capping.

To date, no physical barriers aimed at preventing offsite lateral migration of landfill gas are utilised, for example, stone-filled trenches, or low-permeability constructions such as flexible geomembranes, bentonite slurry walls, piles, or cut-off walls.

Passive venting is also not undertaken, although this is ideally avoided in preference to landfill gas extraction in order to reduce greenhouse gas emissions.

3.7 Leachate collection and treatment system

The Stage 1 and 2 landfills are unlined, and leachate that moves laterally from these landfills is captured in an interception trench that runs along the eastern toe of both landfills. The captured leachate then flows south into a sump, from where it is irrigated over the eastern side of Stage 1.

The Stage 3 landfill is lined, however, the leachate collection system is considered to have failed and is no longer in use. Leachate extraction from Stage 3 comprises the following:

- Overflow drainage into Stage 4, which does have an operational leachate collection system
- A leachate collection strip drain below the toe of the southern batter that drains to a leachate well
- Six sumps located around the perimeter of the northern and eastern batter slopes
- Landfill gas wells fitted with leachate pumps

The Stage 4 and 5 landfills (and all future landfills) are designed and constructed with liner systems and cell floor leachate collection systems that comply with the NT EPA (2013) landfill guidelines. Leachate collected from the waste cells is managed as follows:

- Pumped into the leachate storage ponds and then treated through the leachate treatment plant for on-site disposal (see below)
- If the leachate storage ponds reach capacity prior to or during treatment processes, leachate management will comprise:
  - Irrigation on the top of waste cells prior to final capping
  - Recirculation with buried waste material within the lined landfill cells as appropriate.

Leachate is pumped into two leachate storage ponds, with a combined nominal capacity of 30 ML. Each pond has a floating cover and is lined with a geosynthetic liner. From the leachate storage ponds, leachate is pumped to a leachate treatment plant (currently under construction) designed to treat the leachate to a suitable quality for discharge within the site (i.e. via irrigation, dust suppression or to supplement water requirements for green waste management).

3.8 Underground services

Subsurface pits and trenches have the potential accumulate hazardous levels of landfill gas depending on their location and the direction of any gas migration from the landfill. Figure 3-5 shows the location of water, electricity, sewerage, and communications infrastructure, which is concentrated in the southern portion of the SBWMF site. Service pits are included in the monitoring program outlined in Section 6 below.



Figure 3-5. Map of main underground services present at the SBWMF

4 ENVIRONMENTAL SETTING

4.1 Surrounding land-use

Immediately surrounding the SBWMF to the west, north and east are salt flats, tidal wetlands, and mangroves connected to the Shoal Bay embayment. Immediately to the south is native savannah bushland and the monsoon rainforest of the Holmes Jungle Nature Park. As such, no sensitive human health receptors, such as residences or workplaces, are identified immediately adjacent to the site.

Further afield, land uses within a 2 km radius of the site include the suburb or Karama (800 m to the south-west of the site boundary and 1.1 km from the Stage 5 landfill), the Leanyer Recreation Park (1.5 km to the west), the Darwin Model Flying Club (1.1 km to the north-west), and the Darwin Rifle Club, 1.7 km to the south-east; see Table 4-1 below for a summary. None of these land uses are considered at risk of landfill gas migration given their distance from landfills within the SBWMF.

Table 4-1. Land uses surrounding the SBWMF

Land use	Location	Approximate distance (km)
Darwin Model Flying Club	North-west	1.1
Leaner Recreation Park	West	1.5
Leanyer suburb (residences)	North-west	1.8
Leanyer Sanderson Waste Stabilisation Ponds	North-west	2.1
Karama suburb (residences)	South-west	0.8
Malak suburb (residences)	South-west	1.2
Holmes Jungle Nature Park	South	Adjacent
Crocodylus Park	South	2.3
Darwin Pistol Club, Darwin Riffle Club and Northern Territory Field and Game Association	South-east	1.7+

4.2 Climate

4.2.1 Temperature and rainfall

The Darwin region has a monsoonal tropical climate, with a distinct dry season (approximately May to October) and wet season (November to April). Typically, for this region, humidity, maximum and minimum temperatures are highest during the wet season, and lowest during the dry season. The annual total evaporation far exceeds the annual total rainfall.

The Darwin International Airport station (station no. 014015) is the closest Bureau of Meteorology (BoM) weather station to the SBWMF with a consistent long-term record. This station is located approximately 2 km away. The total average annual rainfall based on the data from this station is 1723 mm (BoM 2020). The variation in temperature and rainfall across the seasons is shown in Figure 4-1. Almost all the annual rainfall occurs during the wet season months of December through to March.

Climate variation throughout the year directly influences the management of surface water at SBWMF, including the potential for leachate generation and contamination of surface waters within the site.

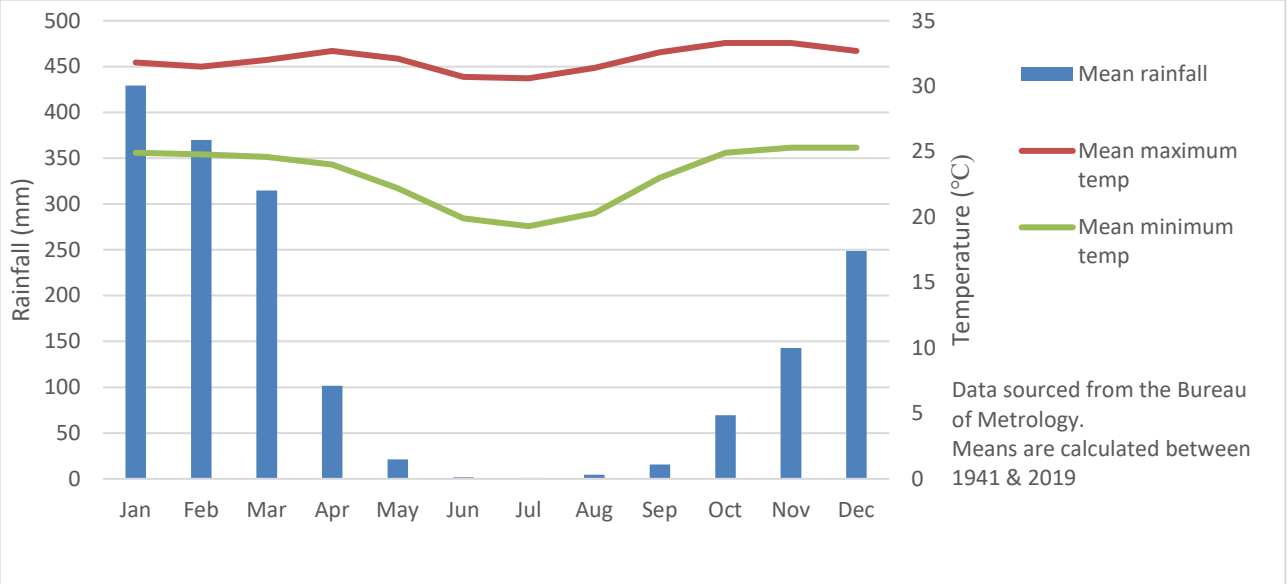


Figure 4-1. Graph of mean temperature and rainfall at Darwin Airport (Station no. 014015)

4.2.2 Atmospheric pressure

Months with the highest average atmospheric pressure are the dry season months of June to August, with an average pressure of 1013 mbar. Months with the lowest average atmospheric pressure are the wet season months of November to March, with an average of 1006 to 1008 mbar. Note however that in Darwin, the diurnal variation in pressure over the course of a day can be greater than these average seasonal variations

Over the course of each day, atmospheric pressure is generally highest during the mid-morning (9-10am) and lowest during the mid-afternoon (4-6pm).

4.2.3 Wind direction and strength

Wind direction and wind speed (km/hr) data has been retrieved from the Darwin airport weather station (Site number: 014015). Wind rose data from January 1942 to April 2019 is available (refer to Table 4-2 and Table 4-3). It is important to consider wind direction and strength when planning and undertaking landfill gas monitoring.

For the Darwin area, the wet season wind direction in the morning is predominantly calm (12%), with winds variable from westerly, easterly, and south easterly direction. During the afternoon, the winds are predominantly north westerly, westerlies and to a lesser extent, northerlies. Dry season wind in the morning is predominantly south easterly and easterly direction, and in the afternoon, the winds are variable between north westerly, northerly and easterlies.

Table 4-2. Darwin Airport wet season wind rose

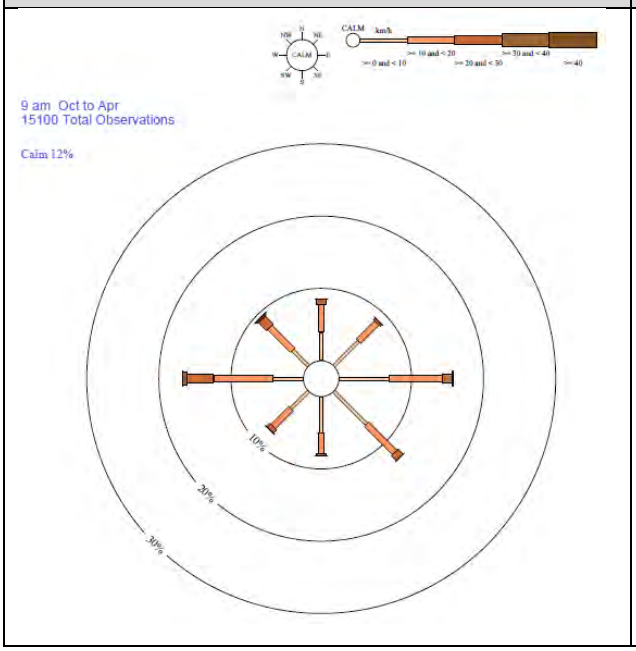
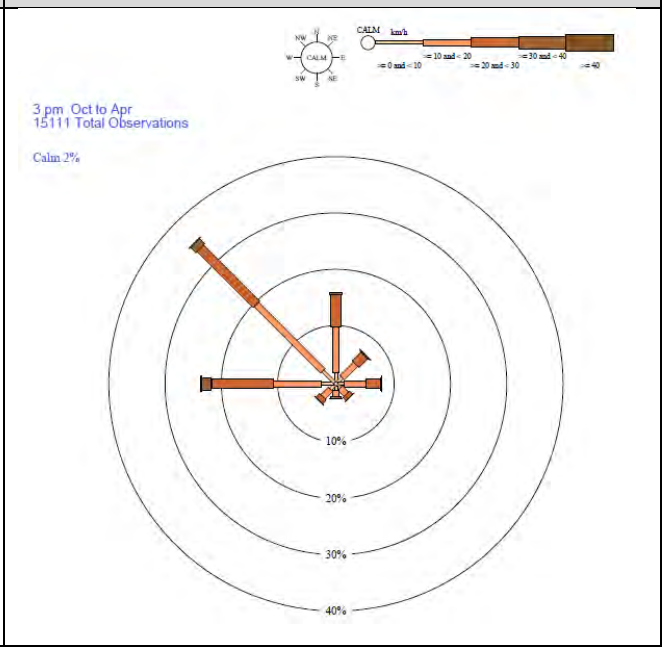
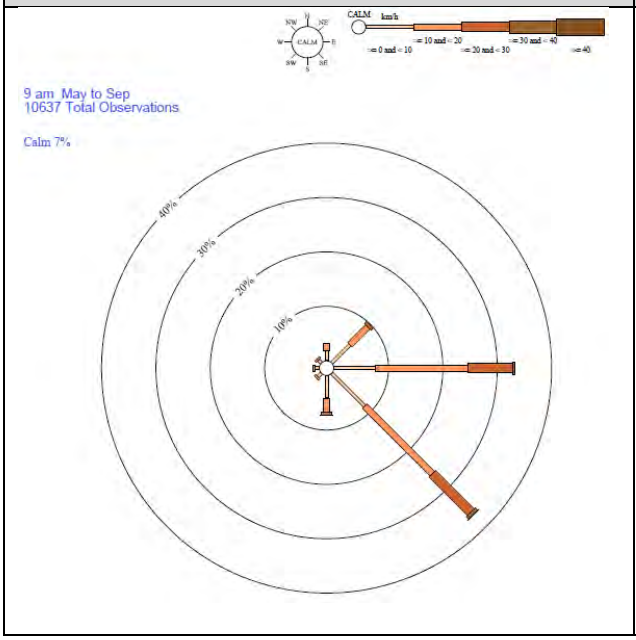
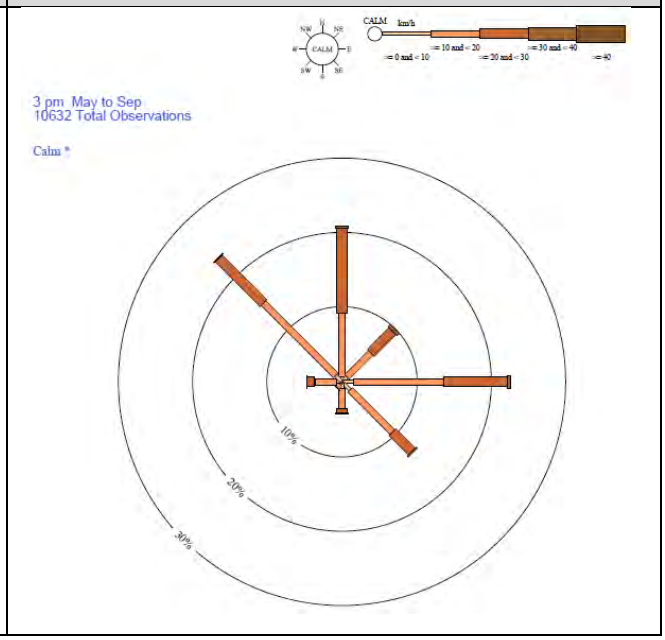
Wet Season (Oct to Apr) 9am	Wet Season (Oct to Apr) 3pm
	

Table 4-3. Darwin Airport dry season wind rose

Dry Season (May to Sep) 9am	Dry Season (May to Sep) 3pm
	

Source: Bureau of Meteorology, Commonwealth of Australia 2019.

4.3 Hydrogeology

Groundwater aquifers beneath the site are described in detail in the *Shoal Bay Waste Disposal Site, Hydrogeological Investigation* (URS 2015). As part of this investigation (and also previous and subsequent investigations), more than 40 groundwater bores have been drilled across the SBWMF and are sampled on an on-going basis for the groundwater monitoring program. Bore depths range from 3 to 30 m below ground level (mBGL). See Appendix A for a map of bore locations.

Lithology encountered during groundwater bore drilling for the URS (2015) investigation comprised top soils (silts and clays), generally underlain by weathered (laterised) siltstone over most of the site, and claystone east of Stage 1. Beneath this, sandstone was encountered at depths of 9 to 20 m below the surface across most of the site. Groundwater exists within the unconsolidated overlying sediments, and fractured and weathered underlying bedrock. Bore yields are generally very poor; less than 5 L/sec.

The shallow (water table) aquifer is recharged by the direct infiltration of rainfall and runoff, and groundwater levels vary seasonally in accordance with rainfall totals. Seasonal groundwater standing water levels (SWLs), measured as part of the SBWMF groundwater quality monitoring program since 2016, are greater than 12 mBGL at the end of the dry season, and usually less than 2 m from the ground surface during the peak of the wet season. An excerpt from the report *Shoal Bay Waste Management Facility, Water quality monitoring data review, 2016 – 2020* (EcOz 2020) is provided in Appendix A. Chapter 6 of this report provides a summary of groundwater levels and flows measured across the site between 2016 and 2020. These are used in Section 6 below in designing appropriate landfill gas monitoring bores.

Higher yielding weathered and fractured carbonate rock aquifers occur in the wider region, with yields commonly greater than 5 L/sec. The *Groundwater Supply Prospects and Hydrogeology of the Cox Peninsula Region* map identifies a high yielding carbonate aquifer south-east of the SBWMF, trending in a northerly direction (NRETAS 2008). Groundwater from this aquifer discharges to the surface within the Holmes Jungle Nature Park and maintains streamflow through the dry season. This spring and associated shallow groundwater support the Holmes Jungle Nature Park. Further to the south-east around the Knuckey Lagoon area, a large number of bores draw groundwater from this carbonate aquifer for domestic and agricultural purposes.

There are no groundwater bores or groundwater users down gradient of the SBWMF; although an important environmental consideration is the supply of groundwater seepage into wetlands and tidal inlets during the dry season.

The carbonate rock aquifer and associated springs, Holmes Jungle Nature Park and groundwater users are all located up gradient of the SBWMF. No significant areas of carbonate rock aquifer are located down gradient of the SBWMF, and no carbonate rocks were encountered when drilling the 32 groundwater bores, to depths of up to 30 m below ground level, across the site for the URS (2015) hydrogeological investigation.

4.4 Surface water

Surface water run-off flows east from the eastern part of the SBWMF, towards the Micket Creek floodplain, and westward from the western part of the SBWMF, towards the Buffalo Creek floodplain. Both Micket Creek and Buffalo Creek are mangrove-lined tidal inlets of Shoal Bay; a coastal embayment with extensive sand and mud flats (see Figure 1-1).

Surface water management within the site includes open drain and stormwater structures that divert surface water away from landfill cells and operational areas, where possible.

5 CONCEPTUAL SITE MODEL

A conceptual site model (CSM) is a description or representation of the current understanding and connections between the contaminant sources at a site, their potential migration pathways and potential human health and/or environmental receptor at risk. A CSM is a useful tool in designing a monitoring program to best target sampling sites, sampling frequency, sampling methods and analytical parameters.

Note that landfill gas is the only contaminant considered in this CSM. See the SBWMF EMP for a CSM that includes all possible contaminants at the site.

5.1 Contaminants of concern

The contaminants considered in this CSM are gases generated in the landfill cells at the site due to the breakdown of putrescible waste. This is mostly methane and carbon dioxide by volume, but may also include hydrogen sulfide, and various other organic volatile compounds.

5.2 Sources

The more recent landfill stages (Stages 3, 4 and 5) are considered to present the highest risk in regards to landfill gas generation, although the older landfills (Stages 1 and 2) may also still be generating significant landfill gas. The current levels of fugitive landfill gas emissions and migration from each of the five Stages remains unquantified, given no monitoring has yet been undertaken.

5.3 Migration pathways

Migration pathways of landfill gas include:

- Vertical migration through the cover/capping into the air above the landfill
- Lateral migration through horizonal layer of waste and/or soil/bedrock to areas adjacent to the landfill
- Lateral migration (as above) into buildings and/or subsurface pits or voids where it may accumulate and reach hazardous levels
- Accumulation within the landfill where it may cause explosion or fire

5.4 Potential receptors

Human health receptors include workers on site that spend various amounts of time in the buildings and structures on site, in subsurface pits, or on the surface of a landfill where emissions and the migration of landfill gas has accumulated to levels that may cause asphyxiation.

A further human health receptor is physical danger to workers and/or the public that are within close proximity to a landfill if it was to explode of have a large fire.

Offsite human health receptors are considered low risk given the nearest enclosed building where people may reside for periods of time would be the suburb of Karama, which is more than 1.1 km away from the nearest landfill cell.

Environmental considerations comprise greenhouse gas emissions to the atmosphere, and their effects on the global climate. Given the habitats immediately surrounding the SBWMF are open-air, environmental receptors in these areas are not considered at risk from landfill gas.

5.5 Preliminary risk assessment

Given the above CSM, the receptor at highest risk from landfill gas is human health in workers at the site who spend time in buildings, or subsurface pits, or on the landfill surface where emissions and the migration of landfill gas has accumulated to levels that may cause asphyxiation.

The risk of gas accumulation within the landfills leading to fire or explosion is mitigated by the active gas collection system, although to what degree remains unquantified, given there is currently no fugitive gas monitoring data available for the site. This risk will require further consideration following the collection of landfill gas monitoring data.

Greenhouse gas emissions do not pose an immediate threat to human health or the environment in the local vicinity, however, these gases must be minimised as much as possible to prevent climate change.

This risk assessment will be further developed in future revisions of the LGMP, following the collection of landfill gas monitoring data, as outlined in Section 6 below.

6 LANDFILL GAS MONITORING PROGRAM

6.1 Design rationale

Monitoring of landfill gas will be undertaken at both the surface (transects across each landfill) and sub-surface (gas monitoring wells). Surface transect sampling aims to monitor vertical emissions through the cover/capping material, whilst sub-surface sampling aims to monitor any lateral migration of landfill gas.

Sampling for landfill gas will also be undertaken within enclosed spaces, where potentially harmful accumulation of gas could occur. This includes within buildings and structures on-site, as well as sub-surface pits used for access and maintenance of underground services.

The following rationale is used in determining the frequency and location of sampling sites:

- Surface transects will be undertaken across all current and historic landfills (i.e. Stages 1 to 5), with a greater density of transects across the currently active Stage 5 landfill. Note however that landfill areas covered only with daily cover in the active cell do not have any gas action levels and should not be subject to surface emissions monitoring (EPA Victoria, 2018, p. 5, Section 5.2). This may not be the case for cells that contain aged waste materials below the active tip area.
- Purpose-built gas monitoring boreholes will be installed along the western edge of the most recent landfills (i.e. those of higher risk; Stages 3, 4 and 5). Bore depths are based on existing knowledge of the groundwater aquifer beneath the site and seasonal groundwater level changes – See Appendix A
- In buildings on-site where the accumulation of landfill gas could present a risk to human health
- In sub-surface pits used to inspect and maintain underground services (water, electricity, communications, sewerage etc) where the accumulation of landfill gas could present a risk to human health

Monitoring of the active gas collection system is undertaken by the LMS Energy and is not included in this LGMP. This includes recording gas composition and volumes at extraction system well heads, as well as gas flow, pressure, and condensate in the collection system.

Apart from monitoring undertaken of the gas extraction system by LMS Energy, no monitoring of fugitive landfill gas emissions or migration has been undertaken at SBWMF to date. As such, this LGMP will need to be reviewed and adjustments made based on the results from the first year of monitoring.

6.2 Monitoring frequency, methods, and sites

All gas monitoring will be conducted in accordance with the *Landfill Gas Fugitive Emissions Monitoring Guidelines* (EPA Victoria 2018) and will be undertaken by a qualified person. These methods are outlined in Appendix B.

All surface transect, subsurface, building and pit monitoring will be undertaken on a **quarterly basis** for the first year, with the frequency of each sampling type and location to be reviewed based on the first year of data collected.

Changes in atmospheric pressure in the days leading up to a monitoring round must be recorded. Surface atmospheric pressure can affect the emissions from a site, and is critical in planning the timing of each monitoring round and in interpreting the results. Similarly, wind speed and direction, rainfall and temperature can also influence emissions, and the timing of monitoring must take forecast weather conditions into consideration.

Prior to sampling at each site (transects, wells, pits and buildings), the field data sheet proforma should be completed with the sampler's name, sample site ID, date and time of sampling, atmospheric pressure, prevailing wind and weather and recent weather conditions, current ground conditions, instruments used (calibration and serial numbers). During monitoring, any observations of significance (like changes in weather) should be noted.

6.2.1 Surface transects

Transects will be undertaken across the surface of each landfill using a low-concentration methane detector with an extendable probe (category 2 detector as per EPA Victoria 2018 guidelines). Transect spacing will be 50 m across the capped landfills (Stages 1 to 4), and 25 m across the currently active landfill (Stage 5); excluding any areas with only daily cover and no aged waste materials below the active tip area. Two sets of transects should be started from two boundaries at right angles to each other so the transects cross in a grid pattern (see Figure 6-1). The number of transects across each landfill has been calculated based on the estimated area of the landfill (see

Surface emissions should be monitored continuously along each transect at a height of approximately 50 mm above the surface. Data should be logged regularly i.e. every few seconds. Monitoring should be at normal walking speed along the transects parallel to the landfill boundary.

During transect monitoring, observations are to be systematically made and recorded on the field data sheet of any vegetation die-back, odour, or cracking of the landfill capping/cover.

Wind speed must be measured at the height in which methane measurements are taken, i.e. 50 mm above the surface. According to EPA Victoria (2018, Appendix A, p. 17), the wind speed should be less than 10 km/h at this height; preferably much less than this. See Section 4.2.3 above for seasonal wind direction and strength patterns.

Table 6-1. Number of transects required across each landfill stage based on estimated landfill area

Landfill Stage	Area (ha) [2]	Transect spacing	Approximate number of transects
1	12.2	50 m	10 north-south 9 east-west
2	18.1	50 m	13 north-south 9 east-west
3	10.5	50 m	5 north-south 9 east-west
4	2.5	50 m	4 north-south 4 east-west
5	1.9	25 m	9 north-south 9 east-west

[2] Golder (2020). Water Balance, Leachate and Stormwater Management Strategies Shoal Bay Landfill, Darwin. Report prepared by Golder for City of Darwin, July 2020

6.2.2 Subsurface monitoring

Landfill gas monitoring wells will be installed in accordance with Section B.7 of the EPA Victoria (2015) publication: *Best Practice Environmental Management; Siting, design, operation and rehabilitation of landfills*. Four wells will be initially installed along the western side of the Stage 3, 4 and 5 landfills (see Figure 6-2 and Table 6-2).

The wells will be to depths of 12 mBGL, which is the typical depth to groundwater during the dry season. During the wet season, only to top 3 m of each well is expected to be in the vadose zone and able to be sampled. More wells may be installed in the future based on the first year of monitoring results.

The wells will be sampled for methane, carbon dioxide and oxygen using an extractive landfill gas analyser (category 1 detector as per EPA Victoria 2018 guidelines). Relative pressure and flow data will also be measured. The maximum methane and carbon dioxide, and minimum oxygen concentrations should be recorded on the field data sheet along with the stabilised concentration for each of these gases.

Once gas measurements are completed, the groundwater level in the bore should be measured using a dip meter. If the groundwater level is above the top of the well screen, then the gas measurements should be disregarded.

Table 6-2. Details of subsurface, building and pit monitoring locations

Monitoring type	Site ID	Purpose	Coordinates	
			Latitude	Longitude
Wells	Well 1	Monitoring lateral migration from Stage 4 landfill	12°22’55.91” S	130°55’21.03” E
	Well 2	Monitoring lateral migration from Stage 3 landfill	12°23’1.31” S	130°55’21.01” E
	Well 3	Monitoring lateral migration from Stage 5 landfill	12°23’7.33” S	130°55’21.12” E
	Well 4	To establish baseline conditions to compare to Wells 1 to 3, and prior to development of the Stage 7 landfill.	12°23’15.63” S	130°55’21.34” E
Buildings	Recycle centre	Monitor for gas accumulation within the building at potentially harmful levels	12°23’24.27” S	130°55’27.89” E
	Contractors’ operations depot (2)	Monitor for gas accumulation within the building at potentially harmful levels	12°23’19.87” S	130°55’37.46” E
	Gatehouse (3)	Monitor for gas accumulation within the building at potentially harmful levels	12°23’25.95” S	130°55’29.50” E
	Leachate treatment plant operations building (4)	Monitor for gas accumulation within the building at potentially harmful levels	12°22’49.60” S	130°55’34.49” E

Monitoring type	Site ID	Purpose	Coordinates	
			Latitude	Longitude
Pits	Electricity Pit 1	Monitor for gas accumulation within the pit at potentially harmful levels	12°23'20.51" S	130°55'29.62" E
	Electricity Pit 2	Monitor for gas accumulation within the pit at potentially harmful levels	12°23'19.11" S	130°55'30.60" E
	Manhole	Monitor for gas accumulation within the pit at potentially harmful levels	12°23'16.79" S	130°55'35.95" E

6.2.3 Buildings and subsurface pits

The landfill gas present within buildings and subsurface pits will be measured using a low-concentration methane detector (category 2 detector as per EPA Victoria 2018 guidelines).

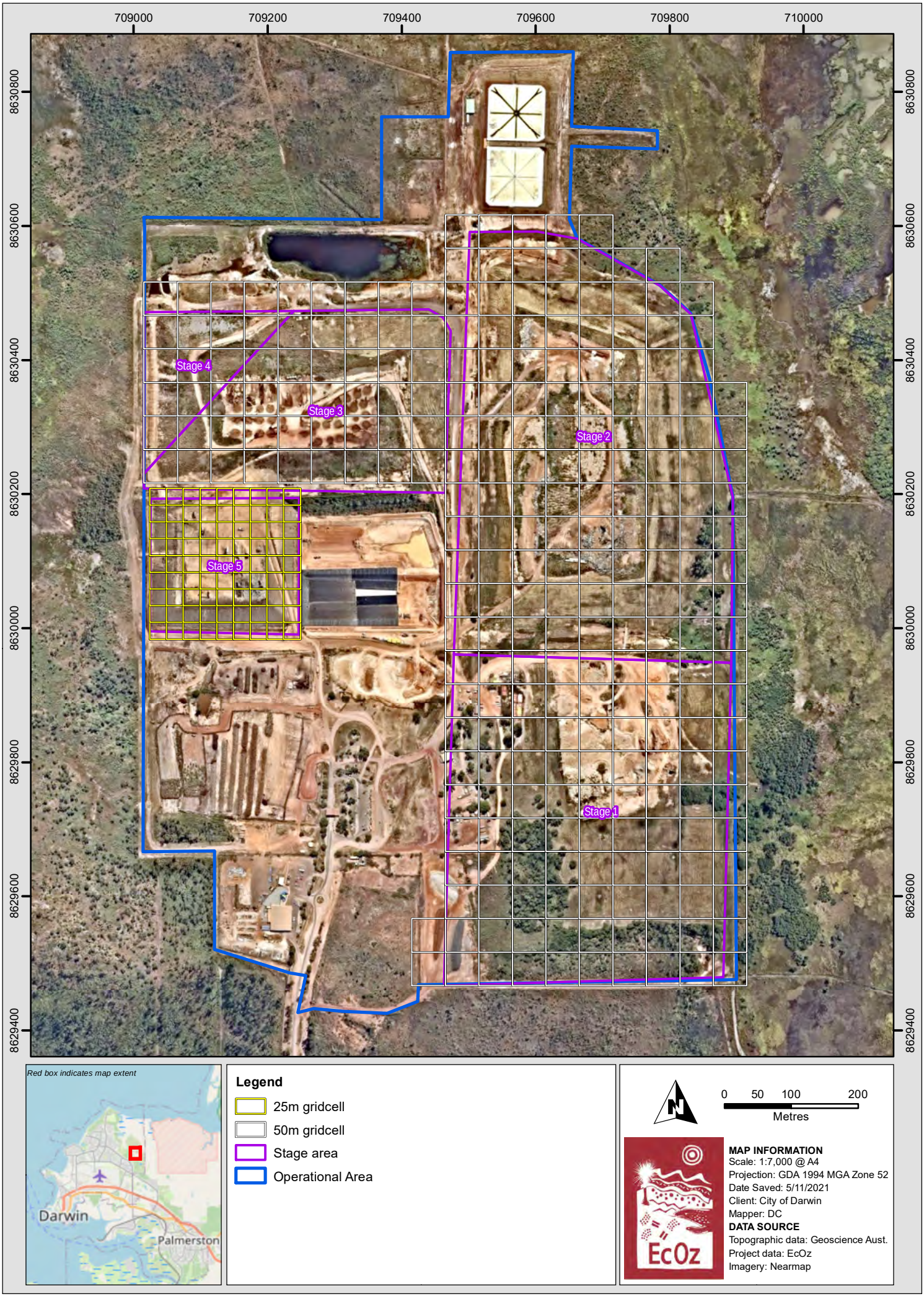
When measuring gas within a pit, turn on the instrument and insert the probe into the pit. This should be done in a way that minimises the ingress of air into the pit. Attempt to monitor across the lateral and vertical profile of the pit to account for the differing densities of landfill gas which may be encountered due to its variable composition. Record the maximum concentration of methane and also the stable concentration (if possible), or the range in concentrations if the concentrations don't stabilise.

When measuring gas within buildings, the following areas should be sampled.

- around service ingress points, such as pipework
- inside electricity meter/fuse box
- inside cabinets within bathrooms, kitchens, laundries, and other rooms
- around cracks and penetrations through floors
- along skirting boards and joins between floors and walls
- within floor voids (underneath floors)
- within wall cavities (access permitting)
- within any other identified confined spaces or possible entry points for landfill gas

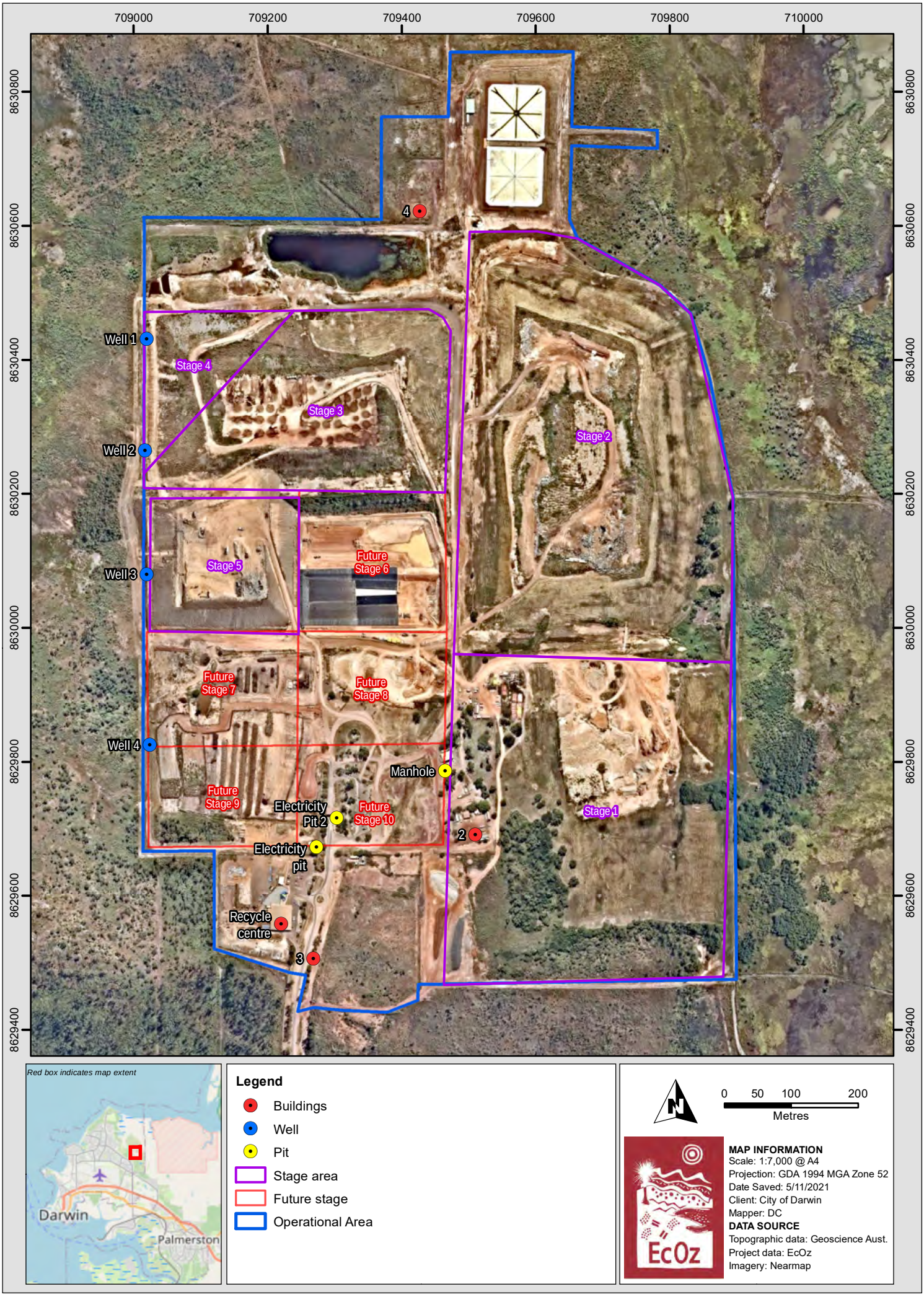
Record the type and location of each area monitored. Inspect the area and record observations (such as holes in floor for services pipes that may act as pathways for migration of landfill gas). Starting in the middle of each room, with the instrument probe at head height, monitor the ambient concentration of methane present. Next, monitor any locations/features as described in the list above. Record the highest concentration of methane found at any location in each room.

After several monitoring rounds and observations made by the sampler around the site, further buildings, structures, pits and underground services may be identified as requiring sampling and adding to the monitoring program. The addition of further identified sites needs to be considered in the LGMP review to be undertaken after a year of monitoring data collection.



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ21181 - Shoal Bay EMP update 2021\01 Project Files\Map of surface monitoring.mxd

Figure 6-1. Map of surface transects



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ21181 - Shoal Bay EMP update 2021\01 Project Files\Map of landfill gas monitoring site.mxd

Figure 6-2. Map of monitoring wells, buildings and subsurface monitoring sites

6.3 Health and safety during monitoring

Landfill gas monitoring presents a number a safety risks that need to be assessed and managed through a Job Safety Analysis (JSA) prior to each monitoring round. The site operator must be contacted prior to sampling to ascertain what operations will be occurring on the planned day of sampling and what precautions may be required. The site operator will likely require a copy of the completed JSA and related Safe Work Method Statements.

Potential hazards include:

- Asphyxiation from landfill gas emissions at sampling locations
- Heavy machinery working at the landfill tip face or any other areas across the landfill where sampling locations are situated
- Contaminants in leachate, soils or waste present at the site that may samplers ay come into contact with
- Fall, trips and slips on unstable/unlevel ground whilst undertaking transects across the landfill or sampling bores

7 ASSESSMENT CRITERIA

7.1 Assessment criteria and notification

The criteria for assessing landfill gas monitoring results is taken from the action levels for landfill gas set out in Table 6.4 of the EPA Victoria (2015) publication *Best Practice Environmental Management; Siting, design, operation and rehabilitation of landfills*. These are listed below in Table 7-1.

If these assessment criteria are exceeded, the NT EPA must be notified within 24 hours. The notification is also to advise what action will be taken to address the matter, what further testing will be done to demonstrate effectiveness of the works, anticipated time frame for the works, or when a detailed landfill gas remediation action plan would be prepared and forwarded to NT EPA.

Table 7-1. Landfill gas assessment criteria

Location:	Surface transects	Monitoring wells	Pits/Buildings
Trigger criteria:	CH_4 in air (50 mm above landfill surface): >100 ppm over final capped landfill >200 ppm over intermediate cover Dead vegetation, cracks in landfill capping/cover, odour	CH_4 >1.0 % v/v, or CO_2 above background >1.5% v/v	Pits and enclosed spaces: CH_4 >10,000 ppm Buildings and structures: CH_4 >5,000 ppm

8 RECORD-KEEPING AND REPORTING

8.1 Database

All data measured during each sampling round must be entered into the database, which will also include the assessment criteria values to allow rapid comparison between measured concentrations and these values. Data entry should be checked for any errors once all data has been entered.

8.2 Reporting

Following each monitoring round, results should be interpreted and analysed to identify long-term trends and/or significant changes between sampling events. Any concerning or erroneous results should be checked by conducting an extra sampling round immediately. If the concerning result is verified, the NT EPA should be advised and the cause of the result investigated. Similarly, if a concerning long-term trend is identified, the NT EPA should be notified, and the cause investigated and addressed.

Monitoring results must be provided to the NT EPA annually in a 'Monitoring Report' submitted by the due date listed in EPL188. This report must provide the raw data, plots of the data over time, and an analysis and interpretation of what the results mean. This analysis and interpretation should be conducted by a suitably qualified professional experienced in landfill gas monitoring.

8.3 Monitoring review

Following one year of data collection, this LGMP will require review, and the sampling sites, frequency of sampling, sampling methods etc may need adjustment based on the results. The CSM and risk assessment presented in Section 5 will also need to be reviewed and updated based on monitoring results.

A detailed operating procedure covering the reviewed and updated monitoring program will be developed that includes the specifications and use of the gas monitoring instrumentation and survey methods. This will allow for the rapid and standardised training of field-technicians in the method and ensure a consistent approach.

The updated LGMP will also provide more prescriptive detail of how the monitoring results are to be analysed, presented and reported.

9 REFERENCES

Bureau of Meteorology (2021) Climate Data Online – Darwin Airport Station 014015. [online] Available at: http://www.bom.gov.au/climate/data/ [Accessed 29 October 2021]

EcOz (2020). *Shoal Bay Waste Management Facility, Water quality monitoring data review, 2016 – 2020*, August 2020, Report prepared by EcOz Environmental Consultants Pty Ltd (EcOz) for City of Darwin.

EPA Victoria (2015). *Best Practice Environmental Management; Siting, design, operation and rehabilitation of landfills*, Publication 788.3, August 2015, Environment Protection Authority (EPA) Victoria, Victoria State Government, Carlton, Victoria.

EPA Victoria (2018). *Landfill gas fugitive emissions monitoring guideline*, Publication 1684, February 2018, Environment Protection Authority (EPA) Victoria, Victoria State Government, Carlton, Victoria.

Golder (2016a). *Final Landform Geometry Options Review, Future Landfill Stages 5 to 10, Shoal Bay Waste Management Facility*, May 2016, Letter prepared by Golder Associates Pty Ltd (Golder) for City of Darwin.

Golder (2016b). *Landfill Development Plan, Stage 5 to Stage 10 General Waste Cells, Shoal Bay Waste Management Facility, Darwin,* August 2016, Report prepared by Golder Associates Pty Ltd (Golder) for City of Darwin.

Golder (2020). *Water Balance, Leachate and Stormwater Management Strategies Shoal Bay Landfill, Darwin*, July 2020, Report prepared by Golder Associates Pty Ltd (Golder) for City of Darwin.

IPCC (2006). *Guidelines for National Greenhouse Gas Inventories, Volume 5 - Waste. Chapter 3- Solid Waste Disposal.* [Online], Intergovernmental Panel on Climate Change (IPCC), obtained from: https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html [Accessed: 7 September, 2021].

NT EPA (2013). *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites in the Northern Territory*, January 2013, Northern Territory Environment Protection Authority (NT EPA), Northern Territory Government, Darwin, NT.

URS (2015). *Shoal Bay Waste Disposal Site, Hydrogeological Investigation*, November 2015, Report prepared by URS Australia Pty Ltd for John Holland Pty Ltd.

URS (2016a). Shoal Bay Waste Disposal Site, Conceptual Site Model, February 2016, Report prepared by URS Australia Pty Ltd for John Holland Pty Ltd.

URS (2016b). *Shoal Bay Waste Disposal Site Water Monitoring Plan*, March 2016, Report prepared by URS Australia Pty Ltd for John Holland Pty Ltd.

WCG (2020). *Shoal Bay Waste Management Facility Environmental Management Plan Leachate Treatment and Irrigation,* July 2020, Prepared by Water and Carbon Group Pty Ltd (WCG) for City of Darwin.

APPENDIX A GROUNDWATER LEVELS AND FLOWS TAKEN FROM ECOZ 2020

Shoal Bay Waste Management Facility

Water quality monitoring data review 2016 - 2020

Report prepared for City of Darwin



www.ecoz.com.au

DOCUMENT CONTROL RECORD

Job	EZ20054
Document ID	190431-65
Author(s)	Emma Smith, Adele Faraone, Emma Lewis

DOCUMENT HISTORY

Rev	Reviewed by	Approved by	Issued to	Date
1	Corinne Hutchinson	Corinne Hutchinson	City of Darwin	1 July 2020
2	Corinne Hutchinson	Corinne Hutchinson	City of Darwin	12 August 2020

Recipients are responsible for eliminating all superseded documents in their possession.

EcOz Pty Ltd.
ABN: 81 143 989 039
Level 1, 70 Cavenagh Street
DARWIN NT 0800
GPO Box 381, Darwin NT 0800

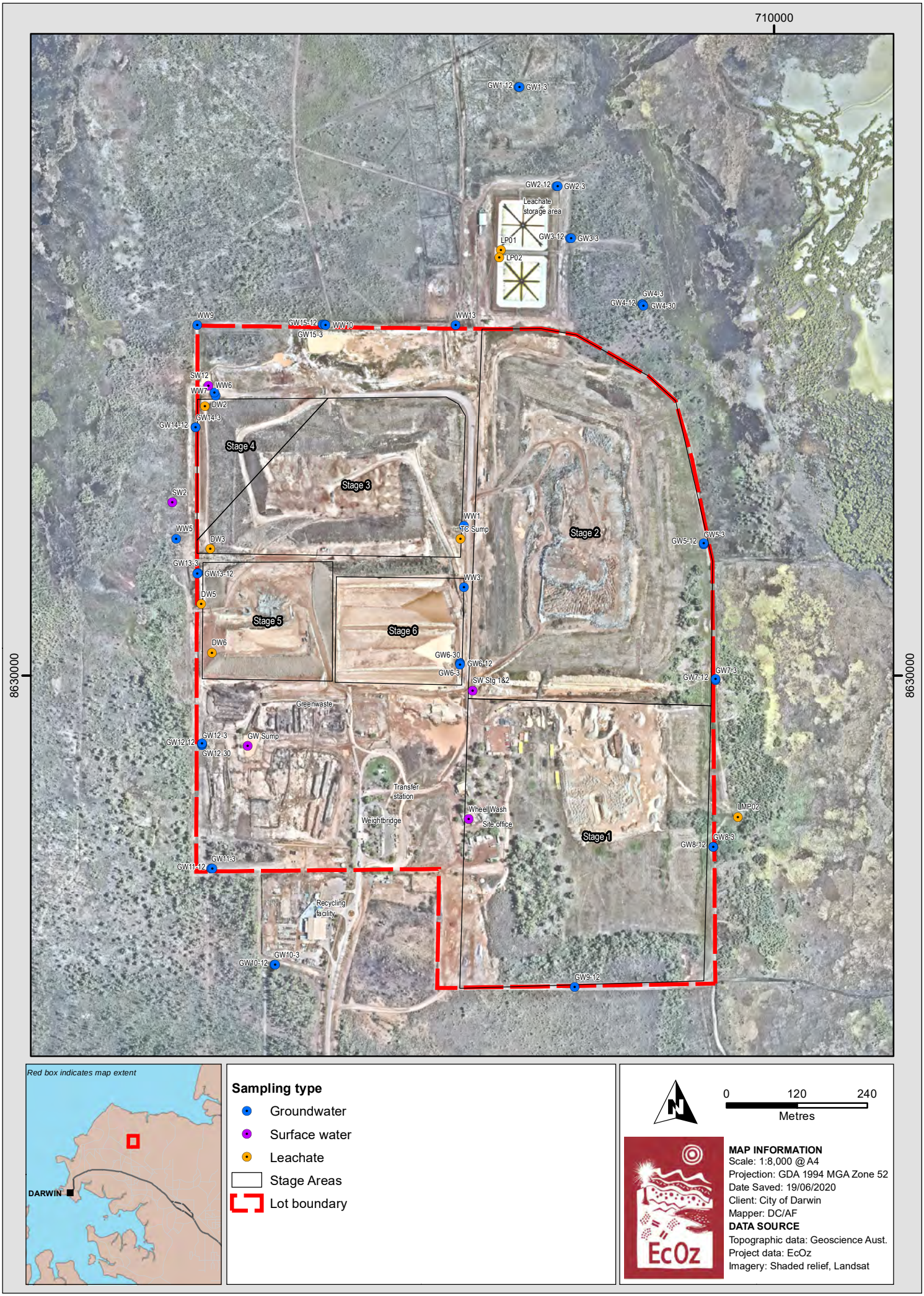
Telephone: +61 8 8981 1100
Email: ecoz@ecoz.com.au
Internet: www.ecoz.com.au

APPROVED COMPANY AS/NZS 4801 Occupational Health & Safety Management Systems QMS Certification Services
APPROVED COMPANY ISO 9001 Quality Management Systems QMS Certification Services
APPROVED COMPANY ISO 14001 Environmental Management Systems QMS Certification Services

RELIANCE, USES and LIMITATIONS

This report is copyright and is to be used only for its intended purpose by the intended recipient, and is not to be copied or used in any other way. The report may be relied upon for its intended purpose within the limits of the following disclaimer.

This study, report and analyses have been based on the information available to EcOz Environmental Consultants at the time of preparation. EcOz Environmental Consultants accepts responsibility for the report and its conclusions to the extent that the information was sufficient and accurate at the time of preparation. EcOz Environmental Consultants does not take responsibility for errors and omissions due to incorrect information or information not available to EcOz Environmental Consultants at the time of preparation of the study, report or analyses.



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20036 - Shoalbay Water Monitoring 2020-2021\01 Project Files\Figure 2-1. Monitoring site locations.mxd

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

Table 4-1. Groundwater monitoring bore details.

[1] *"Time of year sampling usually possible", is based on average, to above average, rainfall year i.e. 2016/17 and 2017/18 wet seasons. The 2018/19 and 2019/20 wet seasons were below average.*

[2] *Top of casing (TOC) PVC bore casing; standing water levels (SWLs) measured during monitoring rounds are measured from this point.*

[3] *Top of outer steel casing around PVC bore casing to protect the top of the bore.*

Bore ID	Easting	Northing	Location	TOC[3] outer elevation mAHD	TOC[2] elevation mAHD	Ground elevation mAHD	Screened interval mBGL	Screened lithology	Time of year sampling usually possible[1]	Exceptions to usual sampling
GW1-3	709564	8631004	On floodplain, 190 m north of leachate storage area	8.71	8.63	8.02	1.5-3	Siltstone	Only mid wet season (January-March)	Bore was dry for entire 2019/20 wet season.
GW1-12	709566	8631004		8.71	8.59	8.00	9-12	Siltstone	All wet season (December–May)	
GW2-3	709629	8630835	On north-east corner of leachate storage area	8.06	7.94	7.33	1.5-3	Siltstone	Only mid wet season (January-March)	Bore was dry for entire 2018/19 and 2019/20 wet seasons.
GW2-12	709631	8630835		8.08	7.94	7.28	9-12	Siltstone	All wet season and early dry season (November–July)	
GW3-3	709652	8630746	East of leachate storage area	9.94	9.80	9.12	1.5-3	Siltstone	Only mid wet season (January-March)	Bore was dry for entire 2018/19 and 2019/20 wet seasons.
GW3-12	709654	8630746		9.87	9.82	9.10	9-12	Siltstone	All wet season and early dry season (November–July)	
GW4-3	709775	8630634	On floodplain, north of Stage 2 landfill	5.65	5.49	4.88	1.5-3	Siltstone	All wet season (December-April)	GW4 bores were inaccessible due to wet ground conditions and could not be sampled January 2019, January 2020 and March 2020.
GW4-12	709776	8630633		5.61	5.44	5.36	9-12	Siltstone	All wet season and early dry season (November–July)	
GW4-30	709777	8630631		5.50	5.20	5.33	15-21	Gravelly sand, Sandstone	Throughout the year Groundwater is usually at top of casing or overflowing during wet season (December – May)	
GW5-3	709880	8630224	East of Stage 2 landfill	5.51	5.41	4.70	1.5-3	Siltstone	All wet season (December-April)	Bore was dry most of 2018/19 and 2019/20 wet seasons and could only be sampled March 2019, February 2020 and March 2020.
GW5-12	709880	8630226		5.48	5.33	4.70	9-12	Siltstone, Gravelly Clay	Throughout the year Groundwater is usually at top of casing or overflowing during wet season (December – May)	

Bore ID	Easting	Northing	Location	TOC[3] outer elevation mAHD	TOC[2] elevation mAHD	Ground elevation mAHD	Screened interval mBGL	Screened lithology	Time of year sampling usually possible[1]	Exceptions to usual sampling
GW6-3	709464	8630022	Centre of SBWMF, south of Stage 3, south-west of Stage 2 and north-west of Stage 1	14.39	14.24	13.60	1.5-3	Gravelly Sandy Silt, Siltstone	All wet season (December-April)	Bore was dry most of 2018/19 wet season and could only be sampled March 2019. Decommissioned in early Sept 2019, and not sampled during 2019/20 wet season.
GW6-12	709464	8630021		14.37	14.18	13.66	9-12	Siltstone	Throughout the year	Can be dry at end of long dry season. Was dry August 2019. Decommissioned in early Sept 2019, so not sampled during 2019/20 wet season.
GW6-30	709464	8630018		14.24	14.12	13.60	17.7-23.7	Siltstone, Sandstone	Throughout the year	Can be dry at end of long dry season. Was dry December 2017 and December 2018. Decommissioned in early Sept 2019, and not sampled during 2019/20 wet season.
GW7-3	709900	8629992	South-east of Stage 2 and north-east of Stage 1	5.18	5.03	4.33	1.5-3	Siltstone	All wet season (November - April)	GW7 bores were inaccessible due to wet ground conditions and could not be sampled January 2020
GW7-12	709900	8629994		5.16	5.08	4.33	9-12	Siltstone, Sandy Silt	Throughout the year Groundwater is usually at top of casing or overflowing during wet season (December – May)	
GW8-3	709896	8629708	East of Stage 1	5.42	5.28	4.65	1.5-3	Claystone	All wet season and early dry season (November–July) Groundwater can be at top of casing or overflowing during mid-wet season (January - March)	
GW8-12	709896	8629708		5.37	5.22	4.62	9.1-12.1	Claystone, Sandstone	Throughout the year	
GW9-12	709660	8629469	On southern boundary of SBWMF – up-gradient of all SBWMF operations and infrastructure	16.18	15.93	15.44	9-12	Siltstone	All wet season (November - April)	Bore was dry most of 2019/20 wet season and could only be sampled March 2020.
GW10-3	709147	8629507	South of SBWMF – up-gradient of all SBWMF operations and infrastructure	18.12	18.06	17.32	1.5-3	Siltstone	Only mid wet season (January-March)	Bore was dry for entire 2019/20 wet season.
GW10-12	709149	8629507		18.13	17.98	17.37	9.1-12.1	Siltstone	All wet season (November - April)	Bore was dry most of 2018/19 and 2019/20 wet seasons and could only be sampled March 2019 and March 2020.

Bore ID	Easting	Northing	Location	TOC[3] outer elevation mAHD	TOC[2] elevation mAHD	Ground elevation mAHD	Screened interval mBGL	Screened lithology	Time of year sampling usually possible[1]	Exceptions to usual sampling
GW11-3	709040	8629671	South-west corner of SBWMF	13.50	13.38	12.72	1.5-3	Siltstone	Only mid wet season (January-March)	Bore was dry for entire 2019/20 wet season.
GW11-12	709042	8629671		13.52	13.38	12.84	9-12	Siltstone, Sandstone	All wet season and early dry season (November–July)	
GW12-3	709024	8629881	West of green waste area	12.20	12.07	11.44	1.5-3	Siltstone	All wet season (December - April)	Bore was dry for entire 2019/20 wet season.
GW12-12	709024	8629883		12.22	12.04	11.50	9-12	Siltstone	All wet season and early dry season (November–June)	
GW12-30	709024	8629885		12.21	12.05	11.55	24-30	Sandstone	Throughout the year	Bore was dry in December 2018.
GW13-3	709017	8630175	On south-west corner of Stage 3/4 and north-west corner of Stage 5 landfills	12.93	12.88	12.32	3-4.5	Siltstone	Only mid wet season (January-March)	Bore was dry for entire 2018/19 and 2019/20 wet seasons.
GW13-12	709016	8630174		12.91	12.86	12.25	10-13.5	Siltstone	All wet season and early dry season (November–June)	Bore was dry most of 2018/19 and 2019/20 wet seasons and could only be sampled March 2019 and January 2020.
GW14-3	709013	8630423	West of Stage 4 landfill	6.78	6.73	6.09	1.5-3	Siltstone	All wet season (December - April)	Bore was dry most of 2018/19 wet season and could only be sampled March 2019. Bore was dry for entire 2019/20 wet season.
GW14-12	709013	8630424		6.77	6.64	6.08	9-12	Siltstone	Throughout the year	Bore was dry between September 2018 and January 2019. Also dry between June 2019 and January 2020.
GW15-3	709230	8630599	North of Stage 3/4 landfill	11.27	11.06	10.44	1.5-3	Siltstone	Only mid wet season (January-March)	Bore was dry most of 2018/19 and 2019/20 wet seasons and could only be sampled March 2019 and March 2020.
GW15-12	709233	8630599		11.20	11.04	10.44	9-12	Siltstone	All wet season and early dry season (November–June)	
WW1	709471	8630151	Between Stage 3 and Stage 2 landfills		16.60	15.90	0-6.3	-	Usually always dry	Bore could be sampled after very wet periods in January 2017, January 2018 and March 2018.
WW3	709471	8630151	South-east corner of Stage 3 and west of Stage 2		16.38	15.68	0-20.3	-	Only mid wet season (January-March)	Bore was dry most of 2018/19 and 2019/20 wet seasons and could only be sampled March 2019 and March 2020.
WW5	708980	8630234	West of Stage 3/4 landfill		8.34	7.64	0-6.0	-	All wet season (December - April)	Bore was dry for entire 2018/19 and 2019/20 wet seasons.
WW6	709047	8630478	North-west corner of Stage 3/4 landfill		7.46	6.76	0-20.4	-	Throughout the year	
WW7	709045	8630483			7.45	6.75	0-5.8	-	All wet season (December - April)	Bore was dry most of 2018/19 wet season and could only be sampled March 2019. Bore was dry for entire 2019/20 wet season.

Bore ID	Easting	Northing	Location	TOC[3] outer elevation mAHD	TOC[2] elevation mAHD	Ground elevation mAHD	Screened interval mBGL	Screened lithology	Time of year sampling usually possible[1]	Exceptions to usual sampling
WW9	709016	8630598	North-west corner of SBWMF		7.09	6.39	1-9.8	Siltstone	All wet season and early dry season (November–July)	Bore could not be accessed for sampling February 2017. Was dry early wet season in 2018/19 and 2019/20, and could only be sampled January and March 2019 and January and March 2020.
WW10	709235	8630598	On northern boundary of SBWMF		10.92	10.21	1-9.7	Siltstone	All wet season and early dry season (November–June)	Bore was dry most of 2018/19 wet season and could only be sampled January and March 2019. Bore was dry for entire 2019/20 wet season.
WW13	709457	8630598	On northern boundary of SBWMF	+0.8	+0.7	Not available	1-10	Siltstone	All wet season (January -April)	Bore was dry for entire 2018/19 wet season and could only be sampled once during 2019/20 wet season (March 2020). .

6 GROUNDWATER LEVELS AND FLOWS

The analysis of groundwater levels and flows has been divided into the following two sections;

- Investigation of groundwater levels across the site and connectivity between shallow and deeper aquifers
- Analysis of groundwater flow directions across the site and potential implications for leachate migration.

As discussed in Section 3.4 detailed analysis of the lithology that lay beneath SBWMF, is discussed in detail in the *Shoal Bay Waste Disposal Site, Hydrogeological Investigation* (URS 2015). Geology of the site is generally comprised top soils (silts and clays), generally underlain by weathered (lateritised) siltstone over most of the site, and claystone east of Stage 1. Beneath this, sandstone was encountered at depths of 9 to 20 m below the surface across most of the site. Groundwater exists within the unconsolidated overlying sediments, and fractured and weathered underlying bedrock.

The shallow (water table) aquifer is recharged by the direct infiltration of rainfall and runoff, and groundwater levels vary seasonally in accordance with rainfall totals. The higher yielding weathered and fractured carbonate rock aquifers that occur in the wider region commonly yield greater than 5 L/sec.

6.1 Seasonal groundwater levels and connectivity

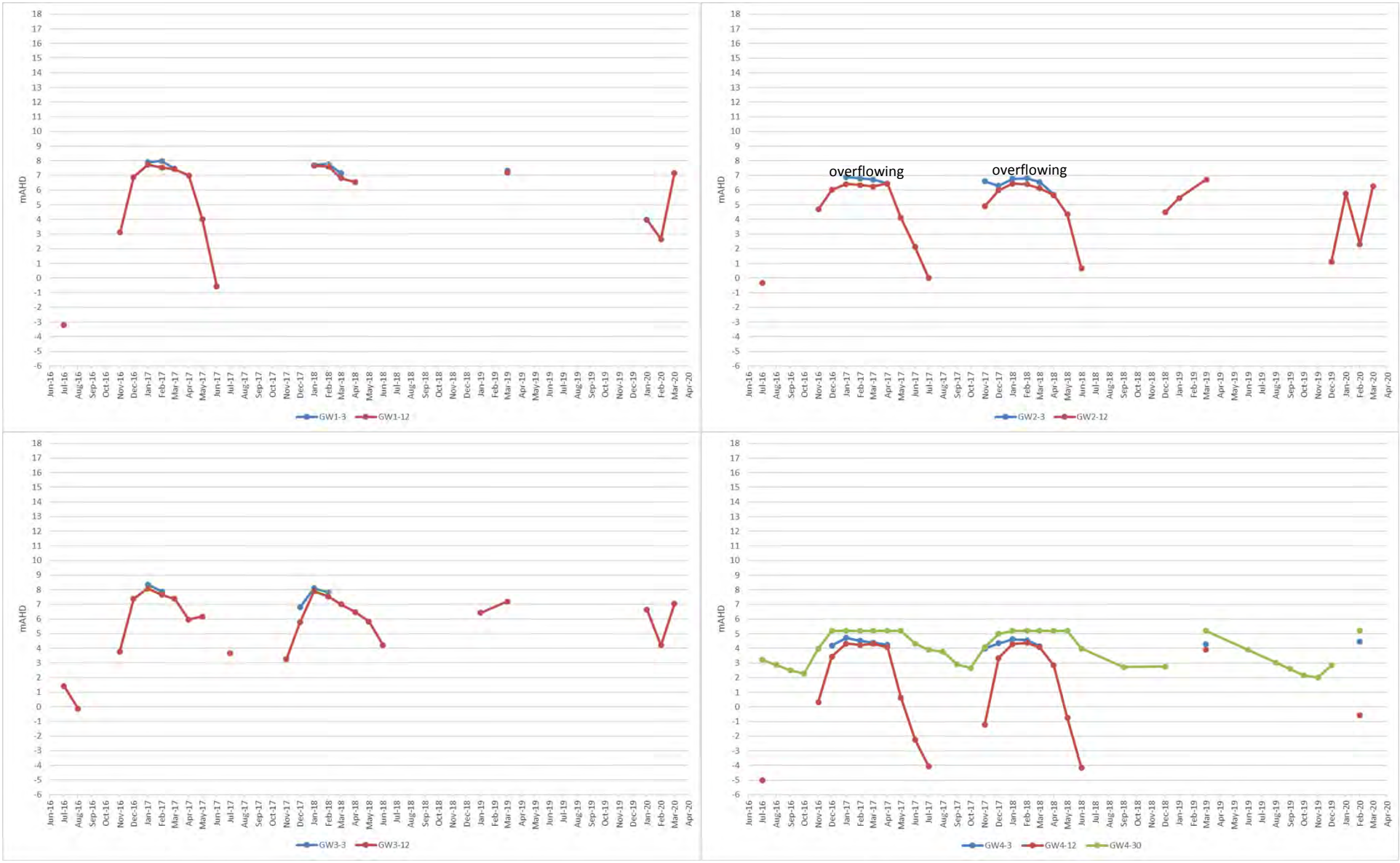
As part of the monitoring program, the standing water levels (SWLs) were measured in the bores below the top of casing (TOC). For the purposes of this report, these values have been converted to mAHD to allow for a comparison of groundwater levels across the site. Figure 6-1 shows the graphed groundwater levels in mAHD at each set of bores from July 2016 and March 2020. Analysis of these graphs identifies three key patterns, which are summarised in Table 6-1, below.

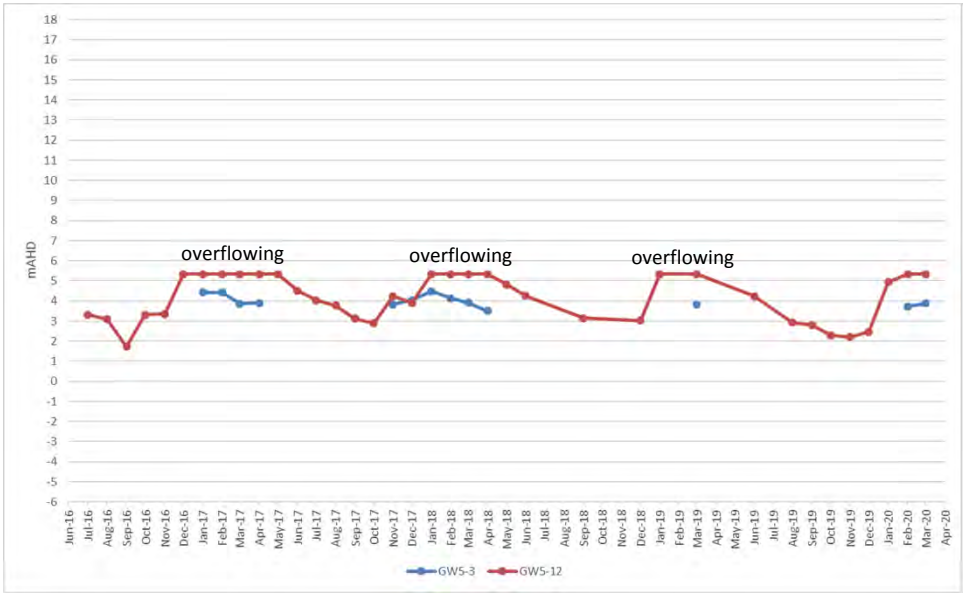
Table 6-1. Seasonal groundwater level trends

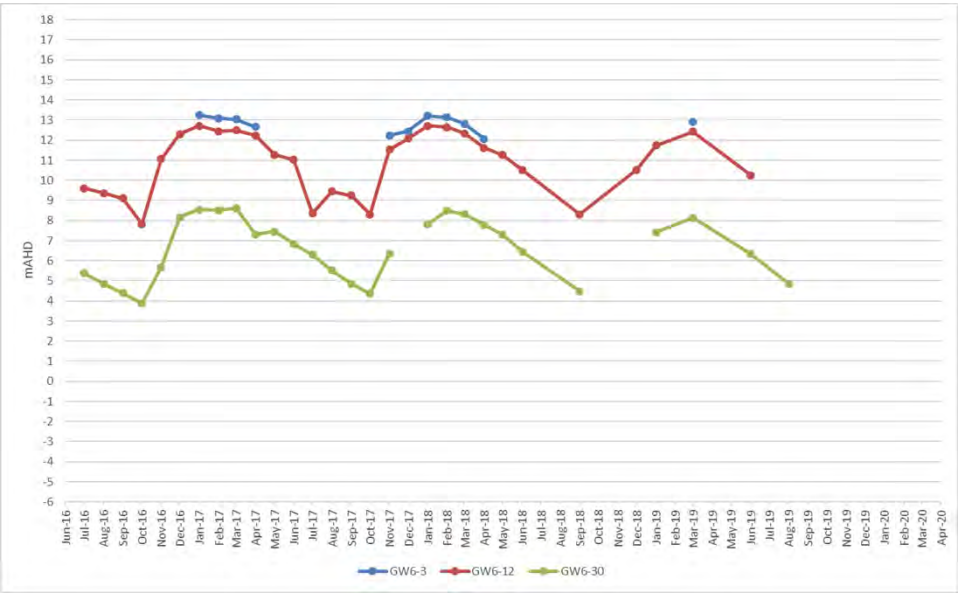
Bores	Trend	Explanation
GW1-3, GW1-12, GW2-3, GW2-12, GW3-3, GW3-12 GW4-3, GW5-3, GW6-3, GW7-3, GW8-3, GW9-12, GW10-3, GW10-12, GW11-3, GW11-12, GW12-3, GW13-3, GW13-12, GW14-3, GW14-12, GW15-3, GW15-12, WW1, WW3, WW5, WW6, WW7, WW9 and WW10	Constantly dry in the dry season, with recharge occurring in the wet season.	These bores are located in the shallow surface water aquifer, whereby recharge occurs via direct infiltration from rainfall and runoff. Water levels are higher during the wet season, with a sharp drop once dry season begins, impacting both the 3 m and 12 m bores.
GW5-12, GW7-12 and GW8-12	12 m bores that are rarely dry and follow distinctive seasonal trend.	All bores are located on the eastern boundary of SBWMF and are likely to be impacted by the fractured carbonate rock aquifers, located south-east of the site. These 12 m bores are rarely dry and during the wet season, water levels reach 5 mAHD and in the dry season sit between 1-2 mAHD. GW5-12 and GW7-12 consistently overflow in wet season, likely due to their topographic positioning. The 3 m bores nested at these sites are listed above and are dry during the dry season and therefore do not follow the same seasonal trend.

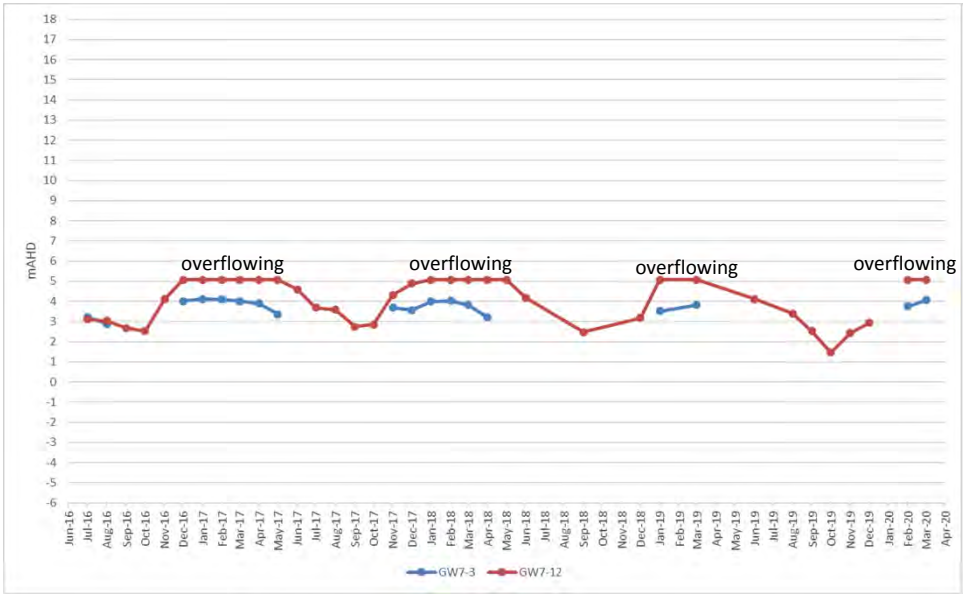
Bores	Trend	Explanation
GW4-12, GW4-30, GW6-12, GW6-30 (now decommissioned) and GW12-12, GW12-30	Distinctive seasonal patterns are observed for these 12 m and 30 m bores. Bore are never dry throughout the year.	These bores are scattered across the site. The three 30 m bores are located within a sandstone aquifer. Bore logs for GW4-30 show a clear confining clay layer, which applies pressure to the groundwater under this layer, creating higher hydraulic head within the bore itself, causing it to consistently overflow during heavy rainfall events. GW6-30 and GW12-30 do not have the same confining layer and therefore do not overflow. GW6-30 is observed to be located in a different aquifer than GW6-3 and GW6-12. The difference in water levels during the wet season are significantly lower (approximately 4.5 m). The 3 m bores nested at these sites are listed above and are dry during the dry season and therefore do not follow the same seasonal trend.

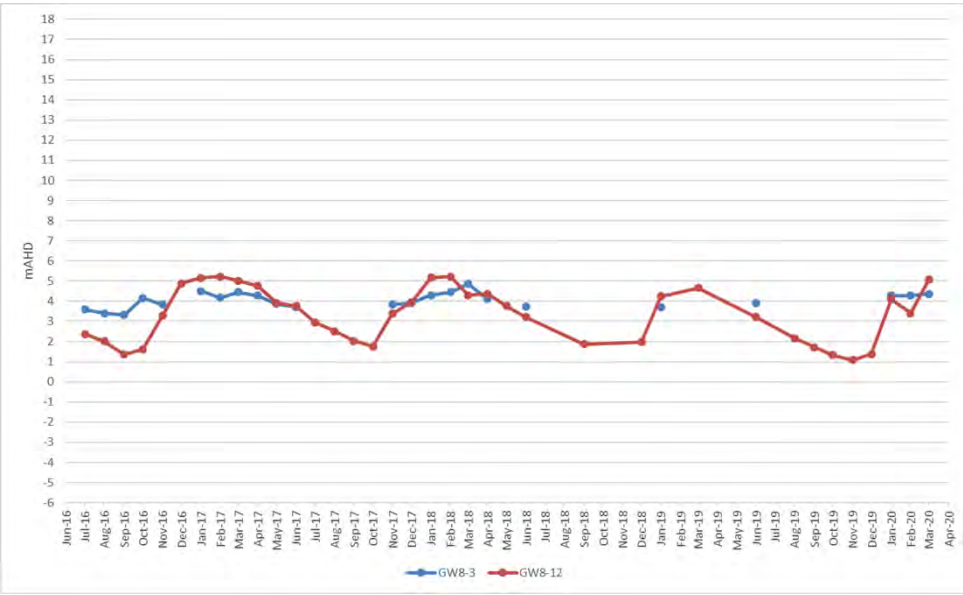
Figure 6-1. Graphs of groundwater levels in mAHD measured in all bores July 2016 to March 2020



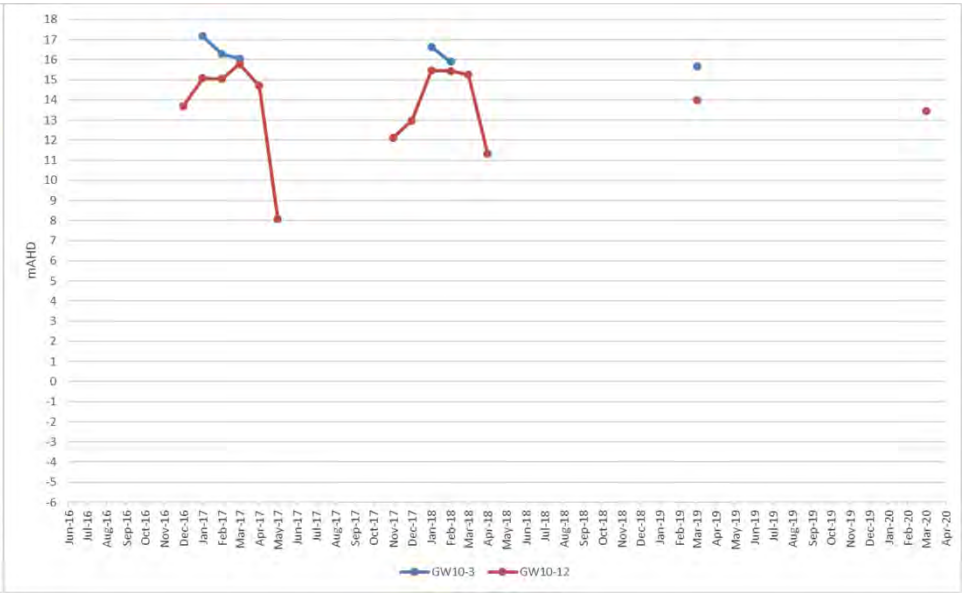

mAHD
overflowing
overflowing
overflowing
GW5-3
GW5-12

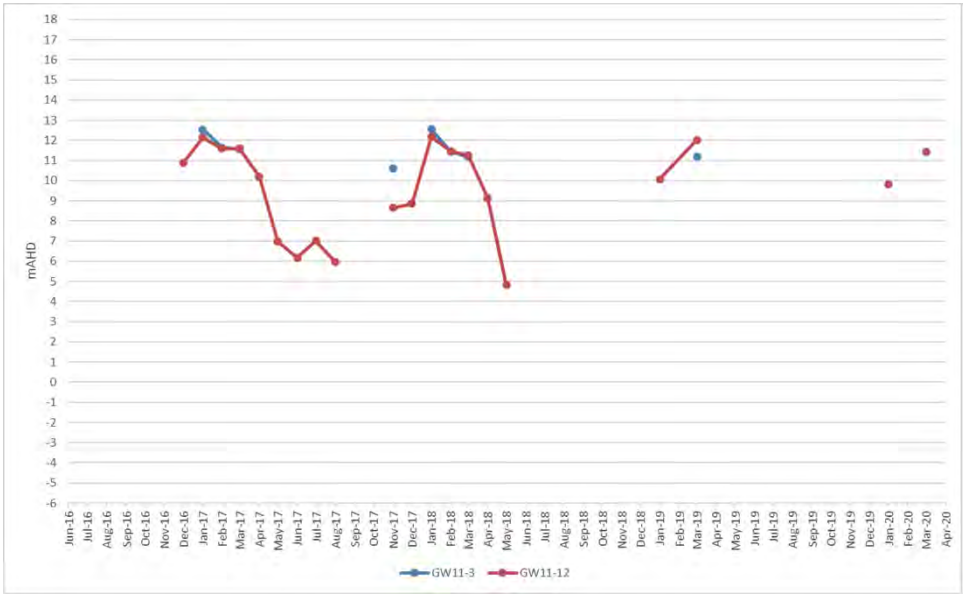

mAHD
GW6-3
GW6-12
GW6-30


mAHD
overflowing
overflowing
overflowing
overflowing
GW7-3
GW7-12


mAHD
GW8-3
GW8-12

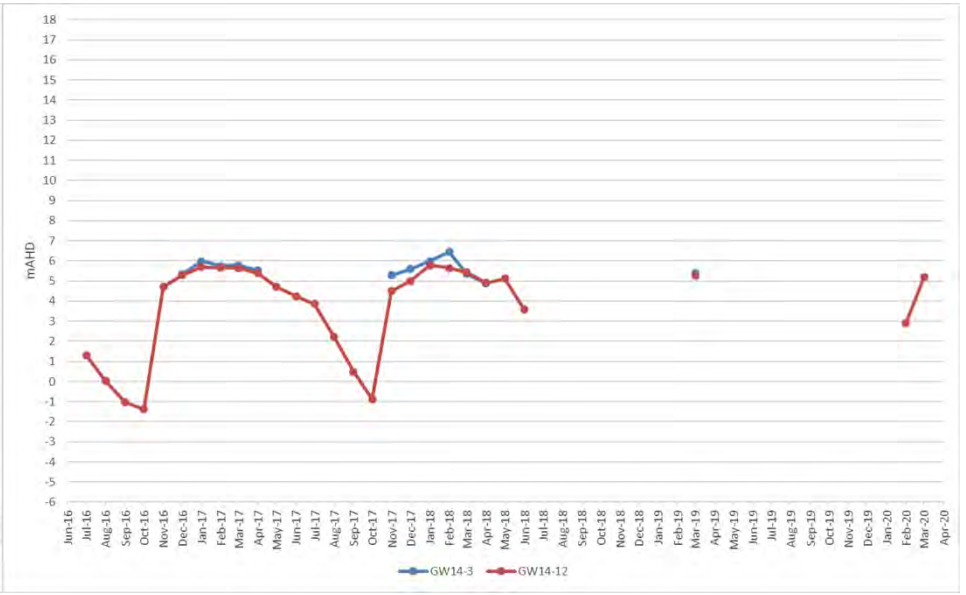

mAHD
GW9-12


mAHD
GW10-3
GW10-12

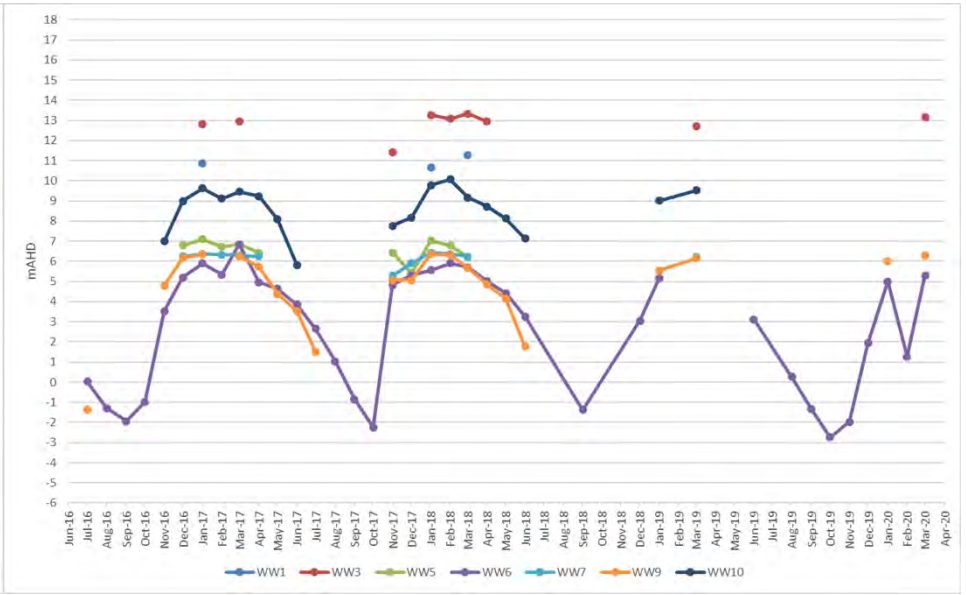

mAHD
GW11-3
GW11-12


mAHD
GW12-3
GW12-12
GW12-30


mAHD
GW13-3
GW13-12


mAHD
GW14-3
GW14-12


mAHD
GW15-3
GW15-12


mAHD
WW1
WW3
WW5
WW6
WW7
WW9
WW10

6.2 Groundwater flow direction

Groundwater level and flow maps were developed to display the hydraulic behaviour of groundwater using the 12 m deep bores, during the mid-wet season (January 2017) and mid-dry season (June 2017). SBWMF topographically, sits on a low-lying peninsula with tributaries from the Leanyer Swamp located on the western and eastern boundaries of the site.

General patterns observed in Figure 6-2 and Figure 6-3, illustrate that the groundwater contours mimic the topography of the site, with higher groundwater levels through the centre of the site (i.e. GW6, GW10, GW15, WW3 and WW10) and lower levels on the eastern and western boundaries (i.e. GW4, GW5, GW7, GW8, GW14). Groundwater is flowing in a western, eastern and north-eastern direction, towards the Leanyer Swamp tributaries.

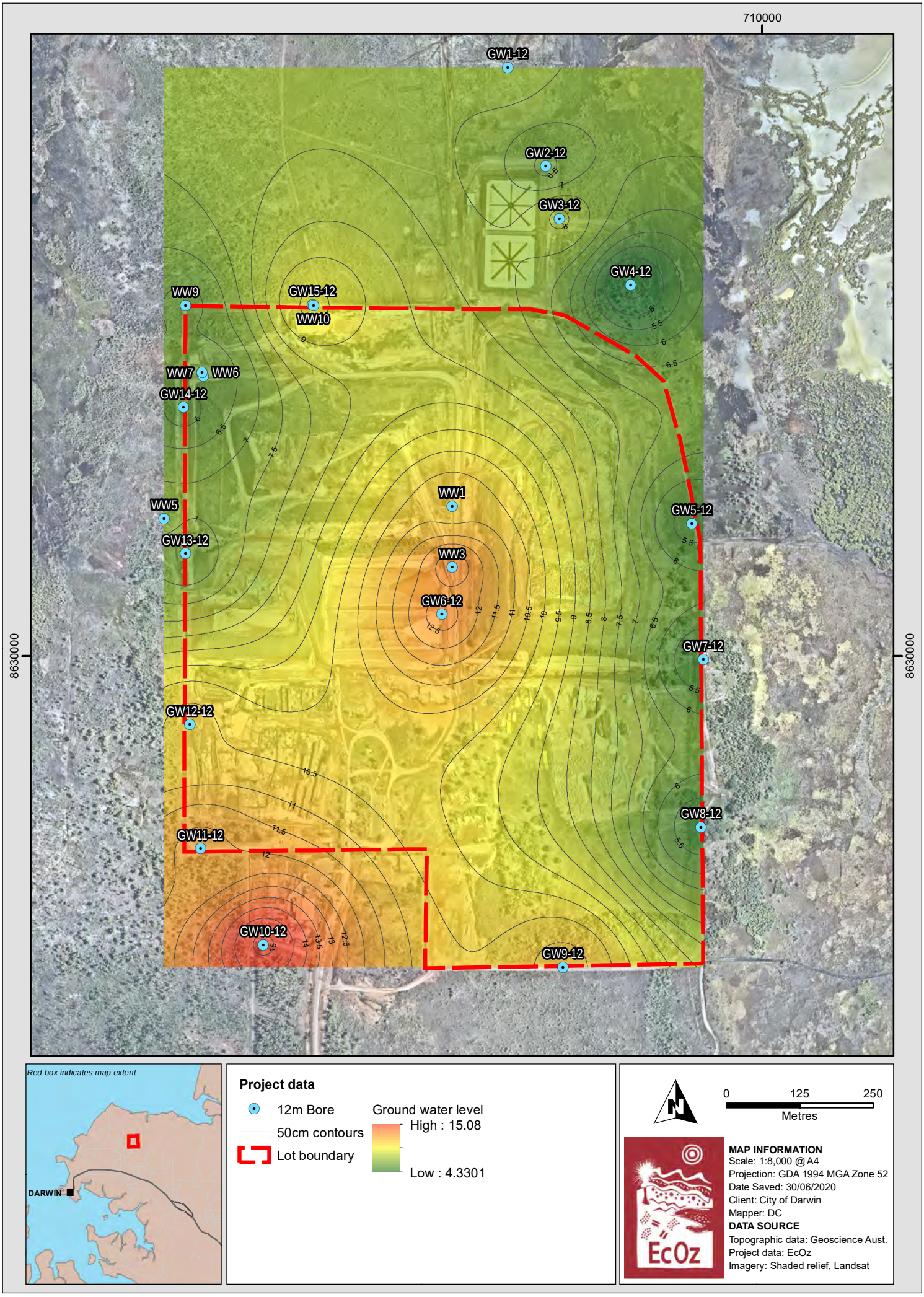
Figure 6-2 illustrates the groundwater contours in January 2017 (mid-wet season). During this sampling period, standing water levels (SWLs) were measured at 22 of the 12 m bores, providing an adequate overview of the hydraulic behaviours of the groundwater across the site, including its boundaries. Groundwater levels were highest at GW10-12 and GW6-12, with a groundwater level of 15.08 mAHD and 12.71 mAHD, respectively, and lowest at GW4-12, with a level of 4.33 mAHD. Groundwater levels across the site generally remained quite consistent when compared with the topographic conditions.

Figure 6-3 illustrates the groundwater contours in June 2017 (mid-dry season). During this sampling period, SWLs were measured at 15 of the 12 m bores. In comparison with the January 2017 samples, the reduced number of samples taken skews the map slightly, and are not considered representative of the entire site's groundwater behaviour during the dry season. However, similar trends are observed to that of the wet season. Groundwater levels were highest at GW6-12, with a groundwater level of 11.03 mAHD and lowest at GW4-12, with a level of -2.24 mAHD. The map illustrates a steep drop in groundwater levels during the dry season, from the centre of the site, towards the western, eastern and north-eastern boundaries.

Comparison between the levels of GW6-12 in both wet and dry seasons, indicate the potential for artificially elevated groundwater levels during the dry season (difference of almost 1.7 m), compared with a significant change in groundwater levels in GW4-12 between seasons of approximately 6.5m. Given the topographic positioning of GW10-12 (i.e. located on higher topography at the southern boundary of the site), the seasonal variation observed is to be expected.

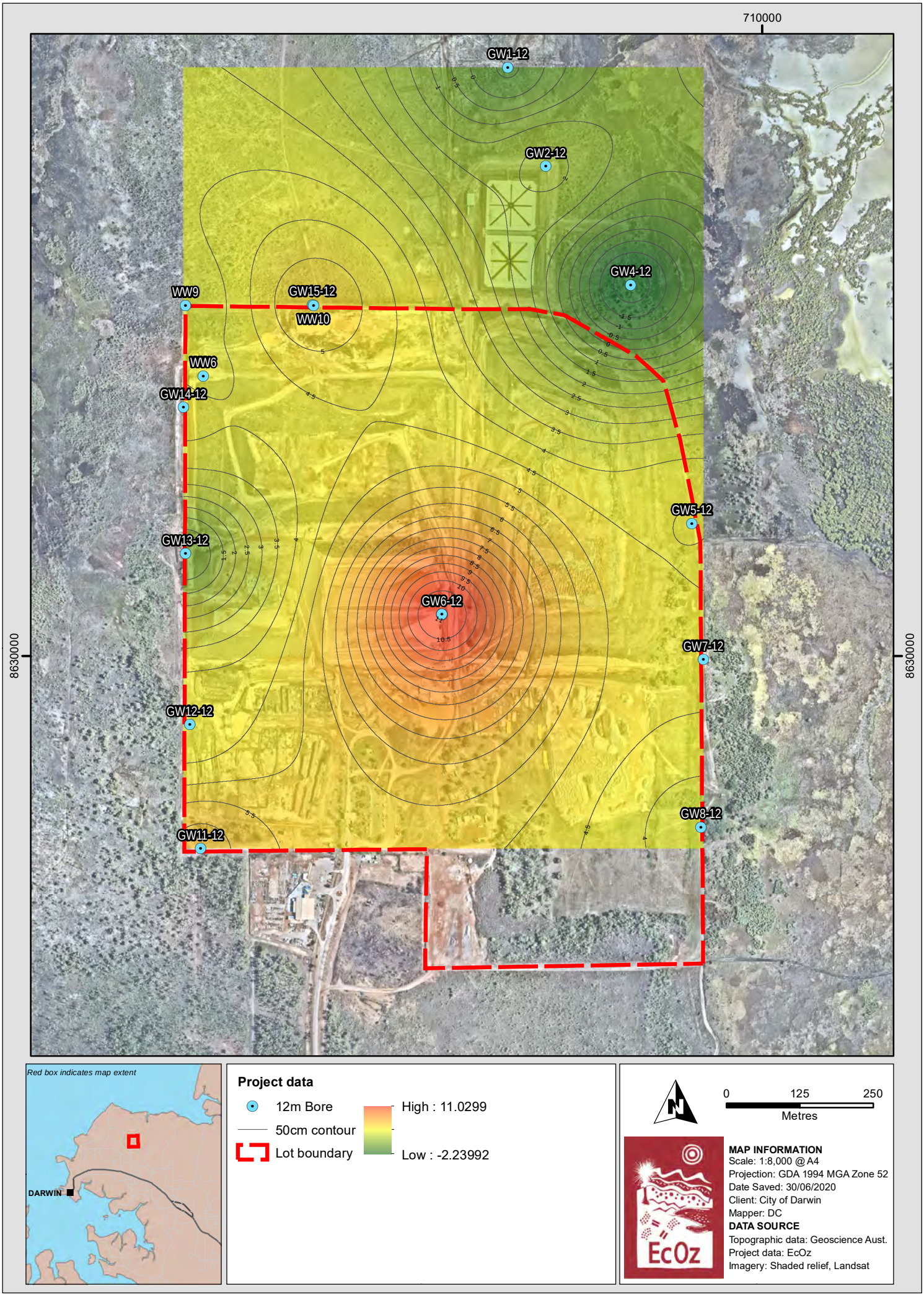
It is likely that groundwater mounding is also present, which can be attributed to the shape of the landfill cells. The presence of a shallow groundwater table and overflowing of some bores is resulting in groundwater mixing with leachate at surface level in some areas of the site. Figures 3 to 6 in the *Shoal Bay Site Conceptual Site Model Report,* written by URS (2016), highlight certain areas where this could be occurring. The report also highlights areas where inferred leachate affected groundwater is present across the site, i.e. underneath Stages 1, 2 and 3 of the landfill.

Leachate migration from the site is possible, considering the topographic conditions of SBWMF and historic landfilling activities on the western boundary of the site. Where groundwater is flowing along the eastern and north-eastern boundaries, those areas would also be of interest in regards to leachate detection and monitoring. Given the sensitive receiving environments for stormwater runoff and groundwater flow, outside of the SBWMF's boundaries (i.e. bushland and Leanyer Swamp), the results of Section 7 are crucial in determining the extent of (if any) leachate migration.



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20054 - Shoal bay data review and report\01 Project Files\Figure X-X. January 2017.mxd

Figure 6-2. Map of groundwater level contours in mAHD for January 2017 (mid-wet season).



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20054 - Shoal bay data review and report\01 Project Files\Figure X-X. June 2017.mxd

Figure 6-3. Map of groundwater level contours in mAHD for June 2017 (mid-dry season).

APPENDIX B MONITORING PROCEEDURES

Monitoring Instruments

Field monitoring of subsurface landfill gas concentrations will be carried out using an extractive landfill gas analyser, such as GA5000 Portable Gas Analyser. The instrument is capable of measuring CH_4, CO_2, O_2, H_2S, CO barometric pressure and relative pressure.

CH_4 concentrations at surface, buildings and pits will be undertaken using a low-concentration methane detector (category 2), such as the Geotech TDL-500 laser spectrometer. An anemometer will also be used for wind speed monitoring.

Monitoring Procedures

Prior to each monitoring event, the portable gas analyser will be calibrated in accordance with recommendations of the manufacturer. All the information related to the monitoring event will be registered in the 'Landfill Gas Monitoring Sheet' shown in Appendix C.

Surface emissions

The monitoring method used for surface emissions is known as walkover survey. The survey consists in monitoring CH_4 concentrations in air present above the cap or intermediate cover, while walking transects over them (EPA Victoria, 2018). Monitoring of surface emissions will be done in accordance with the methods described in Section 5.4 of the Victorian EPA *Landfill gas fugitive emissions monitoring guideline* (EPA Victoria, 2018).

Subsurface emissions

The procedure for monitoring subsurface emissions will follow the method described in Section 6.4 of the Victorian EPA *Landfill gas fugitive emissions monitoring guideline* (EPA Victoria, 2018).

Buildings and subsurface services

Based on the *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites in the Northern Territory* of the NT EPA, monitoring of buildings will be undertaken in all voids and areas in the basement and/or ground flow and wall cavities of the building. If possible, measurements will be made in each location before allowing ventilation to occur (e.g. measure under a door before opening).

The procedures for monitoring of buildings and subsurface services will follow the methods described in Sections 7.4 and 8.4 of the Victorian EPA *Landfill gas fugitive emissions monitoring guideline* (EPA Victoria, 2018).

Odour Monitoring

Daily site inspections will be part of the odour monitoring. The inspections will include the buildings that are part of the landfill gas monitoring sites. When odours are detected during these inspections, a written report will need to be done, including the location and time of detection. An investigation to identify the source of the odour will be investigated immediately.

Ambient odour assessments should be conducted by a suitably trained, calibrated and experienced person. Olfactory calibration should be conducted in accordance with the Australian standard AS4323.3.

APPENDIX C LANDFILL GAS SUBSURFACE MONITORING DATA SHEET

Site:			**Date:**		**Start time:**				**Finish time:**		
Monitoring personnel:			**Monitoring equipment and serial number:**						**Date of last calibration:**		
Atmospheric pressure at start (mb):			**Rising or falling:**						**Weather and ground conditions:**		
Bore ID	**Start time**	**Atmospheric pressure (mb)**	**Relative pressure (mb)**	**Peak (%v/v)**		**Min O_2 (%v/v)**	**Stabilised (%v/v)**				**Aspiration time when stabilised readings were taken (note if not stabilised)**	**Fluctuation (+/- %v/v) or direction and rate of change in concentration (+/- %v/v per 10 seconds)**	**Comments (bore condition)**
				CH_4	CO_2		CH_4	CO_2	O_2	Balance			
Other observations (e.g., changes in weather conditions while sampling)													

APPENDIX D INDEPENDENT EXPERT REVIEW

Andrew Balch
Director and Principal Consultant
Air Environment
andrew@airenvironment.com.au

Monday, 15 November 2021

Emma Smith
EcOz Environmental Consultants
Emma.smith@ecoz.com.au

Technical review of a Landfill Gas Monitoring Plan for Shoal Bay Waste Management Facility

Dear Emma,

Air Environment was commissioned by EcOz Environmental Consultants (EcOz) to conduct a technical review of a Landfill Gas Monitoring Plan (LGMP), prepared by EcOz, for the Shoal Bay Waste Management Facility (SBWMF). This letter provides the details of our technical review.

The SBWMF is operated by the City of Darwin and situated 13 km north-east of Darwin City, within Lot 3952, Town of Sanderson, in the suburb of Holmes. Site operations comprise the following facilities:

- Recycling centre
- Gatehouse and weighbridge
- Transfer station
- Inert waste disposal area
- Putrescible waste disposal area
- Green waste disposal and mulching operations
- Renewable energy facility, which harvests landfill gas to generate electricity via a 1.1 MW engine
- Existing leachate collection system and storage ponds
- Leachate treatment plant (under construction)
- Wash-down bay
- Contractor's operation depot
- Underground services

The LGMP has been designed to monitor surface emissions and sub-surface migration of landfill gas from the facility and assess the effectiveness of the landfill gas extraction system and control measures implemented by the site operators.

Air Environment has reviewed the Landfill Gas Monitoring Plan for the Shoal Bay Waste Management Facility prepared by EcOz, in light of the following guidelines:

- *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites in the Northern Territory*, NTEPA, 2013.
- *Landfill Gas Fugitive Emissions Monitoring Guideline*, Publication 1684, 2018.
- *Best Practice Environmental Management: Siting, design, operation and rehabilitation of landfills*, Publication 788.3, EPA Victoria, 2015.

A suitable monitoring plan should provide information on the objectives of the program and details of the site's operation in order to plan for monitoring key emission sources and assess the effects of the emissions. Key factors that influence the monitoring of landfill gas that should be addressed in the monitoring plan and during surveys include (EPA Victoria, 2018):

- Site features, including:
  - landfill size, layout, design and age
  - types of wastes accepted
  - geology and hydrogeology
  - the location of intermediate cover and final caps
  - location of sensitive receptors
  - leachate management
  - bore design, installation and location
  - training and experience of personnel undertaking the monitoring
  - topography
- Meteorological and environmental conditions (refer to Appendix A), including:
  - atmospheric pressure
  - rainfall
  - wind
  - frost
  - excessive vegetation
- The type of landfill gas monitoring being conducted:
  - landfill surface final cap and penetrations through the final cap
  - landfill surface intermediate cover and penetrations through the intermediate cover
  - subsurface geology (via appropriately designed, installed and sealed landfill gas monitoring bores)
  - subsurface services
  - buildings and structures.

Critical components that are required to be covered in the monitoring plan have been summarized in Table 1, with a notification of whether or not they have been adequately addressed.

Table 1 Key components to be covered in the LGMP

Components of a monitoring plan	Covered in LGMP	Section of report
Purpose/objectives of the program	Yes	1.1
Scope of the program	Yes	1.2
Description of site operations	Yes	3.1 - 3.8
Presentation of site operational maps identifying key activities and areas for monitoring	Yes	3.4, Figures 3-3, 3-4 and 3-5
Identification of location of potential landfill gas emission sources	Yes	5.2
Identification of potential areas where landfill gas accumulation may cause an impact to human health (e.g. asphyxiation) or environmental risk (e.g. explosion or fire)	Yes	5.4
Identification of potential gas migration pathways	Yes	5.3
Identification of off-site sensitive receptors	Yes	4.1, Table 4-1
Description of environmental conditions including climatology, sub-surface conditions (hydrogeology), surface water run-off and surrounding land uses	Yes	4.1 – 4.4

Components of a monitoring plan	Covered in LGMP	Section of report
Preparation of a Conceptual Site Model	Yes	5
Description of the landfill gas monitoring survey method	Yes	6.2, 6.3 Appendix B
Description of information to collected during each sampling survey	Yes	6.2
Description and technical specifications of the landfill gas monitoring instrument	Yes	Appendix B
Establishment of baseline methane concentrations for the surface monitoring	No	
Identification of health and safety risks to surveyors	Yes	6.3
Identification of action levels or assessment criteria for methane concentrations	Yes	7.1
Data collection, recording and management procedures	Yes	8
Data reporting procedures	Yes	8.2

The following points are made in relation to the technical requirements of the monitoring program.

1. Landfill areas covered only with daily cover in the active cell do not have any gas action levels and should not be subject to surface emissions monitoring (EPA Victoria, 2018, p. 5, Section 5.2). This may not be the case for cells that contain aged waste materials below the active tip area.
2. Surface atmospheric pressure is a critical element of a landfill gas monitoring survey. Changes in atmospheric pressure in the days prior to a survey and significant rapid changes just prior to and during a survey can effect the emissions from a site. An assessment and description of diurnal and seasonal atmospheric pressure changes would assist in the planning of monitoring surveys including identifying the types of conditions under which surveys should be conducted.
3. Wind speed is also a critical element of a landfill gas monitoring survey. Wind speed must be measured at the height in which methane measurements are taken, i.e., 50 – 100 mm above the surface. According to EPA Victoria (2018, Appendix A, p. 17), wind speed should be less than 10 km/h at the measurement height above the ground (i.e. 50 mm). EPA Victoria (2018) suggests that this wind speed is equivalent to 0.3 m/s, which is an appropriate wind speed for which to take measurements, but this assertion is incorrect. A wind speed of 10 km/h is equivalent to 2.78 m/s, which I would suggest too high for collecting methane concentration measurements at 50 mm above the surface. Notwithstanding this, an assessment and description of diurnal and seasonal wind speeds would assist in the planning of monitoring surveys including identifying the seasons and times of the day when wind speeds may be light enough to conduct measurement surveys.
4. Planning of measurement surveys around forecasted weather conditions is critical. Key weather parameters to be aware of include:
    a. Atmospheric pressure
    b. Wind speed
    c. Rainfall
    d. Temperature
5. Technical specifications of the landfill gas analyser instrument should be provided to ensure the specifications meet the requirements of the guideline. The inclusion of a simple operating procedure is also useful to allow survey technicians to quickly come to terms with the operation of the analyser and standardise the approach taken by the sampling team.
6. Ambient odour assessments should be conducted by a suitably trained, calibrated and experienced person. Olfactory calibration should be conducted in accordance with the Australian standard AS4323.3.

7. The LGMP covers the key elements of the monitoring program, however it lacks details in several areas. The main area that should be expanded is the development of an operating procedure for the surveys and instrumentation to allow for easy and standardised training of surveyors in the method. This should assist in the performance of a consistent survey approach. A description of how the results are to analysed, presented and reported would also assist in the planning of the surveys.

In summary, the LGMP is a comprehensive and well compiled document that could be improved through the addition of a method operating procedure for each survey component; i.e. surface monitoring, sub-surface emissions monitoring, monitoring of building and sub-surface confined spaces; and an outline of the results reporting. This would assist with developing a standard approach for the survey team to follow and ensure all data is collected correctly in order to complete the data analysis and reporting that meet the project objectives.

Kind regards,



Andrew Balch
Director and Principal Consultant
Air Environment – Consulting | Laboratories | Products
E: andrew@airenvironment.com.au
T: +61 7 3186 4420
M: +61 419 909 808

Andrew Balch is a Certified Air Quality Professional (CAQP) of the Clean Air Society of Australia and New Zealand (CASANZ) and the current President of the CASANZ Queensland Branch.

References:

EPA Victoria (2015). *Best Practice Environmental Management; Siting, design, operation and rehabilitation of landfills*, Publication 788.3, August 2015, Environment Protection Authority (EPA) Victoria, Victoria State Government, Carlton, Victoria.

EPA Victoria (2018). *Landfill gas fugitive emissions monitoring guideline*, Publication 1684, February 2018, Environment Protection Authority (EPA) Victoria, Victoria State Government, Carlton, Victoria.

NT EPA (2013). *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites in the Northern Territory*, January 2013, Northern Territory Environment Protection Authority (NT EPA), Northern Territory Government, Darwin, NT.

Standards Australia, 2001. *Stationary source emissions, Part 3: Determination of odour concentration by dynamic olfactometry*, AS4323.3:2001.

EcOz Environmental Consultants

EcOz Pty Ltd.
ABN 81 143 989 039

Level 1, 70 Cavenagh St,
GPO Box 381,
Darwin, NT 0801

T: +61 8 8981 1100
E: ecoz@ecoz.com.au

www.ecoz.com.au

APPROVED COMPANY ISO 14001 Environmental Management Systems QMS Certification Services

APPROVED COMPANY AS/NZS 4801 Occupational Health & Safety Management Systems QMS Certification Services

APPROVED COMPANY ISO 9001 Quality Management Systems QMS Certification Services

APPENDIX D STOCKPILE MANAGEMENT PLAN

STOCKPILE MANAGEMENT PLAN

Shoal Bay Waste Management Facility

CITY OF DARWIN



www.ecoz.com.au

DOCUMENT CONTROL RECORD

Job	EZ22109
Document ID	217495-20
Author(s)	Andrew Lewis, Harry Owen, Adele Faraone, Paula Martinez

DOCUMENT HISTORY

Rev	Reviewed by	Approved by	Issued to	Date
1	Emma Smith	Emma Smith	City of Darwin	8/12/2021
2	Emma Smith	Emma Smith	City of Darwin	13/12/2021
3	Emma Lewis	Emma Lewis	City of Darwin	01/02/2023

Recipients are responsible for eliminating all superseded documents in their possession.

EcOz Pty Ltd.
ABN: 81 143 989 039
Level 1, 70 Cavenagh Street
DARWIN NT 0800
GPO Box 381, Darwin NT 0800

Telephone: +61 8 8981 1100
Email: ecoz@ecoz.com.au
Internet: www.ecoz.com.au

RELIANCE, USES and LIMITATIONS

This report is copyright and is to be used only for its intended purpose by the intended recipient, and is not to be copied or used in any other way. The report may be relied upon for its intended purpose within the limits of the following disclaimer.

This study, report and analyses have been based on the information available to EcOz Environmental Consultants at the time of preparation. EcOz Environmental Consultants accepts responsibility for the report and its conclusions to the extent that the information was sufficient and accurate at the time of preparation. EcOz Environmental Consultants does not take responsibility for errors and omissions due to incorrect information or information not available to EcOz Environmental Consultants at the time of preparation of the study, report or analyses.

TABLE OF CONTENTS

1 INTRODUCTION 5

1.1 Purpose 5

1.2 Scope 6

1.3 Relevant legislation 6

2 WASTE MINIMISATION 9

3 FACILITY OVERVIEW 10

3.1 Land tenure and location 10

3.2 Landform and future site development 10

3.3 Infrastructure and layout 12

4 ENVIRONMENTAL SETTING 14

4.1 Surrounding land-use 14

4.2 Climate 14

4.2.1 Land units and soils 15

4.2.2 Surface water drainage 16

4.2.3 Geology and hydrogeology 18

4.2.4 Surface water and groundwater quality 18

5 TYPES OF WASTES AND VOLUMES 20

5.1 Types of wastes 20

5.2 Quantities received 20

5.3 Waste hierarchy 21

6 WASTE STORAGE AND DISPOSAL LOCATION 23

7 RISKS ASSOCIATED WITH STOCKPILING MATERIALS 24

7.1 Methodology 24

7.1.1 Risk ranking 24

7.2 Risk assessment 26

8 STOCKPILING REQUIREMENTS 30

8.1 Record keeping of material flow, markets, and timeframes 30

8.2 Site selection for stockpiles 30

8.3 Timeframes for stockpiling 31

8.4 Stability of stockpiles 31

8.5 Stockpile dimensions 32

8.5.1 General dimensions 32

8.6 Dimensions of listed (hazardous) waste stockpiles 32

8.6.1 Separation requirements for stockpiles 33

9 STOCKPILES AT THE SBWMF 35

10 REPORTING REQUIREMENTS FOR FUTURE STOCKPILE MANAGEMENT PLANS 40

11 REFERENCES 41

Tables

Table 1-1. Applicable legislation 6
Table 3-1. Summary of landfill stage lifespans 10
Table 3-2. SBWMF facilities 12
Table 4-1. Land uses surrounding the SBWMF 14
Table 4-2. Land units within the SBWMF site 15
Table 5-1. Landfill wastes quantities handled at SBWMF in addition to listed wastes. 20
Table 5-2. Types and quantities of recycled waste handled at SBWMF in addition to listed wastes 20
Table 5-3. Material risk categories (adapted from SA EPA 2020) 22
Table 6-1. Landfill wastes disposal location at SBWMF 23
Table 7-1. Consequence ranking 24
Table 7-2. Qualitative measures of likelihood 24
Table 7-3. Risk rankings from combined consequences and likelihood 25
Table 7-4. Environmental aspects and impacts register 26
Table 8-1. Stockpile length and separation requirements for freestanding loose and baled materials (ACT EPA 2019) 33
Table 8-2. Minimum stockpile separation requirements to a building for freestanding loose and baled materials (ACT EPA 2019) 33
Table 9-1: Soil, gravel and tyres stockpiles 36
Table 9-2. Green waste stockpiles 38
Table 10-1. Future reporting requirements for SPMPs 40

Figures

Figure 1-1. Map of SBWMF location 8
Figure 2-1. Considerations for the assessment and management of stockpiles (adapted from SA EPA 2020) 9
Figure 3-1. Landfill cell staging 11
Figure 3-2. SBWMF site facilities and access routes 13
Figure 4-1. Graph of mean temperature and rainfall at Darwin Airport (Station no. 014015) 15
Figure 4-2. Mapped land units at SBWMF 17
Figure 9-1. Soil, gravel and tyres stockpiles locations 37
Figure 9-2. Green waste stockpiles 39

Appendices

Appendix A Onsite inspection checklist

ACRONYMS

ANZECC	Australian and New Zealand Environment and Conservation Council
ARI	Average Recurrence Interval
AS	Australian Standard
BoM	Bureau of Meteorology
CoD	City of Darwin
CoPC	Contaminants of Potential Concern
CSM	Conceptual Site Model
DoD	Department of Defence
EMP	Environmental Management Plan
EPA	Environmental Protection Approval
EPL	Environmental Protection Licence
LFG	Landfill Gas
LGMP	Landfill Gas Monitoring Plan
LDP	Landfill Development Plan
LTP	Leachate Treatment Plant
NT EPA	Northern Territory Environmental Protection Authority
SDS	Safety Data Sheet
SWMP	Site Water Monitoring Plan
SBWMF	Shoal Bay Waste Management Facility
SPMP	Stockpile Management Plan
UXO	Unexploded Ordinance
WMPC Act	*Waste Management and Pollution Control Act*

1 INTRODUCTION

The City of Darwin (CoD), Shoal Bay Waste Management Facility (SBWMF) is a municipal waste resource recovering and disposal site servicing both domestic and commercial customers in the Darwin area. The SBWMF is located 13 km north-east of Darwin City, within Lot 3952, Town of Sanderson, in the suburb of Holmes (see Figure 1-1).

This Stockpile Management Plan (SPMP) details the rationale, design, potential risks, mitigation measures and controls to be implemented at the SBWMF regarding stockpile management. Stockpiling of materials is considered a temporary measure, whereby the materials and/or waste are eventually either transferred to another facility, or transferred within the SBWMF for further processing, reuse, recycling or resale, or placed into the landfill.

This SPMP aims to provide guidance to inform effective management of on-site and off-site stockpile related human-health and/or environmental risks.

Guiding principles of stockpile management include:

- A tool for environmental performance improvements
- Are practical, risk based and reasonable for management and operational purposes
- Providing clear regulatory criteria for assessment by governing authorities such as the NT EPA
- Providing clear and appropriate measures in instances where the stockpiling approach may be considered inappropriate and lead to a risk of harm to human health and/or the environment (i.e ensuring that materials are classified in accordance to a waste hierarchy).
- Supporting the market for recovered resources (i.e. cardboard, soil, green waste)

Once implemented within the SBWMF, this document can be used to measure the effectiveness of actions taken by CoD regarding stockpile management, as well as identifying where future improvements can be made. This document will be required to be updated annually at a minimum, to reflect the most up to date volumes of waste, progression of the construction of landfill cells within SBWMF and the location and potential movement of stockpiles.

1.1 Purpose

The purpose of this SPMP aim to inform the following:

- Prevent or minimise the risk of harm to human health and/or the environment
- Support the most preferable use of waste and secondary materials in accordance with the waste management hierarchy.
- Ensure that materials are circulated through the most appropriate and authoritative waste management processes to assist in the market for recovered resources (i.e. recycling)
- Ensure that stockpiling is not used as a means to avoid waste compliance and authoritative obligations
- Reduce liability of detrimental environmental harm from active stockpiled or abandoned stockpiled materials
- Ensure that there is an appropriate response in place for inappropriate stockpiling of materials that may not meet the waste hierarchy criteria

Pursuant to Section 30, Part 2 of Schedule 2 of the *Waste Management and Pollution Control Act*, a landfill servicing the waste disposal requirements of more than 1,000 persons requires an Environment Protection Licence (EPL). CoD hold EPL188-03, covering the SBWMF, issued by the Northern Territory Environment Protection Authority (NT EPA). This licence also allows for the storage, treatment, recycling, and disposal of 'listed wastes' prescribed under the *Act*; see EPL188-03 for the specific listed waste types authorised at the

SBWMF, as well as the operational, monitoring and reporting requirements CoD must comply with. This SPMP assists CoD in meeting several EPL188-03 conditions. It also assists in implementing and assessing the effectiveness of stockpile management measures prescribed in the *SBWMF Environmental Management Plan* (EMP).

1.2 Scope

This SPMP has been prepared in accordance with *the Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites In the Northern Territory* (NT EPA, 2013), *Guideline for stockpile management* (SA EPA, 2020) and the *Guideline for Stockpile Management* (ACT EPA, 2019) and includes the following:

- An outline of SBWMF operational aspects that relate to stockpile construction and locations, including details of historic, current and future-planned landfill cells
- Description of the environmental setting (climate, landform, hydrogeology, surface water flows etc) and surrounding land uses of the SBWMF, that may be considered sensitive receptors and also the human health and/or environmental receptors at risk from poor management of stockpiles.
- Development of a conceptual site model (CSM) that identifies the contaminants of concern, and their potential sources, migration pathways and receptors
- A list of types of wastes and respective volumes of waste entering SBWMF. This also includes a summary of the waste hierarchy, which is used to inform the risk associated with stockpiles or certain materials.
- Risk assessment associated with the stockpiling of materials
- Management approach for stockpiles including outline of required data recording and record-keeping.
- Overview of reporting requirements for future SPMPs.
- An onsite stockpile inspection checklist (Appendix A)

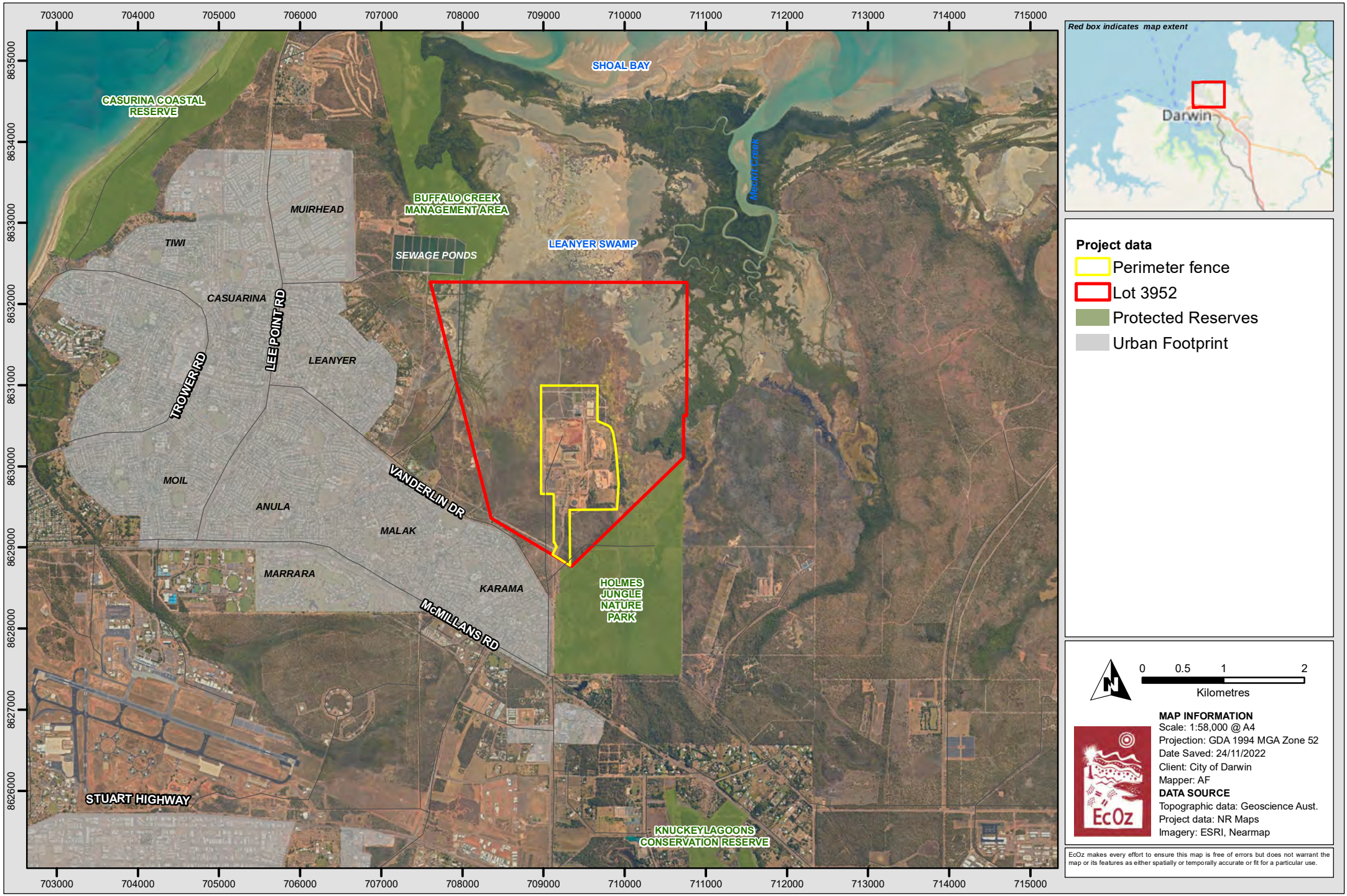
1.3 Relevant legislation

Table 1-1 lists the Commonwealth and Northern Territory legislation applicable the SBWMF.

Table 1-1. Applicable legislation

Environmental aspect	Applicable legislation
Air quality	• *Ozone Protection Act 1989 (Cwlth)* • *Waste Management and Pollution Control Act (NT) (WMPC Act)* • *National Environment Protection Council. 2003 National Environment* • *Protection (Ambient Air Quality) Measure (NEPM)* • *National Environment Protection Council. 2011 National Environment* • *Protection (Air Toxics) Measure (NEPM)* • *National Environment Protection Council. 1998 National Environment* • *Protection (National Pollutant Inventory) Measure (NEPM)*
Bushfire	• *Bushfires Act (NT)* • *Fire and Emergency Act (NT)*
Dangerous goods	• *Dangerous Goods Act (NT)* • *Road Transport (Dangerous Goods) Act 1995 (NT)* • *Dangerous Goods (Storage and Handling) Regulations 2000 (NT)* • *Road Transport Reform (Dangerous Goods) Act 1995 (Cwlth)*

Environmental aspect	Applicable legislation
Flora and Fauna (including weeds and pests)	• *Animal Welfare Act (NT)* • *Bushfires Act (NT)* • *Environment Protection and Biodiversity Conservation Act 1999 (Cwlth)* • *Fisheries Act (NT)* • *National Environmental Protection Council (Northern Territory) Act (NT)* • *Plant Health Act (NT)* • *Public and Environmental Health Act (NT)* • *Public Health (General Sanitation, Mosquito Prevention, Rat Exclusion and Prevention) Regulations (NT)* • *Soil Conservation and Land Utilisation Act (NT)* • *Territory Parks and Wildlife Conservation Act (NT)* • *Weeds Management Act (NT)*
Heritage	• *Australian Heritage Commission Act 1975 (Cwlth)* • *Heritage Act (NT)* • *National Heritage Trust of Australia Act 1997 (Cwlth)*
Noise	• *Environmental Protection and Biodiversity Conservation Act 1999 (Cwlth)* • *Waste Management and Pollution Control Act (NT)*
Waste and Hazardous Waste	• *Environmental Offences and Penalties Act (NT)* • *Work Health and Safety (National Uniform Legislation) Act (NT)* • *Hazardous Waste (Regulation of Exports and Imports) Act 1989 (Cwlth)* • *Litter Act (NT)* • *National Environment Protection Council. 2011. National Environment* • *Protection (Used Packaging Materials) Measure as varied 16 September 2011* • *Public and Environmental Health Act (NT)* • *Public Health (General Sanitation, Mosquito Prevention, Rat Exclusion and Prevention) Regulations (NT)* • *Waste Management and Pollution Control Act (NT)*
Water (surface and groundwater)	• *Water Act (NT)* • *Waste Management and Pollution Control Act (NT)*
Future Development	• *Environment Protection Act (NT)* • *Waste Management and Pollution Control Act (NT)*



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Fig 1-1. SBWMF location.mxd

Figure 1-1. Map of SBWMF location

2 WASTE MINIMISATION

Landfilling is considered the last resort for the management of unwanted materials and waste. Municipal landfills, such as SBWMF, are part of a management system, where every opportunity should have already been taken to avoid waste production and remove recyclable material from the waste stream before it arrives at the landfill (NT EPA, 2013). In some cases, material is taken to facilities such as SBWMF, where it may undergo further waste characterisation and assessment to determine whether there is a market for the material and/or waste to be reused, recycled or re-sold. As part of this process, stockpiling of such materials and waste are required, whereby this SPMP provides guidance as to how that is to be completed and the reporting requirements to be submitted to the NT EPA in regards to stockpile management.

As stockpiles are considered a temporary measure only, there are a series of various considerations, terminology and legislative requirements that must be upheld, when assessing the viability of stockpiling for various reasons. Figure 2-1 below outlines these considerations with appropriate terminology that is considered when assessing stockpile management at SBWMF.

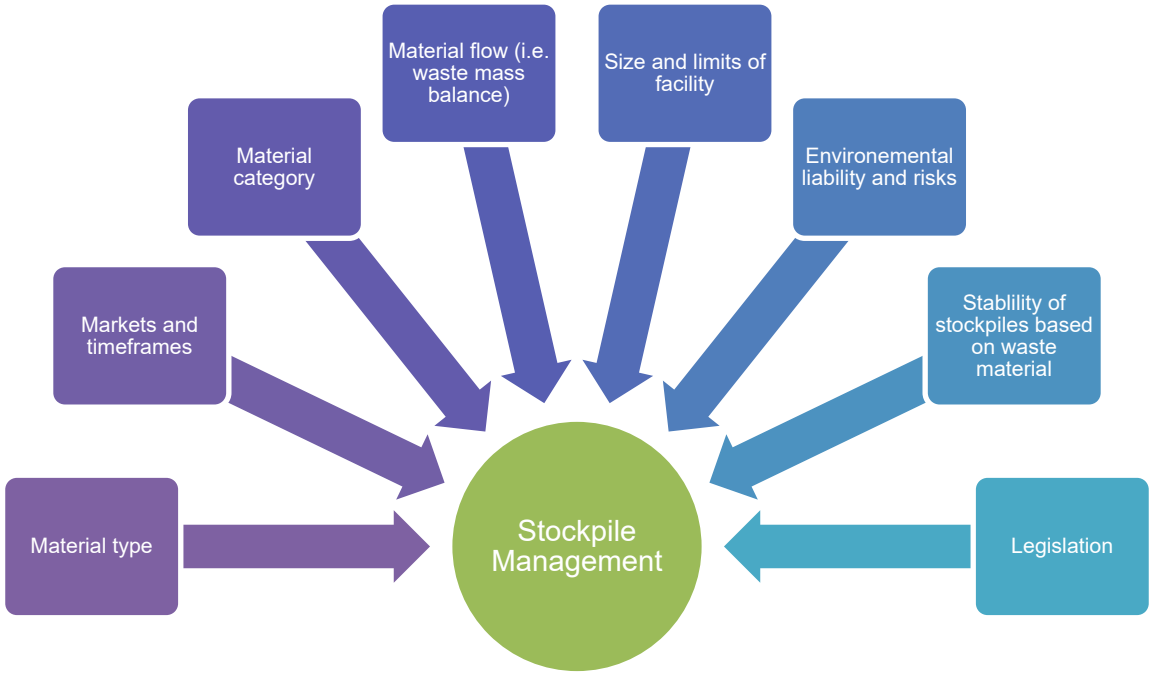


Figure 2-1. Considerations for the assessment and management of stockpiles (adapted from SA EPA 2020)

3 FACILITY OVERVIEW

The following section gives a brief overview of operations at the SBWMF. Further detailed information can be found in the *SBWMF Environmental Management Plan*.

3.1 Land tenure and location

CoD lease the property (Lot 3952) from the Commonwealth Department of Defence. Under the lease agreement, only a portion of the property is designated as a Waste Management Project Area in which CoD is authorised to conduct waste management and ancillary activities. The rest of the property remains uncleared of unexploded ordinance (UXO) and cannot be utilised at present.

The SBWMF operational area lies within the central-southern part of the property. This operational area is bound to the north and east by floodplains, wetlands, and mangroves of the 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, approximately 800 m to the south-west, with a bushland buffer in between.

3.2 Landform and future site development

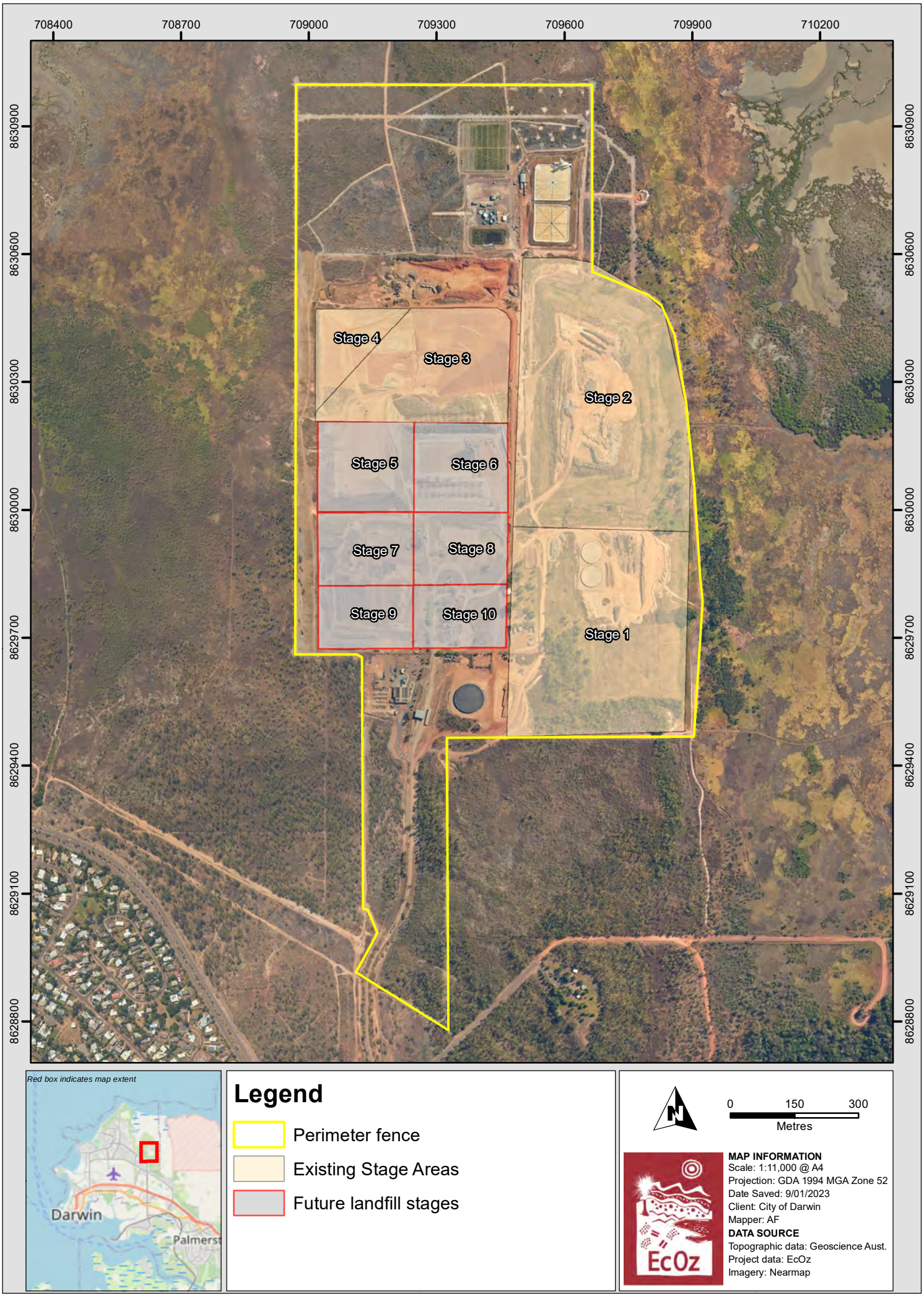
Waste disposal and landfilling activities have been occurring at the site since the 1980's. The initial Stages 1 and 2 are located on the eastern side of the operational area and are unlined cells that previously accepted all waste types. Stage 3 was constructed between 2001 and 2007 with a geo-membrane liner and was progressively filled with general waste during this time. In 2013, Stage 4 was constructed on the north-west corner of Stage 3 by tying in the new geomembrane liner with existing infrastructure. Filling activities in Stage 3 and 4 ceased in 2018. Capping activities on Stage 3 and 4 have been completed in October 2022.

Stage 5 and all future landfill cells consist of a composite liner system built to best-practice standards, including leachate collection systems. All new cells and liner designs are subject to an Environment Protection Approval regulated by the NT EPA.

CoD have developed a landfill plan that shows the sequence and timing for Stages 5 to 10 to be constructed south of Stage 3. Current and future staged landfill cells are estimated to manage average waste disposal volumes over the next 15 to 20 years. Landfill cell development (including the current Stage 5) volumes and associated lifespan estimates are included in Table 3-1 below.

Table 3-1. Summary of landfill stage lifespans

Stage	Estimated airspace (m^3)	Lower range filling rate lifespan	Upper range filling rate lifespan
Stage 5	510,000	35 months	27 months
Stage 6	950,000	65 months	50 months
Stage 7	450,000	31 months	23 months
Stage 8	1,220,000	83 months	64 months
Stage 9	525,000	36 months	28 months
Stage 10	1,180,000	81 months	62 months
Totals	**4,835,000**	**331 months**	**254 months**



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Figure 2-3. Future general waste stage layout plan.mxd

Figure 3-1. Landfill cell staging

3.3 Infrastructure and layout

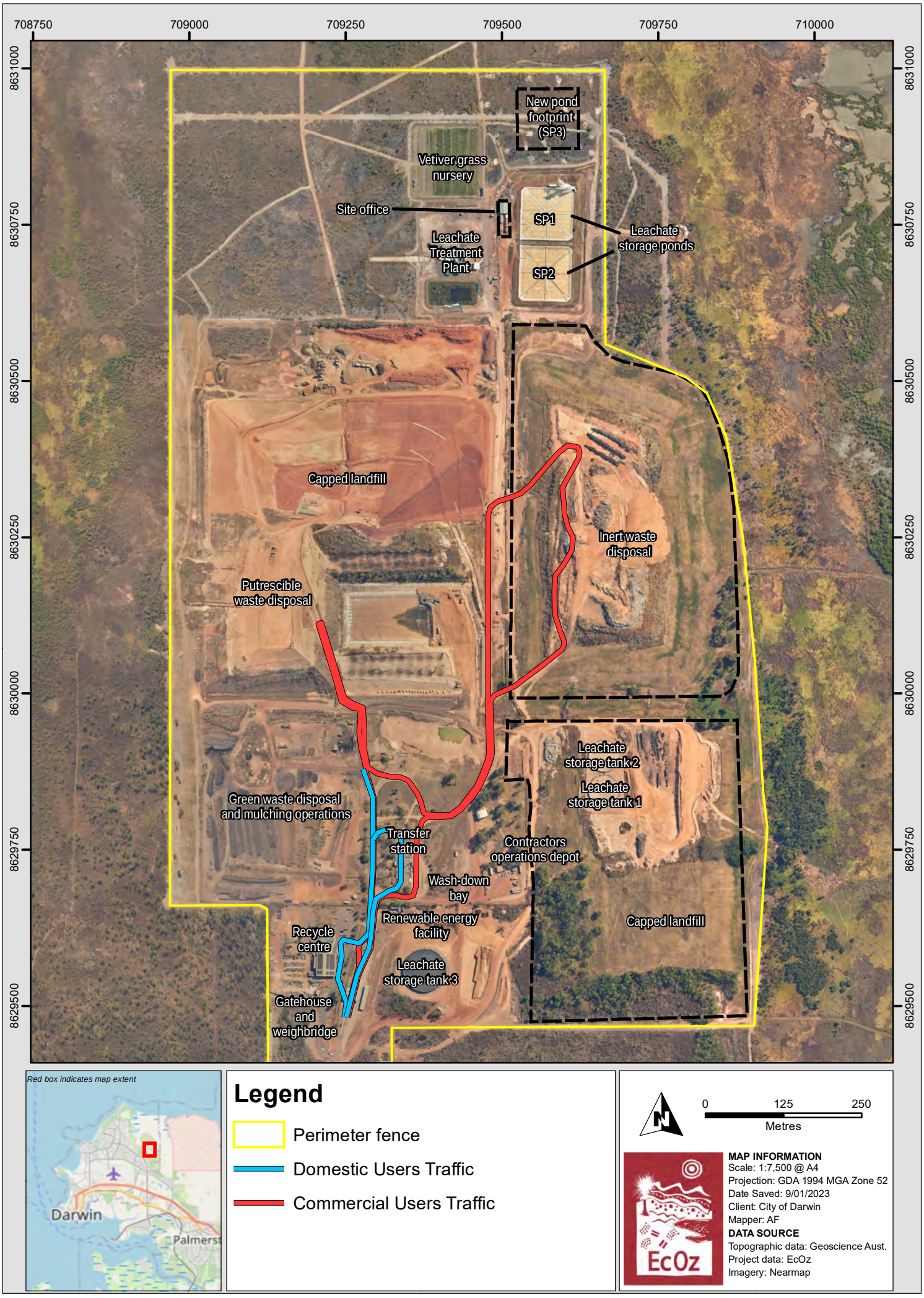
The SBWMF consists of the facilities outlined in Table 3-2, to support waste management activities.

Table 3-2. SBWMF facilities

Facility	Description
Recycle centre	A facility where users can drop off unwanted goods to be recycled, repurposed or resold to other users. The facility accepts a wide range of goods, including building materials, furniture, electronics and bric-a-brac.
Gatehouse and weighbridge	Located at the entrance to the site, the gatehouse includes office space and amenities for staff and a dual weighbridge system to allow for tracking of incoming and outgoing materials.
Transfer station	The transfer station is primarily for domestic users to drop off household waste for recycling, landfill or disposal off-site to a licenced facility. The transfer station allows for segregation of general, recyclable and domestic quantities of listed wastes. Users access the facility directly with their vehicles to unload.
Inert waste disposal	All inert waste loads are directed to the inert waste disposal cell. Where possible, recyclable materials such as steel and concrete are salvaged from the tip face prior to burial. The inert cell also caters for the disposal of asbestos products and asbestos containing material.
Putrescible waste disposal	All putrescible waste loads and listed wastes licenced for burial are directed to the active lined landfill cell for disposal.
Green waste disposal and mulching operations	All green waste loads are directed to the green waste disposal area for stockpiling. The green waste is then processed into mulch products for reuse on site or resold as a commercial product.
Renewable energy facility	Landfill gas is harvested from the landfill by a third-party contractor and directed to an on-site gas processing facility. The facility consists of a 1.1 MW engine which converts the gas to electrical power for supply back into the grid.
Leachate storage ponds and treatment area	Located at the northern end of the site, the leachate storage ponds are 3 x 15 ML lined and covered ponds that store leachate extracted from the putrescible waste cells. Directly to the east of the storage ponds is the nominated site for the leachate treatment plant.
Temporary leachate storage tanks	One tank of 13 ML near the weighbridge and two tanks of 3 ML each on Stage 1. All these tanks are covered and have leak detection mechanism in place.
Wash-down bay	A wash-down bay is located near the site exit for use by commercial users after disposing of waste to landfill. The wash-down water is collected in a sump, processed through an oily-water separator and then irrigated as required over an existing landfill area.
Contractors operations depot	A hardstand compound located at the southern end of site adjacent to Stage 1. The compound area is comprised of a series of demountable buildings and sheds and a workshop area for minor servicing of plant and equipment.

Access to the SBWMF (with exception to the recycle centre) is via the gatehouse. Domestic users can enter the facility through a pre-approved access boom-gate or via the gatehouse operator. Domestic users can only access the green waste area or transfer station to dispose of waste. Commercial users accessing the facility, must use the weighbridge for assessment of waste type and to complete payment. Commercial users are then directed to correct disposal area within the facility, depending on waste type (i.e. putrescible waste, inert waste, green waste, etc.). All users have access to the recycle centre without having to pass through the gatehouse.

The facilities and access routes described above are shown in Figure 3-2.



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Figure 2-1. SBWMF site facilities and access routes.mxd

Figure 3-2. SBWMF site facilities and access routes

4 ENVIRONMENTAL SETTING

4.1 Surrounding land-use

Immediately surrounding the SBWMF to the west, north and east are salt flats, tidal wetlands, and mangroves connected to the Shoal Bay embayment. Immediately to the south is native savannah bushland and the monsoon rainforest of the Holmes Jungle Nature Park. As such, no sensitive human health receptors, such as residences or workplaces, are identified immediately adjacent to the site.

Further afield, land uses within a 2 km radius of the site include the suburb or Karama (800 m to the south-west of the site boundary and 1.1 km from the Stage 5 landfill), the Leanyer Recreation Park (1.5 km to the west), the Darwin Model Flying Club (1.1 km to the north-west), and the Darwin Rifle Club, 1.7 km to the south-east; see Table 4-1 below for a summary. None of these land uses are considered at risk of landfill gas migration given their distance from landfills within the SBWMF.

Table 4-1. Land uses surrounding the SBWMF

Land use	Location	Approximate distance (km)
Darwin Model Flying Club	North-west	1.1
Leaner Recreation Park	West	1.5
Leanyer suburb (residences)	North-west	1.8
Leanyer Sanderson Waste Stabilisation Ponds	North-west	2.1
Karama suburb (residences)	South-west	0.8
Malak suburb (residences)	South-west	1.2
Holmes Jungle Nature Park	South	Adjacent
Crocodylus Park	South	2.3
Darwin Pistol Club, Darwin Riffle Club and Northern Territory Field and Game Association	South-east	1.7+

4.2 Climate

The SBWMF is classified within a monsoonal tropical climate, with a distinct Dry season (approximately April to October) and Wet season (November to March). Typically, for this region, humidity, maximum and minimum temperatures are highest in the Wet season, and annual evaporation far exceeds annual rainfall.

The Darwin International Airport station (Station no. 014015) is the closest Bureau of Meteorology (BoM) weather station to the proposal area, located approximately 2 km away. The annual rainfall data of the station is 1724 mm (BoM 2022). The variation in temperature and rainfall across the seasons is shown in Figure 4-1.

Climate variation throughout the year directly influences the management of surface water at SBWMF, including the potential for leachate generation and contamination of surface waters within the site. Surface water drainage and quality are further discussed in the following sections.

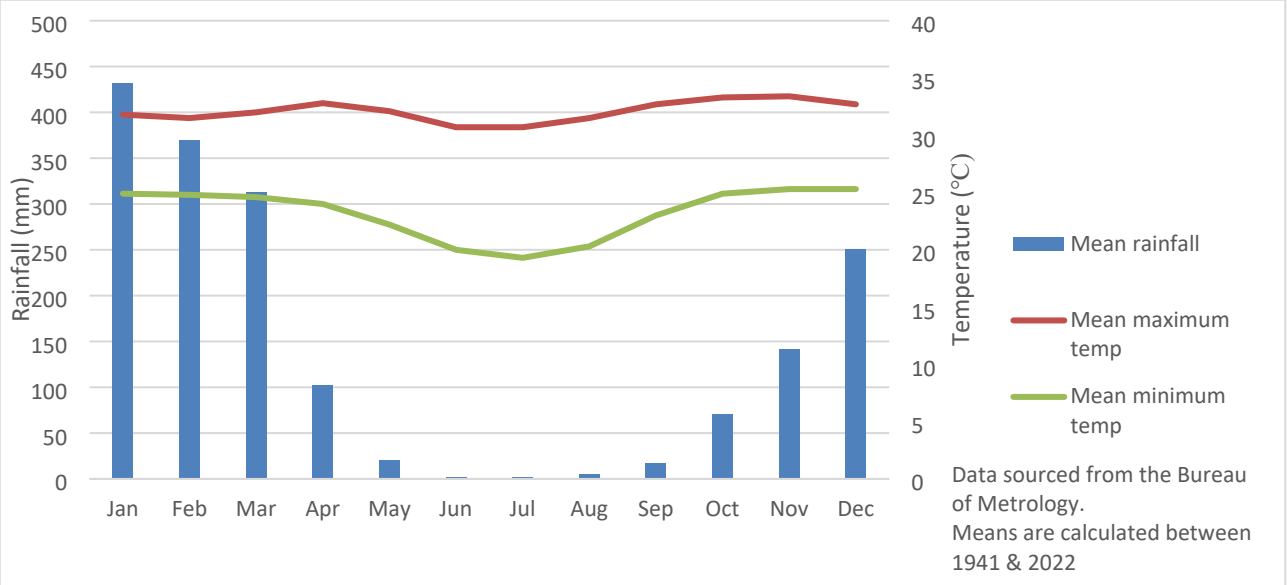


Figure 4-1. Graph of mean temperature and rainfall at Darwin Airport (Station no. 014015)

4.2.1 Land units and soils

Land unit mapping by Fogarty *et al.* (1984) indicates that the area comprises three different land units, 1c, 3d and 4c, as described in Table 4-2 and shown in Figure 4-2. The majority of the site is covered by land unit 3d, with a small section of 1c to the west and small section of 4c to the east.

Directly west of the site there is a drainage system-based landform (land unit 6b), and to the north-east is a swamp system-based landform (land unit 8c).

There are two recognised landform types within the SBWMF site, rises and plains, with most of the site classified as plains, with two small area of rises on the western side and the south-eastern section of the site.

Drainage associated with the identified landforms and land units tends to be rapid draining for the majority of the site (i.e. land units 1c and 3d), with the area to the west classified as prone to Wet season waterlogging.

Table 4-2. Land units within the SBWMF site

Land unit	Landform Class	Landform Description	Soil	Vegetation description	Slope	Drainage
1c	Rises	Rises and short steep slopes	Organosols / rudosols	Woodland of *Eucalyptus tetrodonta*, *E. miniata*, over *S. intrans* and *H. triticeus.*	5 - 15%	Rapid draining, nil to low level of seasonal soil waterlogging
3d	Plains	Gently undulating upland surface	Rudosols	Open woodland of *Eucalyptus miniata*, *E. tetrodonta* over Sorghum spp.	1 – 3%	Rapid draining, low level of seasonal waterlogging
4c		Gentle lower slopes	Hydrosols	Open forest *Eucalyptus tetrodonta*, *E. papuana* over mixed grasses.	0.5 – 1.5%	Slow drainage, Wet season waterlogging soil with often dry season seepage

4.2.2 Surface water drainage

Within the SBWMF there are no defined surface water drainage lines. Palm Creek flows directly through the Homes Jungle Nature Park, and to the east of the site, then joins with Meckitt Creek to the north-east of the SBWMF.

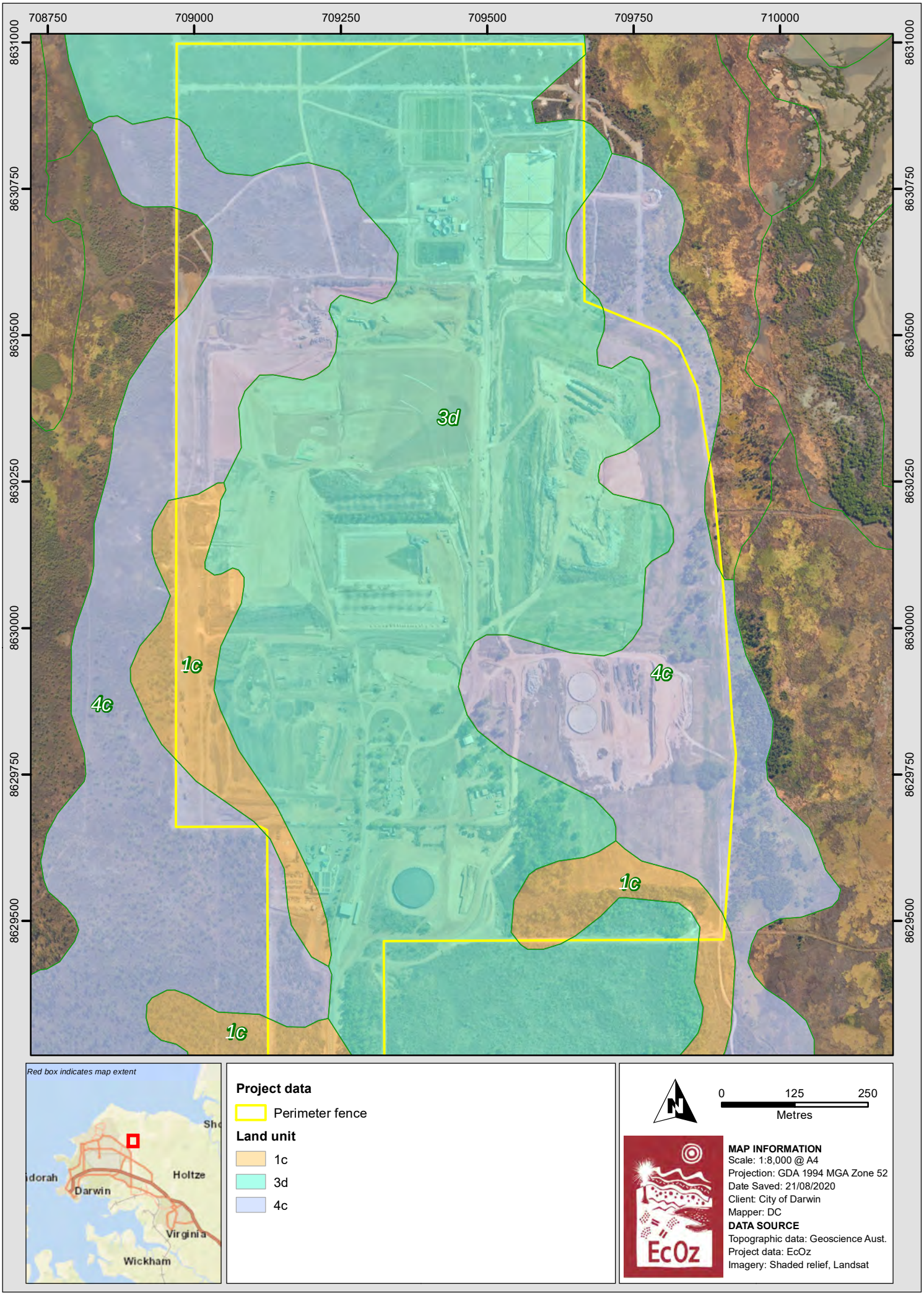
Surface water from the eastern portions of the SBWMF flows north towards the Meckitt Creek floodplain (CDM Smith 2019). Flows from the western portion of the site are towards the Leanyer Swamp and Buffalo Creek. Both Meckitt Creek and Buffalo Creek are mangrove-lined tidal inlets of Shoal Bay; a coastal embayment with extensive sand and mud flats.

The site is mainly characterised by rapid drainage landforms (see Table 4-2), therefore localised flow is managed through the onsite surface water drainage system, which consists of stormwater structures and open drains. Surface water is diverted away from the landfill cells that have the possibility of contaminating surface waters and towards water management infrastructure (CDM Smith 2019).

SBWMF is not within a Water Control District or within a Water Plan Management Zone, however it is within the Darwin Harbour Region for Water Beneficial Uses and has been identified for four beneficial uses including:

- Aquaculture
- Environment
- Cultural
- Rural stock and domestic.

The operational area sits outside the estimated highest astronomical tide zone and the 1 in 100-year Average Recurrence Interval (ARI) primary storm surge impact zone, however may experience some impacts from a 1 in 1,000 or 10,000 ARI storm surge around the perimeter of the operations (GHD 2014).



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20118 - Shoal Bay Leachate Treatment SAQP\01 Project Files\Figure X-X. Land units.mxd

Figure 4-2. Mapped land units at SBWMF

4.2.3 Geology and hydrogeology

The site is located within the Money Shoal Basin, which is of sedimentary succession composition. The 2013 Northern Territory Geological Survey describes the basin as a tilted passive margin basin with no specific depocentre (Ahmad & Munson 2013). The basin generally consists of formations that are monoclonal and relatively under formed. The Money Shoal Basin overlies the Arafura Basin, the Pine Creek Orogen and the McArthur Basin.

Groundwater aquifers beneath the site are described in detail in the *Shoal Bay Waste Disposal Site, Hydrogeological Investigation* (URS 2015). Lithology encountered during groundwater bore drilling for the investigation comprised top soils (silts and clays), generally underlain by weathered (lateritised) siltstone over most of the site, and claystone east of Stage 1. Beneath this, sandstone was encountered at depths of 9 to 20 m below the surface across most of the site. Groundwater exists within the unconsolidated overlying sediments, and fractured and weathered underlying bedrock. Bore yields are generally very poor; less than 5 L/sec.

The shallow (water table) aquifer is recharged by the direct infiltration of rainfall and runoff, and groundwater levels vary seasonally in accordance with rainfall totals. Seasonal groundwater standing water levels (SWLs), measured as part of the SBWMF water quality monitoring program since 2016, are greater than 12 m below ground level at the end of the Dry season, and usually less than 2 m from the ground surface during the peak of the wet season.

Higher yielding weathered and fractured carbonate rock aquifers occur in the wider region, with yields commonly greater than 5 L/sec. The *Groundwater Supply Prospects and Hydrogeology of the Cox Peninsula Region* map identifies a high yielding carbonate aquifer south-east of the SBWMF, trending in a northerly direction (NRETAS 2008). Groundwater from this aquifer discharges to the surface within the Holmes Jungle Nature Park and maintains streamflow through the Dry season. This spring and associated shallow groundwater support the Holmes Jungle Nature Park. Further to the south-east around the Knuckey Lagoon area, a large number of bores draw groundwater from this carbonate aquifer for domestic and agricultural purposes.

There are no groundwater bores or groundwater users down gradient of the SBWMF; although an important environmental consideration is the supply of groundwater seepage into wetlands and tidal inlets during the dry season.

The carbonate rock aquifer and associated springs, Holmes Jungle Nature Park and groundwater users are all located up gradient of the SBWMF. No significant areas of carbonate rock aquifer are located down gradient of the SBWMF and no carbonate rocks were encountered when drilling the 32 groundwater bores, to depths of up to 30 m below ground level, across the site for the hydrogeological investigation (URS 2015).

As part of the environmental monitoring program for SBWMF a total of 39 groundwater bores have been drilled. The bores drill depth varies between 3 to 30 m.

4.2.4 Surface water and groundwater quality

Water quality within the SBWMF has been monitored through the Shoal Bay Waste Disposal Site Water Monitoring Plan (URS 2016), and as per the Environmental Protection Licence (EPL188-03), issued by the NT EPA. This monitoring plan includes the monitoring of five surface water sites, 39 groundwater bores and three leachate sites, for leachates generated within SBWMF.

Water quality parameters measured through the monitoring plan include physical parameters (pH, electrical conductivity, dissolved oxygen), major cations and anions, nutrients, metals, and total recoverable hydrocarbons.

Surface water typically records elevated ammonia and lead concentrations above guideline values, with the majority of other parameters measured within guideline limits. Groundwater and leachate water frequently

record elevated ammonia, copper, lead and zinc concentrations above guideline values. The migration of leachate water into the surface and groundwater is known to be causing the transportation of some contaminants.

Groundwater quality is highly variable in terms of salinity, pH, metals and nutrients (CDM Smith 2019). Groundwater down gradient of the SBWMF is saline due to its close proximity to the coast and tidal saline intrusion; see the Groundwater Resources of the Darwin Area map (DIPE 2003). There are no groundwater bores or groundwater uses down gradient of SBWMF other than that potentially associated with environmental supply of groundwater seepage into wetlands and tidal inlets.

The carbonate rock aquifer and associated springs, Holmes Jungle Nature Park and groundwater users are all located up gradient of the SBWMF. No significant areas of carbonate rock aquifer are located down gradient of the SBWMF and no carbonate rocks were encountered when drilling the 39 groundwater bores, to depths of up to 30 m below ground level, across the site for the hydrogeological investigation (URS 2016).

5 TYPES OF WASTES AND VOLUMES

5.1 Types of wastes

The SBWMF receives several types of commercial and domestic waste throughout the year which may or may not be of value as a recycled or repurposed product.

The waste is separated into individual material types and stored in outdoor stockpiles while awaiting sale, reuse or recycling.

The SBWMF receives Construction and Demolition waste such as scrap metal, steel frameworks, roofing materials, untreated timber, paper and cardboard. Industrial and demolition material waste such as concrete, excavated material and other sedimental waste is stockpiled for processing or reuse as fill product used in waste and soil management.

Stockpiled green waste is of particular value as a recycled mulch product used in domestic and commercial gardening. SBWMF receives green waste including grass clippings, palm fronds and tree branches etc which is broken down, dried and stabilised while stockpiled to produce a commercial mulch product for resale.

In addition to the key materials listed above, SBWMF also stores acid solutions or acids in solid forms, lead and other lead compounds, tyres, unfit mineral oils as well as pigments and dyes such as inks, paints, lacquers and varnishes.

5.2 Quantities received

The 2021/22 landfill waste quantities handled at SBWMF are listed below. In summary, the SBWMF handles over 370,000 tonnes of landfill waste each year while also managing a further 74,400 tonnes of recycled waste such as e-waste, concrete and oils.

Table 5-1. Landfill wastes quantities handled at SBWMF in addition to listed wastes.
Information obtained from the NT EPA (2022)

Description of waste/ source	Quantity (tonne)
Inert Waste (Virgin excavated material; concrete and bricks)	21,432
Municipal Waste	48,893
Commercial & Industrial (include clan fill 198,832 tonne)	292,406
Construction & Demolition (fittings, fixtures, cabinetry, steel framework, woofing material, furniture, construction materials)	10,270

Table 5-2. Types and quantities of recycled waste handled at SBWMF in addition to listed wastes
Information obtained from the NT EPA (2022)

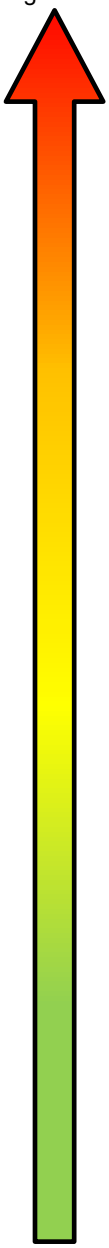
Type of waste	Quantity	Unit (tonne, Litre)
e-waste	48	Tonne
White goods/Scrap Metal	2,664	Tonne
Green waste	12,866	Tonne
Used Lead Acid Batteries	89	Tonne
Cardboard	160	Tonne
Gas bottles & Fire extinguishers	11	Tonne
Paint	20	Tonne

Type of waste	Quantity	Unit (tonne, Litre)
Concrete for crushing	9,055	Tonne
Chemicals	1,695	Litre
Oil (motor)	46,301	Litre
Cooking oil	1,500	Litre

5.3 Waste hierarchy

There is a level of risk associated with material flow and abandonment in and out of SBWMF, dependant on the type of material and how recoverable they are (i.e. can they be re-used or recycled?). The following table (Table 5-3 adapted from the *Guideline for stockpile management* (SA EPA, 2020)) outlines the risk categories for different types of wastes, dependant on their abandonment risk.

Table 5-3. Material risk categories (adapted from SA EPA 2020)

Material risk category	Materials	Description of risk	Risk level
Materials that are not recoverable (may require further processing or treatment prior to final disposal) i.e. contaminated soils with hydrocarbons, PFAS	• Many materials for disposal at a landfill • Materials for other forms of final disposal • Hazardous materials (listed wastes)	High risk of illegal dumping and waste levy avoidance	High risk  Low risk
Materials that have untested or unproven markets	• Industrial residues • Mixed commercial and industrial materials • Residual wastes	Due to the lack of established markets or clearly identified future markets, the abandonment risks are considered very high for these materials	
Materials that cost to recycle	• e-waste • tyres • mixed construction and demolition waste • co-mingled recyclable	Some of these materials are known to be recyclable and contain recyclable components. However, collection, processing and transport exceed any value that will be obtained from the recovery of materials in the wastes, leading to higher abandonment risks.	
Materials that area product and meet published standards for contamination (i.e. ANZECC, NEPM) or are to the NT EPA standard (i.e. NATA accredited laboratory testing has been completed to the satisfaction of the NT EPA) but are being stockpiled and therefore have no immediate fate, there is a market but it is limited or highly variable or anticipating that the market will or can improve.	Large volumes of • Sorted plastics • Cardboard and paper • Compost and mulch • Mixed glass • Inert construction and demolition waste • Treated waste soil • Recyclable materials	As there is a market, there is a lower risk of abandonment and lower liability. However the market may be limited and highly variable. This may lead to speculative stockpiling which can undermine the market. This behaviour is to be monitored to minimise environmental liability and to prevent avoidance of regulatory requirements.	
Materials that meet a published or EPA standard and have an immediate fate	Small volumes of • Pelletised plastics • Carboard paper • Compost and mulch • Segregated glass • Inert construction and demolition waste • Treated waste soil (ready for sale) • Recyclable materials	As there is an established market, there is lower risk of abandonment and lower liability. At suitable sites, large volumes of these materials can be stored without posing a significant environmental harm or material flow risk.	

6 WASTE STORAGE AND DISPOSAL LOCATION

A list of wastes and their disposal or storage location within the SBWMF is detailed in Table **6-1**. The location of the disposal and storage facilities within the site area is shown in Figure 3-2

Table 6-1. Landfill wastes disposal location at SBWMF

Description of waste/ source	Disposal/Storage location
Inert Waste (Virgin excavated material; concrete and bricks)	Inert waste disposal (Stage 2)[1]
Municipal Waste	Active putrescible cell[1]
Commercial & Industrial	Active putrescible cell [1]
Construction & Demolition (fittings, fixtures, cabinetry, steel framework, woofing material, furniture, construction materials)	Inert waste disposal (Stage 2) [1]
e-waste	Recycle centre[2]
White goods/Scrap Metal	Transfer station[3]
Green waste	Green waste disposal and mulching operations[2]
Used Lead Acid Batteries	Transfer station[2]
Cardboard	Recycle centre[2]
Gas bottles & Fire extinguishers	Recycle centre[2]
Paint	Transfer station[2]
Concrete for crushing	Transfer station[2]
Chemicals	Transfer station[2]
Oil (motor)	Transfer station[2]
Cooking oil	Transfer station[2]
Metal – all	Inert waste disposal (Stage 2) [2]
Soil-clean fill	Inert waste disposal (Stage 2) [2]
Listed Waste	
Acid solutions or acids in solid forms	Transfer station[2]
Animal effluent and residues	Transfer station[2]
Asbestos	Inert waste disposal (Stage 2) [2]
Clinical and related wastes	Inert waste disposal (Stage 2) [2]
Lead, lead compounds	
Sewerage sludge and residues including nightsoil and septic tank sludge	Inert waste disposal (Stage 2) [2]
Soils contaminated with a listed waste	Inert waste disposal (Stage 2) [2]
Tyres	Inert waste disposal (Stage 2) [2]
Waste from the production, formulation and use of inks, dyes, pigments, paints, lacquers, and varnish	Transfer station
Waste mineral oils unfit for their original intended use	Transfer station[2]

[1]Obtained from KESAB (2021)[2]Obtained from City of Darwin (2021a)[3]Obtained from City of Darwin (2021b)

7 RISKS ASSOCIATED WITH STOCKPILING MATERIALS

7.1 Methodology

The risk assessment process involves identification of aspects and impacts, and is systematic and consistent with the following international best practice standard methodologies:

- AS/NZS ISO 31000:2009: Risk management - Principles and Guidelines (Standard).
- HB 203:2006: Environmental risk management - Principles and Process (Guide).
- HB 158:2010: Delivering assurance based on ISO 31000:2009 - Risk management - Principles and Guidelines (Guide).

Aspects are defined as the elements of an organisations activities, products or services that can interact with the environment (e.g. use of machinery, storage of wastes). Impacts are any change to the environment, whether adverse or beneficial, wholly or partially resulting from the organisations environmental aspects.

Identifying the aspects and impacts relevant to the stockpiling works undertaken at SBWMF allows an assessment of the environmental risk to be completed, using a standard consequence and likelihood matrix. Management or mitigation measures can be assigned to each aspect, with a residual risk calculated based on the resulting potential impacts. Environmental management activities can then be prioritised according to risk. Risks have only been assessed for activities related to the stockpiling operations undertaken at SBWMF.

7.1.1 Risk ranking

The ranking for event consequence is shown in Table 7-1. The likelihood of an event occurring provides a measure of the known or anticipated frequency of occurrences (Table 7-2). Combining likelihood with consequence provides guidance on risk levels of each aspect and enables key risks to be identified and management strategies to be prioritised (Table 7-3). The risk assessment for the activities associated with SBWMF is provided in Table 7-4.

Table 7-1. Consequence ranking

Consequence		
1	Insignificant	No/low measurable impact on the environment.
2	Minor	Some minor, temporary environmental impact.
3	Moderate	Contained temporary or permanent minor, localised environmental damage.
4	Major	Severe environmental damage.
5	Catastrophic	Environmental disaster.

Table 7-2. Qualitative measures of likelihood

Probability/Likelihood			Likelihood criteria
A	Rare	May occur only in exceptional circumstances.	0-1%
B	Unlikely	Could occur at some time.	2-10%
C	Moderate	Might possibly occur at some time.	11-50%
D	Likely	Will probably occur in most circumstances.	51-90%
E	Almost certain	Expected to occur in most circumstances.	91-100%

Table 7-3. Risk rankings from combined consequences and likelihood

		Consequence				
Likelihood		1	2	3	4	5
	A	1	3	6	10	15
	B	2	5	9	14	19
	C	4	8	13	18	22
	D	7	12	17	21	24
	E	11	16	20	23	25

Where;

Red =	extreme risk	intolerable
Orange =	high risk	intolerable or tolerable
Yellow =	medium risk	tolerable or acceptable
Green =	low risk	acceptable

7.2 Risk assessment

Table 7-4. Environmental aspects and impacts register

Aspect	Impact	Potential Impact	Initial Risk			Management Measure / Controls	Residual Risk		
			Likelihood	Consequence	Risk Score		Likelihood	Consequence	Risk Score
Water quality (groundwater and surface water)	Pollution of waters – leaching or runoff of contaminants	• Reduced natural resource quality (Shoal Bay and Darwin Harbour) • Site contamination and degradation (land, surface water and groundwater • Reduced ecosystem quality and function	C	3	**H (13)**	• Containment of leachate and diversion and control of stormwater • Bunding around stockpiles • Low permeability surfaces applied to stockpiles (i.e. soil binder, vegetation) • Enclosed or covered facility for storage of stockpiles • Stormwater runoff controls such as silt traps and settlement ponds • Monitoring and review of management plans (i.e. SWMP, SPMP, SBWMF EMP)	B	3	**M (9)**
	On site operations leading to erosion of sediments from disturbed areas, generation of sediment laden runoff	• Contamination of receiving surface waters, through uncontrolled water release	C	2	**M (8)**	• Installation of erosion and sediment controls • Implementation of a regular inspection and maintenance program for erosion and sediment controls • Stormwater infrastructure designed to direct clean runoff from disturbed areas • Stormwater infrastructure designed to capture runoff within operation/disturbed areas • Leachate system effectively capturing leachate volumes generated on site • Rehabilitation and revegetation for exposed slopes and disturbed areas to be implemented in accordance with the closure and post closure plans	B	2	**L (5)**
Fire	Heat generation with potential to cause fire	• Damage to property, risk to human health, risk to environment • Pollution of atmosphere with toxic chemicals • Offensive odours	C	2	**M (8)**	• Materials to be sampled and results given to SBWMF prior to being accepted into facility • Minimise stockpile size to design guidelines • Ensure that there is suitable access and spacing between stockpiles. Fire breaks and fuel reduced areas are maintained regularly. • Monitor stockpile temperatures	B	2	**L (5)**

Aspect	Impact	Potential Impact	Initial Risk			Management Measure / Controls	Residual Risk		
			Likelihood	Consequence	Risk Score		Likelihood	Consequence	Risk Score
						• Maintain aerobic conditions • Implement operational procedures if a fire were to break out • Appropriate firefighting equipment is located throughout the site • Hazardous substances to be stored in appropriately bunded containers or within impervious areas • An Emergency Response Plan has been developed and all personnel and contractors have received training into Emergency Response Procedures • Develop and implement a regular vegetation/weed management program that details control measures i.e. seasonal weed spraying, slashing			
Waste management	On site waste management i.e. cross contamination of wastes, asbestos handling, windblown litter	• Threat to flora and fauna • Reduced recycling ability due to cross contamination • Human health risk due to inappropriate management of asbestos • Reduced visual amenity leading to community complaints	C	3	**H (13)**	• Waste acceptance and segregation procedures are adhered to, to ensure waste is accepted into lined cells and only inert waste is placed in unlined cells • Waste segregation requirements are clearly labelled with signage at the Transfer Station • An asbestos disposal cell is appropriately constructed and signed • Waste is covered as required i.e. daily covers, temporary covers and/or capping • Recyclable materials that are incorrectly deposited are salvaged following regular inspections • Approvals are required and obtained prior to receipt of any Special Wastes • Litter fences are installed, regularly inspected and maintained as required • Regular inspections and clean-up operations are undertaken to prevent wind-blown litter leaving site boundaries	B	3	**M (9)**
Noise, Dust, Odours and Greenhouse Gas Emissions	On site operations generating excessive noise, dust,	• Off-site dust deposition resulting in community complaints • Excessive noise causing community disturbance and resulting in community complaints	C	2	**M (8)**	• Water trucks are in regular use and static dust suppression techniques i.e. stockpile sprinklers, are implemented when dust is being generated on site. Compaction, screening, enclosures, windbreaks, soil binders and permanent road surfaces to also be considered.	B	2	**L (5)**

Aspect	Impact	Potential Impact	Initial Risk			Management Measure / Controls	Residual Risk		
			Likelihood	Consequence	Risk Score		Likelihood	Consequence	Risk Score
	offensive odours and/or excessive greenhouse gases	• Offensive odours causing community disturbance resulting in community complaints • Fugitive methane gas emission release resulting in an increased in net greenhouse gases emitting to the atmosphere. • Adverse impacts on amenity • Human health impacts (i.e. respiratory problems				• Employ a traffic management plan to control frequency and speed of vehicles entering and/or working in the facility. • Operations are confined to site opening hours, afterhours works will only occur through prior arrangement with appropriate notification and controls implemented • A vegetation buffer is maintained between the site and the nearest sensitive receptors • Waste is covered as required i.e. daily covers, temporary covers and/or capping • Maintain aerobic conditions of stockpiles • Physical controls such as containment, cover, enclosure and vapour filtration systems			
Flora and Fauna	Uncontrolled release of contaminated water in areas of native vegetation and habitat	Flora stress or die back resulting from exposure to contaminated water and soils	C	2	**M (8)**	• Leachate collection systems are installed, maintained and regularly inspected to ensure their effectiveness • Installation and maintenance of a leachate treatment system • Leachate ponds are lined to prevent seepage to groundwater, and covered to prevent surface water infiltration • Emergency backflow infrastructure is installed and working effectively to return leachate from ponds to landfill	B	2	**L (5)**
Weeds and Pests	On site operations providing a habitat for pests i.e. vermin, biting insects	• Introduction and/or spread of pests within the site and to the surrounding land	C	2	**M (8)**	• Waste is covered as required i.e. daily covers, temporary covers and/or capping • Regular inspections and clean-up operations are undertaken to prevent wind-blown litter leaving site boundaries • Regular inspections across the site to minimise ponding of water at any area of operations • Installation and maintenance of a boundary fence to prevent access by larger animals	B	2	**L (5)**
Stockpiling activites	Stockpile instability leading to collapse of stockpile	• Stockpile collapse leading to potential injury and damage to surrounding infrastructure • Potential impact to human health	C	3	**H (13)**	• Implement appropriate material handling procedures such as sampling regimes and placement of stockpiles with appropriate bunding • Minimise the sizes of stockpiles to ensure they are in accordance with design guidelines	A	3	**L (6)**

Aspect	Impact	Potential Impact	Initial Risk			Management Measure / Controls	Residual Risk		
			Likelihood	Consequence	Risk Score		Likelihood	Consequence	Risk Score
						• Monitoring stockpiles regularly			
	Inadequate platform stability and suitability (i.e. location of stockpile) leading to damage of area and site contamination	• Site contamination (i.e. waterways, runoff, groundwater) • Infiltration of leachate into and damage to underlying groundwater aquifers • Damage to stockpiled area and infrastructure leading to collapse of stockpile • Potential damage to capping material if storage if on old landfill leading to increased risk of emissions from leachate and gas generation • General ground and surface instability	C	3	**H (13)**	• Stockpiles are designed by a suitably qualified engineering consultant with a background in waste management • Assessment of suitable locations for location of stockpiles • Stockpiles are constructed to design standard and guidelines to avoid overloading • Suitable sizes and separation distances considered based on material types stockpiled	A	3	**L (6)**
	Excessive accumulation of material leading to adverse impacts on the environment and surrounding area	• Adverse impact of amenity and functionality of the facility • Increased risk of dust emissions, contaminated runoff • Expanding capacity of the site, not capable of facilitating and managing waste volumes • Increased environmental liability and increased risk of abandonment of stockpile remediation • Creates distortion of market value of materials which may not have a sustainable end use (i.e. reuse)	C	3	**H (13)**	• Planning of stockpile locations • Appropriate materials flow calculations, management and procedures of stockpiles being construction and decommissioned from site • Contingency plans for stockpiles • Ensuring only appropriate wastes are accepted (i.e. considering both types and volumes) • Storing materials that await recycling or reuse for no longer than 24 months • 'Ensure that there is appropriate disposal and payment of waste levies on materials without a genuine reuse sector or market for reuse. • Ensure sustainable materials flows practices are in place (i.e. recycling and reuse facilities, planning etc). • Ensure that appropriate ownership, contractual and management are in place for the management of stockpiles.	A	3	**L (6)**

8 STOCKPILING REQUIREMENTS

The following section details the requirements to manage stockpiles effectively at SBWMF. This includes material inventories (material flow, markets, and timeframes), stockpile designs and setbacks, and stability of stockpiles on site.

8.1 Record keeping of material flow, markets, and timeframes

Prior to the acceptance of waste into SBWMF, CoD must maintain an inventory of materials that are managed and stored onsite, to inform the risk assessment and controls required to minimise any risks that can have a detrimental impact on the environment, human health and the infrastructure of the SBWMF. At a minimum, CoD must:

- Record inventory information on:
  - Types of materials stockpiled at SBWMF, particularly materials that are high risk and are a listed waste as per EPL188-03
  - The location of the materials stockpiled at SBWMF
  - The volumes (tonnes and/or cubic metres) of materials stockpiled at SBWMF
  - If the waste is considered contaminated, that it has been tested and verified prior to being accepted at SBWMF to ensure that it has met the criteria derived by the NT EPA.
- Ensure that the inventory is maintained on a daily basis and is easily accessible for review by CoD or the NT EPA
- Record the:
  - Date and time that the material is transported into and out of SBWMF
  - Generation and/or source of the material and any potential/actual contaminants within the materials
  - Material type
  - Material volumes/size
  - Total volume of material stockpiled
- Storage time and market availability of materials that enter SBWMF that are appropriate for reuse, recycling and/or resale.
- Length of time required for stockpiling to ensure that materials being stockpiled are in a good condition and will not detrimentally impact the environment or human health (i.e. leaching of materials from stockpile into groundwater, sediment laden runoff etc).

As the volumes of materials entering SBWMF can vary considerably depending on the nature of the activity of the market, supplying or targeting the materials, stockpiling needs to be conducted with material flow and site capacity in mind. CoD must keep in mind that that stockpiling of materials, whilst growing with the rates of markets availability and need and population growth, must also have a systematic approach which considers input, processing, output, storage, reuse/resale and/or removal offsite to demonstrate responsible and sustainable management of stockpiles, particularly for material recycling and reuse. Reporting on materials flow and mass balances is the easiest way to demonstrate to the NT EPA that appropriate materials management is being adhered to.

8.2 Site selection for stockpiles

The following must be considered and adhered to when finding a suitable location for stockpiled materials at SBWMF:

- Stockpiled materials must be stored away from watercourses, flood zones and groundwater recharge areas to prevent environmental harm to water (*Waste and Management Pollution Control Act* 1998).
- Consultation of the *Guideline: Recommended Land Use Separation Distances* (NT EPA, 2017) to ensure the appropriate management of noise, dust, smoke, and odour emissions.
- Areas between stockpiles and along the boundary of SBWMF are kept free of obstruction to allow easy movement of operational and emergency vehicles.
- All materials are required to be inspected as per EPL188-03 and the *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites In the Northern Territory* (NT EPA, 2013). More specifically, materials which have been inspected are sorted as follows
    - Each individual material type (including that of each hazardous material that may enter SBWMF) clearly labelled or signposted to indicate the individual material type being stored in that area
    - Each label or signpost must be legible and clearly visible within SBWMF
    - The labels or signposts at all storage areas containing materials awaiting compliance test results (i.e. contaminated soils with suspected hydrocarbons or PFAS for example) must contain the words ‘awaiting validation;
    - Stockpiled materials should be segregated into discrete and manageable piles with clear signage defining the various stockpile areas.

8.3 Timeframes for stockpiling

In general, stockpiling should be considered as a temporary measure, whereby stockpiling of materials should not occur for speculative purposes (i.e. just in case or if there is no-where else to go).

- Temporary stockpiling of materials that has a market for recycling, resale or reuse must not be stockpiled for longer than 6 months to reduce the potential abandonment rick or speculative indefinite stockpiling
- Longer stockpiling for materials such as biosolids (i.e. manures or sludge) may be suitable to allow for stabilisation and drying prior to reuse, provided the most appropriate controls are in place. Guidelines for the storage of biosolids can be found *in Environmental Guidelines: Use and disposal of biosolids products* (NSW EPA, 2000).
- Municipal, commercial and industrial wastes, including putrescible biosolids, must only be temporarily stockpiled whilst awaiting processing and/or transfer and disposal appropriately on site (i.e. in landfill cell). These types of waste should be moved within 24 hours of being stockpiled, however may be acceptable to be left in the stockpile for up to 72 hours.

8.4 Stability of stockpiles

When considering a stockpile’s stability, size and management the following should be considered:

- Material composition (i.e. is it contaminated?)
- Relevant sub-surface geology and geotechnical characteristics
- Structure of the stockpile base and sub-base including ability to protect groundwater and susceptibility to dissolution from rainwater or materials held in the stockpile.

- Likelihood of failure (i.e. poor design and management including excessive height and unrealistic batter slopes, decreased internal friction caused by water inundation or gas generation within the stockpile)
- Proximity to extraneous sources of ground vibrations (i.e. railway lines, main roads or heavy vehicle movements)
- Material handling procedures to prevent surface collapse of the land where the stockpile is place
- Climate conditions (i.e. wet season vs dry season)

8.5 Stockpile dimensions

CoD must demonstrate they have taken all reasonable and practical measures to prevent incidents by managing adequate separation between stockpiles. If the recommended dimensions and deemed unsuitable for SBWMF, alternative stockpile dimensions can be used where it can be demonstrated that it provides a better or equivalent substitute.

Stockpile height limits are usually governed by stockpile manageability, dust impacts, stability, potential impact to underlying infrastructure, aesthetics and fire risks. Stockpile heights should generally be lower than surrounding structures. However where required, stockpile heights may be higher ensuring than an adequate assessment of the additional risks the extra height may impose to the environment and human health due to instability.

8.5.1 General dimensions

The following dimensions of stockpiles are a guideline only, and require assessment of the material prior to placement of stockpiles.

- Maximum height of 4 m for any type of loose material
- Maximum height of 4 m or 4 bales for type of baled material (whichever is lower in height)
- Stockpile width must not exceed 20 m for loose and baled materials of any type that is considered ‘free standing’ (i.e. that is not separated by walls or bunkered), with easy access from all sides.
- Stockpile width must not exceed 10 m for both loose and baled material of any type that is ‘free standing’ with easy access from at least one side.
- In some situations, where there has been an environmental risk assessment completed and the risks are considered medium to high risk, this may result in lower stockpile dimensions being required.
- 45 degree angles are the maximum batter slopes.
- The risk posed by specific materials should be considered when determining the suitable width and overall footprint of the stockpile (e.g. accessibility or risk of fire).

8.6 Dimensions of listed (hazardous) waste stockpiles

Consideration may need to be given to the reception and storage of small quantities of hazardous materials, if there is no immediate waste treatment or disposal measures available. Temporary storage should also be provided for possibly hazardous waste awaiting analysis and classification before appropriate decisions can be made regarding disposal.

If inappropriately managed, they can impact adverse on the environment and this must be stored at dedicated locations, such as SBWMF. The storage and handling of flammable and combustible liquids must be in

accordance with the Australian Standard AS1940 *The Storage and Handling of Flammable and Combustible Liquids*. During the storage there must be no visible leakage of the contents from any storage vessel and suitable spill. Kits must be available.

Waste tyres are not to be stored in the open for more than 5 days, unless:

- The waste tyres are covered by an impervious membrane which excludes water in totality
- Waste tyres are made incapable of retaining water (i.e. have been shredded)
- Waste tyres are individually treated with larvicide. The concentration of the larvicide is to be of a strength to stop the breeding cycle of mosquitos.

According to the EPL188-03, stockpile dimensions for each tyre stockpile must not exceed the following guidelines:

- Maximum height of 3 m
- Maximum width of 5 m
- Maximum length of 45 m
- Separation between stockpiles must be equal or greater than 15 m
- Separation to distance from end of stockpile must be equal or greater than 10 m
- Firebreak perimeter around each tyre stockpile must be equal or greater than 4 m

8.6.1 Separation requirements for stockpiles

For the purposes of calculating separation distances, the different types of stockpiled materials have been grouped based on their burn temperature and stockpile type. The guidelines have been adapted from the *Guideline for Stockpile Management* by the ACT EPA.

Table 8-1. Stockpile length and separation requirements for freestanding loose and baled materials (ACT EPA 2019)

	Material type			
	Paper, cardboard, wood, textile, organic material, refuse derived fuel Burn temperature of 850-950 degrees Celsius		Rubber, plastic, specified electronic waste, metals Burn temperature > 1200 degrees Celsius	
	Stockpile type			
	Free standing loose stockpiles	Free standing baled stockpiles	Free standing loose stockpiles	Free standing baled stockpiles
Stockpile length (m)	**Separation distance (m)**			
10	7	13	15	20
15	9	15	20	24
20	10	17	21	27

Table 8-2. Minimum stockpile separation requirements to a building for freestanding loose and baled materials (ACT EPA 2019)

	Material type	
	Paper, cardboard, wood, textile, organic material, refuse derived fuel Burn temperature of 850-950 degrees Celsius	Rubber, plastic, specified electronic waste, metals Burn temperature > 1200 degrees Celsius
	Stockpile type	

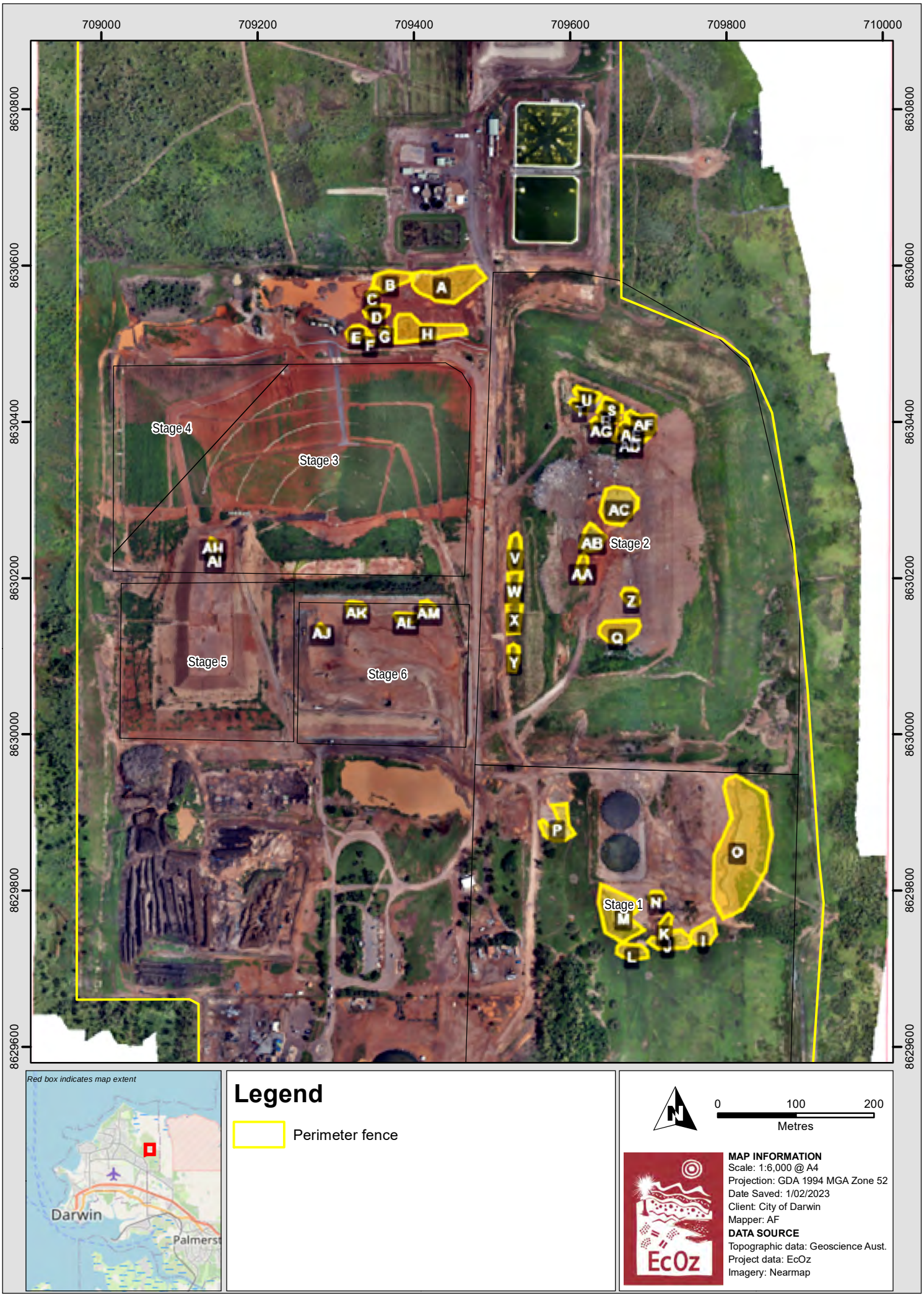
	Free standing loose stockpiles	Free standing baled stockpiles	Free standing loose stockpiles	Free standing baled stockpiles
Stockpile length (m)	**Separation distance (m)**			
10	9	12	18	18
15	12	14	22	22
20	13	15	25	24

9 STOCKPILES AT THE SBWMF

A total of 77 stockpiles are located at the SBWMF as of 4 January 2023. The stockpiles of soil, gravel, tyres are located on on Stages 1, 2, 5 and 6 including the borrow pit. Green waste stockpiles are found in the green waste disposal area. Information about the type of waste stockpiles, their location and volumes are provided in Tables 9-1 and 9-2 with corresponding locations in Figures 9-1 and 9-2.

Table 9-1: Soil, gravel and tyres stockpiles

Map Key	Location	Stockpile type	Volume (m^3)
A	Borrow pit	soil	290
B		soil	61.09
C		soil	2.18
D		soil	2.69
E		soil	17.81
F		soil	0.7
G		gravel	0.07
H		soil	60.47
I	Stage 1	soil	11.7
J		rocks	19.84
K		soil	2.22
L		soil	47.25
M		soil	36.1
N		soil	2.69
O		soil	43.91
P		soil	50.66
Q	Stage 2	soil	44.02
R		tyres	0.17
S		tyres	1.24
T		tyres	2.21
U		tyres	8.49
V		tyres	11.07
W		tyres	19.3
X		tyres	26.59
Y		tyres	4.18
Z		soil	0.87
AA		soil	0.53
AB		mixed C&D waste	9.28
AC		Crushed concrete	6.96
AD		tyres	2.72
AE		tyres	0.22
AF		tyres	9.89
AG		tyres	0.9
AH	Stage 5	soil	0.35
AI		soil	1.56
AJ	Stage 6	soil	1.02
AK		soil	0.3
AL		soil	1.29
AM		soil	4.67

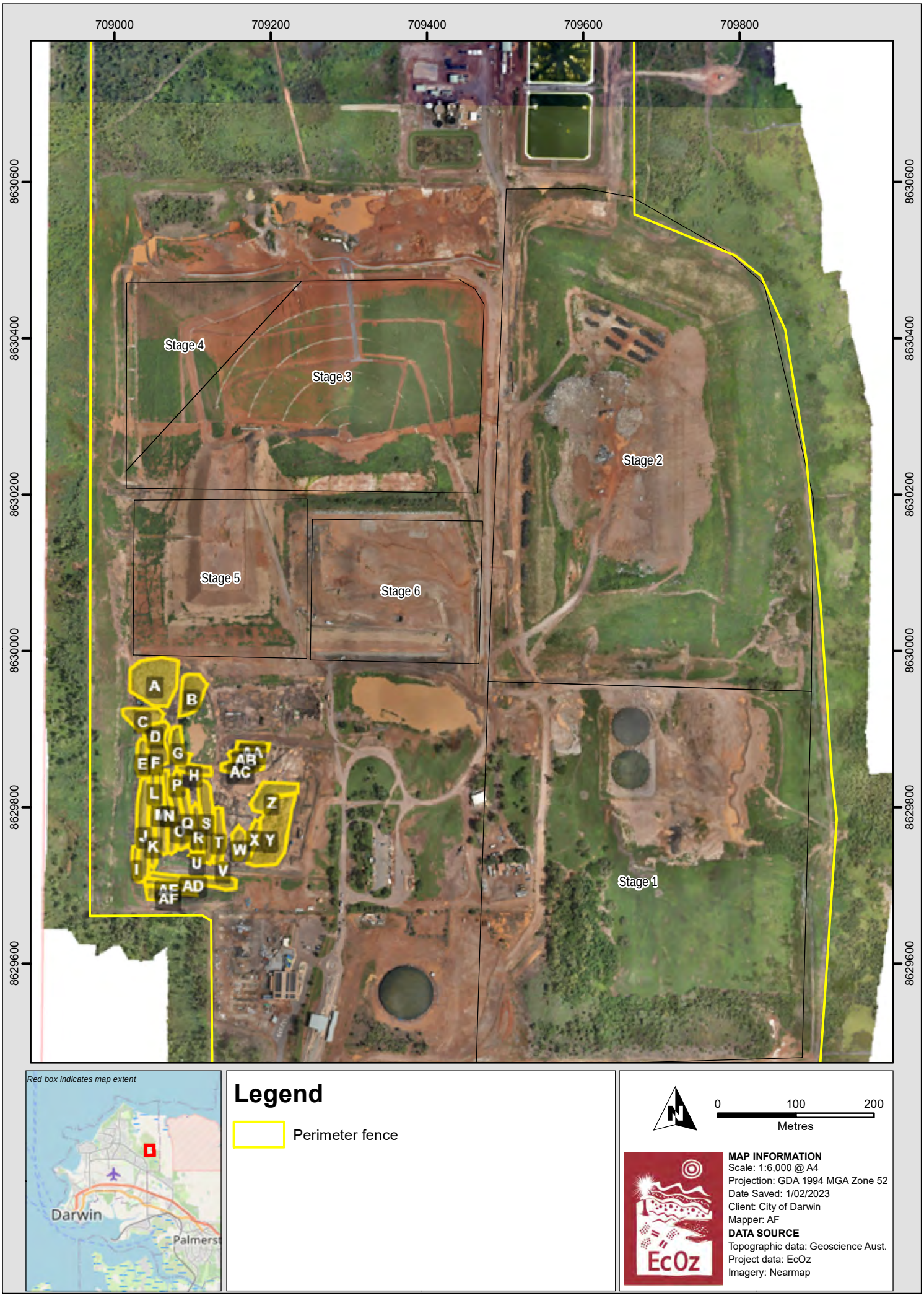


Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Stockpile report map.mxd

Figure 9-1. Soil, gravel and tyres stockpiles locations

Table 9-2. Green waste stockpiles

Map Key	Stockpile type	Volume (m^3)
A	Green waste	30.33
B		50.32
C		15.45
E		1.74
F		2.34
G		4.6
H		0.12
I		3.38
J		9.33
K		1.4
L		3.15
M		68.38
N		6.18
O		4.32
P		0.09
Q		2.35
R		0.13
S		6.82
T		13.53
U		4.8
V		0.91
W		5.32
X		2.89
Y		34.8
Z		16.84
AA		3.27
AB		1.34
AC		1.98
AD		111
AE		9.51



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ20089 - SBWMF EMP\01 Project Files\Stockpile report map - green waste.mxd

Figure 9-2. Green waste stockpiles

10 REPORTING REQUIREMENTS FOR FUTURE STOCKPILE MANAGEMENT PLANS

This SPMP, provides an overview of the requirements needed to manage stockpiles within SBWMF. It is a requirement of this SPMP that this document be updated each year with the most up to date data from SBWMF, including updated risks, specific details of waste volumes, details of waste processing undertaken at the site and relevant management procedures.

The SPMP update should also include details of milestones achieved over the past 12 months and proposed milestones (including timeframes and volumes) for material flow.

Table 10-1. Future reporting requirements for SPMPs

Item	Assessment criteria
1	Map of site layout that clearly identifies specific stockpile areas for each material type, water access, fire breaks/buffers between stockpiles and vacant spaces necessary to move smouldering material in the event of a fire
2	Details of identified risks to the environment and human health and their relevant management procedures.
3	Details of the specific wastes and other materials received and stockpiled at the premises and their intended fate
4	Details of the waste processing undertaken on site over the past 12 months and details of any changes to waste processing proposed in the next 12 months
5	Details of management practices for stockpile shape and type (baled, loose, bunded, undercover, enclosed), footprint, stability (batter slop and stacking layout), separation distances and number of stockpiles
6	Milestones for stockpile material flow management (including timeframes and volumes for the past 12 months and future 12 months)
7	Details of methodologies for QA/QC processing processes implemented for wastes to be received for processing, processing procedures, procedures that ensure no unauthorised wastes or materials and included in final products, and sampling and assessment to confirm that the physical and chemical quality of the material meets appropriate criteria for the intended fate of all material and waste.
8	Analysis of market conditions, potential fluctuations and intended customers for stockpiled materials and waste
9	A contingency plan should market conditions become unfavourable to lower the risk of abandonment of materials and waste
10	Details of material flow for the facility, e.g. material movements in and out of the facility are to be recorded and provided to the NT EPA.

11 REFERENCES

ACT EPA (2019*). Guideline for stockpile management*, November 2019, ACT Environment Protection Authority, ACT Government, Canberra.

Bureau of Meteorology (2022) Climate Data Online – Darwin Airport Station 014015. [online] Available at: http://www.bom.gov.au/climate/data/ [Accessed 23 November 2021]

City of Darwin (2021a) *Recycling & Waste Guide*. [online] Available at: https://www.darwin.nt.gov.au/resident-services/waste-recycling/recycling-waste-guide [Accessed 10 December 2021]

City of Darwin (2021a) *Sorting Your Waste*. [online] Available at: https://www.darwin.nt.gov.au/resident-services/waste-recycling/shoal-bay-waste-management-facility/sorting-your-waste [Accessed 10 December 2021]

EcOz (2020). *Shoal Bay Waste Management Facility, Water quality monitoring data review, 2016 – 2020*, August 2020, Report prepared by EcOz Environmental Consultants Pty Ltd (EcOz) for City of Darwin.

Golder (2016a). *Final Landform Geometry Options Review, Future Landfill Stages 5 to 10, Shoal Bay Waste Management Facility*, May 2016, Letter prepared by Golder Associates Pty Ltd (Golder) for City of Darwin.

Golder (2016b). *Landfill Development Plan, Stage 5 to Stage 10 General Waste Cells, Shoal Bay Waste Management Facility, Darwin,* August 2016, Report prepared by Golder Associates Pty Ltd (Golder) for City of Darwin.

Golder (2020). *Water Balance, Leachate and Stormwater Management Strategies Shoal Bay Landfill, Darwin*, July 2020, Report prepared by Golder Associates Pty Ltd (Golder) for City of Darwin.

KESAB (2021) *Development & Implementation of Shoal Bay Waste Management Facility Disposal – Based Waste Audits*, April 2021. Report prepared by KESAB Environmental Solutions for City of Darwin

NT EPA (2013). *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites in the Northern Territory*, January 2013, Northern Territory Environment Protection Authority (NT EPA), Northern Territory Government, Darwin, NT.

NT EPA (2022). Annual Return 2021 to 2022 Reporting Period. [online] Available at: https://ntepa.nt.gov.au/__data/assets/pdf_file/0019/1123057/epl188-city-of-darwin-annual-return2022.pdf [Accessed 04 August 2022]

NT EPA (2021). Environmental Protection Licence (EPL) 188-03. [online] Available at: https://ntepa.nt.gov.au/__data/assets/pdf_file/0005/955238/epl188-03.pdf [Accessed 11 December 2021]

SA EPA (2020). *Guideline for stockpile management*, October 2020, South Australia Environment Protection Authority (SA EPA), South Australian Government, Adelaide, SA.

URS (2015). *Shoal Bay Waste Disposal Site, Hydrogeological Investigation*, November 2015, Report prepared by URS Australia Pty Ltd for John Holland Pty Ltd.

URS (2016a). Shoal Bay Waste Disposal Site, Conceptual Site Model, February 2016, Report prepared by URS Australia Pty Ltd for John Holland Pty Ltd.

URS (2016b). *Shoal Bay Waste Disposal Site Water Monitoring Plan*, March 2016, Report prepared by URS Australia Pty Ltd for John Holland Pty Ltd.

WCG (2020). *Shoal Bay Waste Management Facility Environmental Management Plan Leachate Treatment and Irrigation,* July 2020, Prepared by Water and Carbon Group Pty Ltd (WCG) for City of Darwin

APPENDIX A ONSITE INSPECTION CHECKLIST

Material Type	No. of stockpiles	Stockpile type				Access		Stockpile measurements			Separation (m)		Compliant with SPMP? (Y/N)
		Freestanding loose (Y/N)	Freestanding baled (Y/N)	Separated by walls (Y/N)	Bunkered loose (Y/N)	From both sides (Y/N)	Only from one side (Y/N)	Height	Length	Width	To other stockpiles	To buildings (if applicable)	



EcOz Environmental Consultants

EcOz Pty Ltd.
ABN 81 143 989 039

Level 1, 70 Cavenagh St,
GPO Box 381,
Darwin, NT 0801

T: +61 8 8981 1100
E: ecoz@ecoz.com.au

www.ecoz.com.au







APPENDIX E SITE INSPECTION CHECKLIST

Inspection items	Yes	No	N/A	Comments
General site management				
Have all actions raised in the previous inspections been closed out?				
Have all actions from any recent environmental incidents been adequately investigated and appropriately addressed?				
Is the work area free from visible incidents (i.e. chemical / hydrocarbon spills, leachate pools etc.)?				
Is the complaints register being used correctly?				
Are complaints being addressed?				
Have all incidents been reported?				
Have daily visual site inspections been undertaken?				
Have monthly environmental inspections against EPL conditions and this EMP been implemented?				
Have annual environmental audits of EPL conditions and EMP been undertaken?				
Have all personnel working at SBWMF been inducted about environmental risks?				
Have all personnel working at SBWMF been inducted about mitigation measures in the EMP?				
Have all personnel working at SBWMF been inducted about emergency response procedures?				
Is the induction register up to date?				
Waste acceptance and disposal				

Inspection items	Yes	No	N/A	Comments
Has relevant staff been trained on the types of waste accepted and how they should be disposed at SBWMF?				
Has relevant staff been trained on pre-approvals required for disposal of waste at SBWMF?				
Are clear signage indicating the types of waste accepted at SBWMF been located on-site?				
Have visual inspections of waste loads been undertaken by weighbridge staff?				
Has waste not listed in the EPL been only accepted after special approval from NT EPA?				
Have validation sampling results been always provided prior to the disposal of potentially contaminated soils?				
Are clear labelled signs located at the transfer station?				
Are recyclable materials incorrectly disposed salvaged?				
Is scattered and inappropriately disposed waste being regularly clean-up?				
Are daily cover, intermediate cover and capping applied as required?				
Is all liquid waste disposed directly into site septic tanks?				
Are drivers informed about how to identify hot loads and who should be informed about them?				
Have daily visual inspections of the waste transfer stations and active tip face been implemented during the dry season?				
Have visual inspections of the waste transfer stations and active tip face been implemented twice daily during the wet season?				
Storage and use of chemicals, oils and fuels				
Has there been any spill or leak of hazardous substances?				

Inspection items	Yes	No	N/A	Comments
Have all spills or leaks been reported to the NT EPA?				
Have all spills or leaks of hazardous materials been treated in accordance with the emergency response plan – spill response procedure?				
Are all chemicals, oils and fuels stored in accordance with their SDS?				
Is the storage of oils and fuels in accordance with the AS1940?				
Are SDS available in the area where the chemicals, oils and fuels are stored?				
Is equipment containing hazardous materials (including hydrocarbons, and hoses/pipes free of spills/leaks?				
Is chemical use in accordance with the SDS?				
Are spill response kits located in all storage areas?				
Are spill response kits fully stocked?				
Are spill response kits regularly checked?				
Has all site staff been trained in spill response?				
Have daily visual inspection been implemented to identify any hazards or spills in the waste disposal area?				
Have monthly site inspections been implemented to check the correct use and storage of hazardous materials?				
Water quality				
Is water quality monitoring being undertaken as per the program in the EMP/EPL?				
Have additional controls been installed, when required, for periods of high rainfall?				

Inspection items	Yes	No	N/A	Comments
Are all surface water courses unobstructed?				
Are erosion and sediment control structures intact and maintained?				
Are surface water structures free from erosion or scour?				
Is potentially contaminated storm water prevented from being discharged into the environment?				
Is clean water diverted from operational areas and other waste types?				
Is all wash down bay water captured and contained?				
Leachate				
Is early waste placement scheduled during dry periods?				
Is leachate irrigated only over lined landfill cells?				
Are active areas monitored after high rainfall events for signs of discoloured runoff/leachate?				
Has there been any leachate contamination of surface runoff?				
Have incidents been reported to the NT EPA?				
Have strategies been implemented to minimise the surface area and volumes of green waste kept on site?				
Are leachate collection systems installed?				
Are collection systems regularly inspected and maintained?				
Are leachate ponds lined and covered?				
Is there an emergency backflow infrastructure installed?				

Inspection items	Yes	No	N/A	Comments
Is the emergency backflow infrastructure regularly inspected?				
Has a leachate treatment system been installed?				
Is the leachate treatment system regularly maintained?				
Are daily checks undertaken on the treatment infrastructure?				
Is leachate stored in ponds specifically designed for its storage?				
Is leachate treated to a quality suitable for on-site discharged?				
Is leachate sampled prior to discharge?				
Has an irrigation management plan been developed and implemented?				
Is irrigation stopped during rainfall events?				
Is ground saturation monitored and logged to avoid overland flow?				
Is leachate regularly monitored (including flow and volumes)?				
Dust and odour				
Is the work area free from excessive visible dust?				
Are activities in the area creating minimal dust?				
Is dust dispersion of dirt roads and other cleared areas being undertaken where excessive dust is visible?				
Are speed limits being enforced at site to reduce dust?				
Are all equipment and machinery being maintained to manufacturers standards to prevent noise issues?				

Inspection items	Yes	No	N/A	Comments
Are any operations occurring outside standard work hours? Have the public, users and surround land owners been notified of works?				
Are odorous waste immediately covered?				
Are skip bins used at the transfer station cleaned at least monthly?				
Landfill gas				
Is an active landfill gas collection system installed on site?				
Is the landfill gas monitored as per monitoring schedule?				
Is the landfill gas collection system regularly inspected?				
Has there been any gas leak detected?				
Has any non-compliance been reported to the NT EPA?				
Is a passive landfill gas collection system being installed at the SBWMF?				
Is a passive landfill gas collection system planned to be installed as part of the SBWMF closure plan?				
Noise				
Are all equipment and machinery maintained to manufacturers standards?				
Are all equipment and machinery regularly inspected?				
Are all operations conducted during standard work hours?				
Has there been any noise complaint?				
Litter				

Inspection items	Yes	No	N/A	Comments
Is litter regularly cleaned up and disposed appropriately by SMWMF staff?				
Is there scattered rubbish around the site?				
Are all skip bins emptied before they are completely full?				
Is the perimeter fence regularly maintained?				
Are there controls in place to catch wind-blown litter? Do these require maintenance?				
Are daily site inspections implemented for visual check of litter?				
Are monthly site inspections implemented for the inspection of litter and litter controls?				
Flora and fauna				
Do all clearing works have the required approvals?				
Have any significant fauna sightings been reported to the Site Manager?				
Have any injured fauna been reported to the Site Manager?				
Are clear signs located at the SBWMF indicating that pets/domestic animals are not allowed on-site?				
Are speed limit being enforced to minimise potential for fauna impact?				
Are rehabilitation areas being monitored?				
Are disturbed areas being progressively rehabilitated, and done with species local to the surrounding environment?				
Are monthly site inspections implemented to check for signs of impacted flora and fauna?				
Pests and weeds				

Inspection items	Yes	No	N/A	Comments
Have declared weeds only been disposed at SBWMF after approval was obtained?				
Has a weed survey been undertaken at least annually?				
Are pests and weeds checked in operational areas during monthly site inspections?				
Are there any pests and weeds in operational areas?				
Are pests and weeds being managed/controlled on site?				
Are post control activities regularly undertaken at SBWMF?				
Are there any signs of pooled water that could provide a breeding ground for mosquitos?				
Fire prevention				
Are staff undertaking visual monitoring of loads going to landfill cells for evidence of smoking or hot loads?				
Are appropriate hot works procedures being followed?				
Is all fire-fighting equipment in date and accessible?				
Is there a designated smoking area? Is it being used?				
Is the 4 m wide fire break (around the perimeter of the SBWMF, around buildings and operational areas) being maintained?				
Has there been a report of hot loads?				
Special Waste				
Has all special waste disposed at SBWMF received approval through completion of a *Special Waste Disposal Application*?				

Inspection items	Yes	No	N/A	Comments
Is all approved special waste disposed in a pre-prepared pit excavated within the active tip face?				
Is all special waste immediately covered with waste material after disposal?				
Is the tip face inspected regularly to verify correct disposal?				
Are other tip areas inspected regularly for the identification of any illegal dumping of special wastes?				
Are all listed waste volumes reported in the EPL Annual Return?				
Contaminated soil management				
Have all contaminated soils disposed at SBWMF received approval through completion of a *Soil Disposal Application*?				
Is all relevant information (i.e. soil originating location, potential contaminants of concern and sampling results) obtained prior to the disposal of contaminated soil?				
Are all soil results assessed against relevant guidelines to determine acceptance?				
Are soil loads declared as contaminated disposed in a pre-prepared pit excavated within the active tip face?				
Is the tip face inspected regularly to verify correct disposal?				
Are other tip areas inspected regularly for the identification of any illegal dumping of contaminated soil?				
Asbestos and asbestos containing material				
Have all asbestos loads disposed at SBWMF received approval through completion of an *Asbestos Disposal Application*?				
Are all approved loads given a booking time for disposal?				

Inspection items	Yes	No	N/A	Comments
Is the asbestos cell adequately prepared prior to disposal and efficiently used?				
Are all asbestos loads disposed at SBWMF compliant with the *National Occupational Health and Safety Commissions Asbestos Code of Practice and Guidance Notes*?				
Are all accepted asbestos correctly wrapped?				
Are deposited asbestos waste at the asbestos cell area immediately covered by suitable material?				
Is the final cover of asbestos fibre and dust wastes at least 3 m thick?				
Is the final cover of stabilised asbestos wastes at least 1 m thick in a bonded matrix?				
Is the final cover of the asbestos marked with an orange marker mesh?				
Are GPS location and total volume of disposed waste recorded for each asbestos disposal?				
Are records of asbestos waste location and volume kept in the listed waste tracking register?				
Is the asbestos cell inspected regularly to verify correct disposal?				
Are other tip areas inspected regularly for the identification of any illegal dumping of asbestos material?				
Battery and paint management				
Are batteries and paint products only being accepted from residential users?				
Are batteries and paint products being stored on bunded pallets at the transfer station?				
Are batteries and paint products being stored in areas protected from rainfall ingress?				
Are batteries and paint products being removed from site by a licenced waste transporter, for recycling/disposal at an appropriately licenced facility?				

Inspection items	Yes	No	N/A	Comments
Are empty, dry and clean paint tins disposed in the scrap metal skip after inspected?				
Is the transfer station disposal area inspected regularly to verify correct disposal?				
Waste tyre management				
Are all tyres presented to the weighbridge prior to their disposal?				
Are tyres properly spread amongst the tip face to minimise movement?				
Are visual inspections of the tyre storage area implemented regularly?				
Waste oil management				
Are only domestic volumes of waste mineral oil or cooking oil being accepted at SBWMF?				
Is the storage of fuels and oils in accordance with the Australian Standard 1940-2004?				
Has any leak of waste oil been reported?				
Has any leak of waste oil been treated in accordance with the emergency response procedure?				
Has any oil spill been reported to the Site Manager?				
Are spill kits available at the waste oil storage area?				
IS waste oil removed from the site only by a licenced waste transporter, for recycling/disposal at an appropriately licenced facility?				
Are inspections regularly undertaken to verify correct disposal and signs of any leaks or spills?				

APPENDIX F STAGE 3 /4 CAPPING DESIGN

TRANSMITTAL

11 June 2021

Project No. 20145676-013-T-Rev3

Mathew Vitucci
City of Darwin
GPO Box 84
Darwin, NT
0801

FROM Iwan Owen

EMAIL IOwen@golder.com.au

SHOAL BAY WASTE DISPOSAL FACILITY: STAGE 3 / STAGE 4 CAPPING - ISSUED FOR CONSTRUCTION (IFC) DRAWINGS

Select one checkbox only

☐ **Mail/Express Post**	☐ **Enclosed**
☐ **Same Day Courier**	☐ **Picked Up**
☐ **Overnight Courier**	☐ **Hand Delivered**
☐ **Air Freight**	☐ **Other**
☑ **Email** Mathew.Vitucci@darwin.nt.gov.au	

Quantity	Item	Description
20	.pdf (file attached)	Stage 3/ Stage 4 Detailed Design – IFC Drawings (Rev 3)

Notes

D001	LOCALITY PLAN, DRAWING INDEX AND COVER SHEET
D002	EXISTING SITE CONDITIONS PLAN
D003	GENERAL ARRANGEMENT PLAN – TOP OF WASTE
D004	CUT / FILL PLAN – TOP OF WASTE
D005	GENERAL ARRANGEMENT PLAN – TOP OF CAPPING
D006	GENERAL ARRANGEMENT PLAN – CAPPING REINFORCEMENT
D007	GENERAL ARRANGEMENT PLAN – PASSIVE GAS SYSTEM
D008	GENERAL ARRANGMEENT PLAN – SUB-SURFACE WATER MANAGEMENT
D009	GENERAL ARRANGMEENT PLAN – SURFACE WATER MANAGEMENT
D010	LANDFILL CROSS SECTIONS
D011	SUB-SURFACE WATER MANAGEMENT – SECTIONS AND DETAILS
D012	ANCHOR TRENCH AND LINER CONNECTION DETAILS – SHEET 1 OF 2
D013	ANCHOR TRENCH AND LINER CONNECTION DETAILS – SHEET 2 OF 2
D014	PASSIVE GAS SYSTEM SECTIONS AND DETAILS – SHEET 1 OF 2
D015	PASSIVE GAS SYSTEM SECTIONS AND DETAILS – SHEET 2 OF 2
D016	CAPPING SYSTEM PENETRATION DETAILS
D017	STORMWATER CHUTE INLET- SECTIONS AND DETAILS
D018	STORMWATER CHUTE OUTLET- SECTIONS AND DETAILS
D019	NORTHERN DIVERSION BUND – LAYOUT PLAN AND LONGITUDINAL SECTION
D020	REINFORCEMENT AT CORNERS – TYPICAL SECTIONS AND DETAILS

Golder Associates Pty Ltd
147 Coronation Drive, Milton, Queensland 4064, Australia
T: +61 7 3721 5400 F: +61 7 3721 5401

A.B.N. 64 006 107 857

Golder and the G logo are trademarks of Golder Associates Corporation

Please advise us if enclosures are not as described.

ACKNOWLEDGEMENT REQUIRED:
☑ YES (please email/fax to Golder) ☐ NO

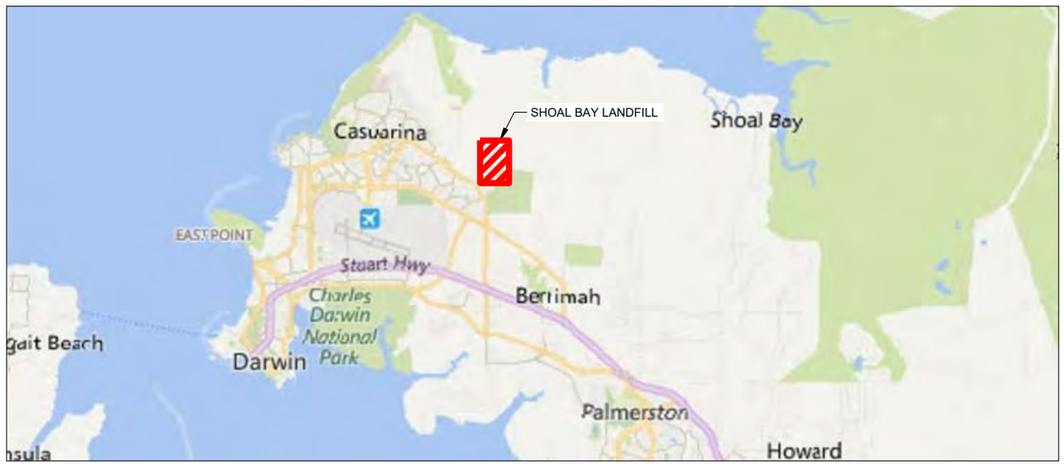
SW/JSB/IO

https://golderassociates.sharepoint.com/sites/128818/shared documents/deliverables/20145676-013-t-rev_detailed design drawings/20145676-013-t-rev3 - sbwmf stage3-4 capping project ifc drawing transmittal.docx

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.
   - FILENAME: 11615-2A.dwg
   - CAPTURE DATE: 2020-10-10
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
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	

CLIENT
CITY OF DARWIN

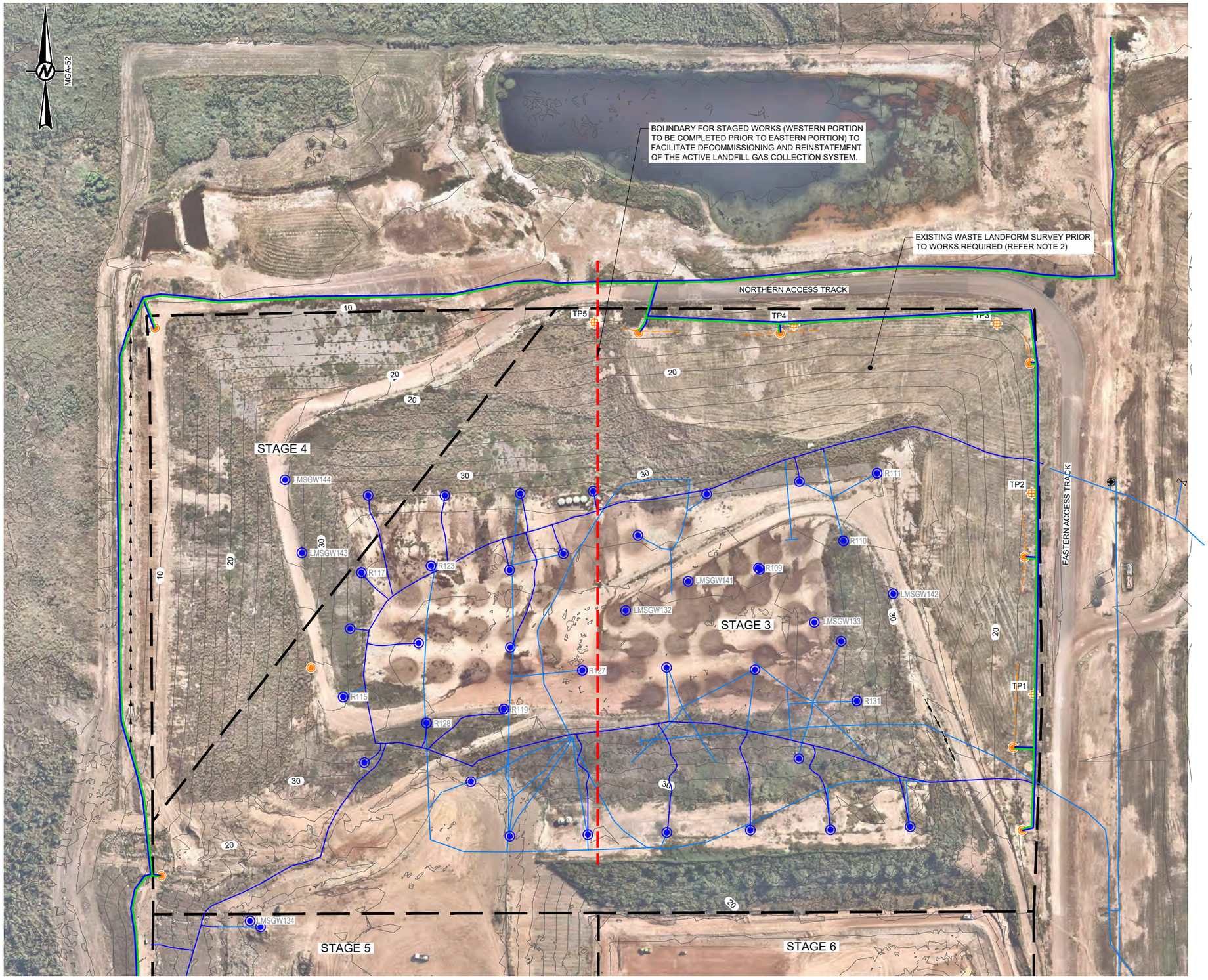
CONSULTANT
GOLDER
MEMBER OF WSP
BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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	3	1 of 20	001

Path: \\golder.gds\gap\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\199_PROJECTS\20145676 - Stage 3-4 Capping\ConceptDesign\013-Stage3-4_Capping\DetailedDesign\02_PRODUCTION\DWGS\ | File Name: 20145676-013-001.dwg | Last Edited By: bkanther Date: 2021-06-11 Time:10:32:10 AM | Printed By: BKanther Date: 2021-06-11 Time:10:46:42 AM
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	
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	

CLIENT
CITY OF DARWIN

CONSULTANT
GOLDER
MEMBER OF WSP

BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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

TITLE
EXISTING CONDITIONS

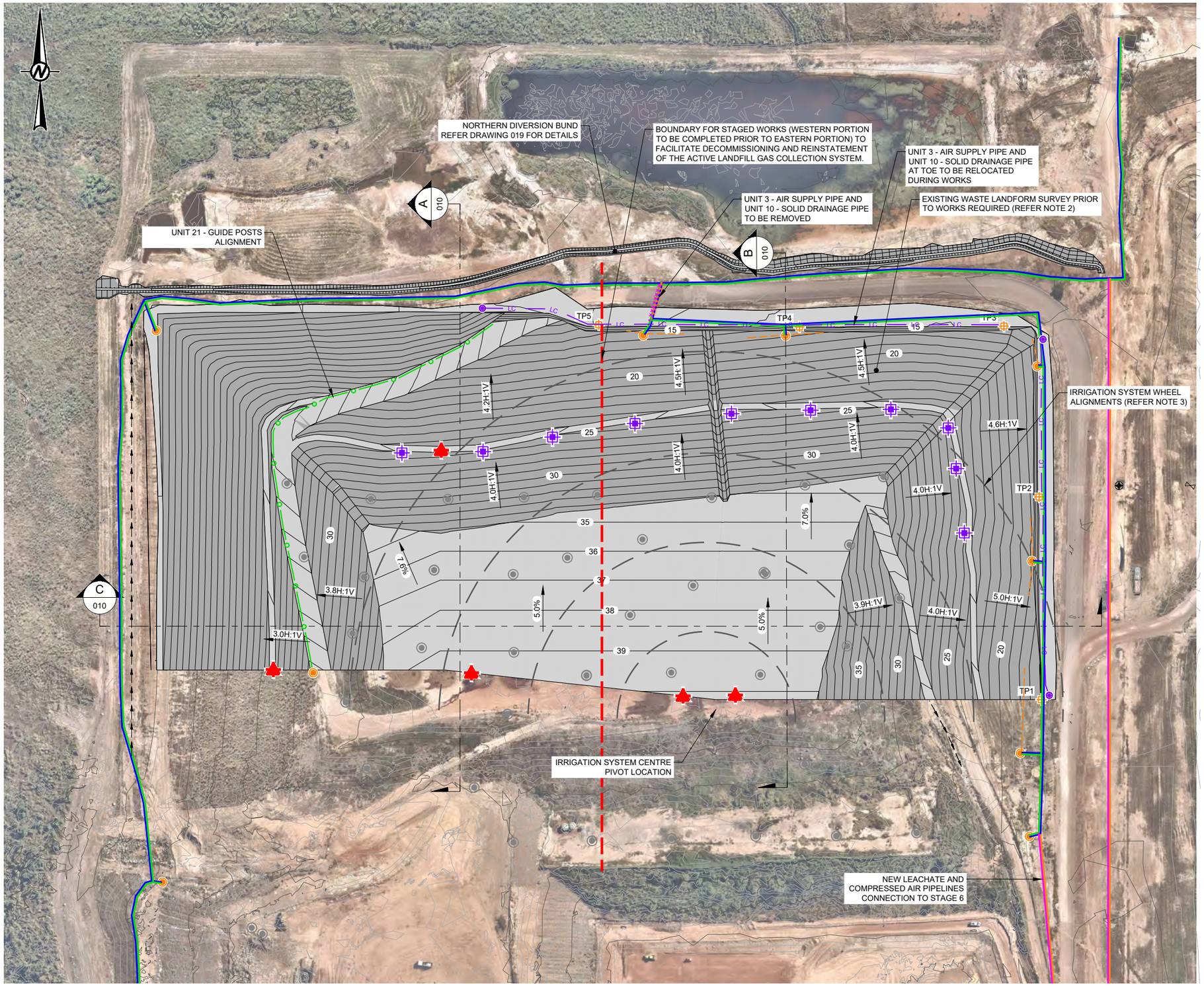
PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	3	2 of 20	002

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

25 mm

0

Path: \\golder.gbl\ggp\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\199_PROJECTS\20145676 - Stage 3-4 Capping\ConceptDesign\013-Stage3-4_Capping\DetailedDesign\02_PRODUCTION\DWGs | File Name: 20145676-013-002.dwg | Last Edited By: bkanther Date: 2021-06-11 Time:10:32:37 AM | Printed By: BKanther Date: 2021-06-11 Time:10:46:48 AM



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.

ISSUED FOR

CONSTRUCTION

0 50 100

1:2,000 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
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	

CLIENT
CITY OF DARWIN

CONSULTANT
GOLDER
MEMBER OF WSP

BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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	3	3 of 20	003

Path: \\golder.gds\gan\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\DWG\ | File Name: 20145676-013-003.dwg | Last Edited By: bkanther Date: 2021-06-11 Time:10:34:56 AM | Printed By: BKanther Date: 2021-06-11 Time:10:46:55 AM
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
0 25 mm

MGA-52

CUT FILL VOLUMES	
CUT (m³)	20,903
FILL (m³)	15,083

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

LEGEND

EXISTING GROUND CONTOURS (2 m INTERVALS)

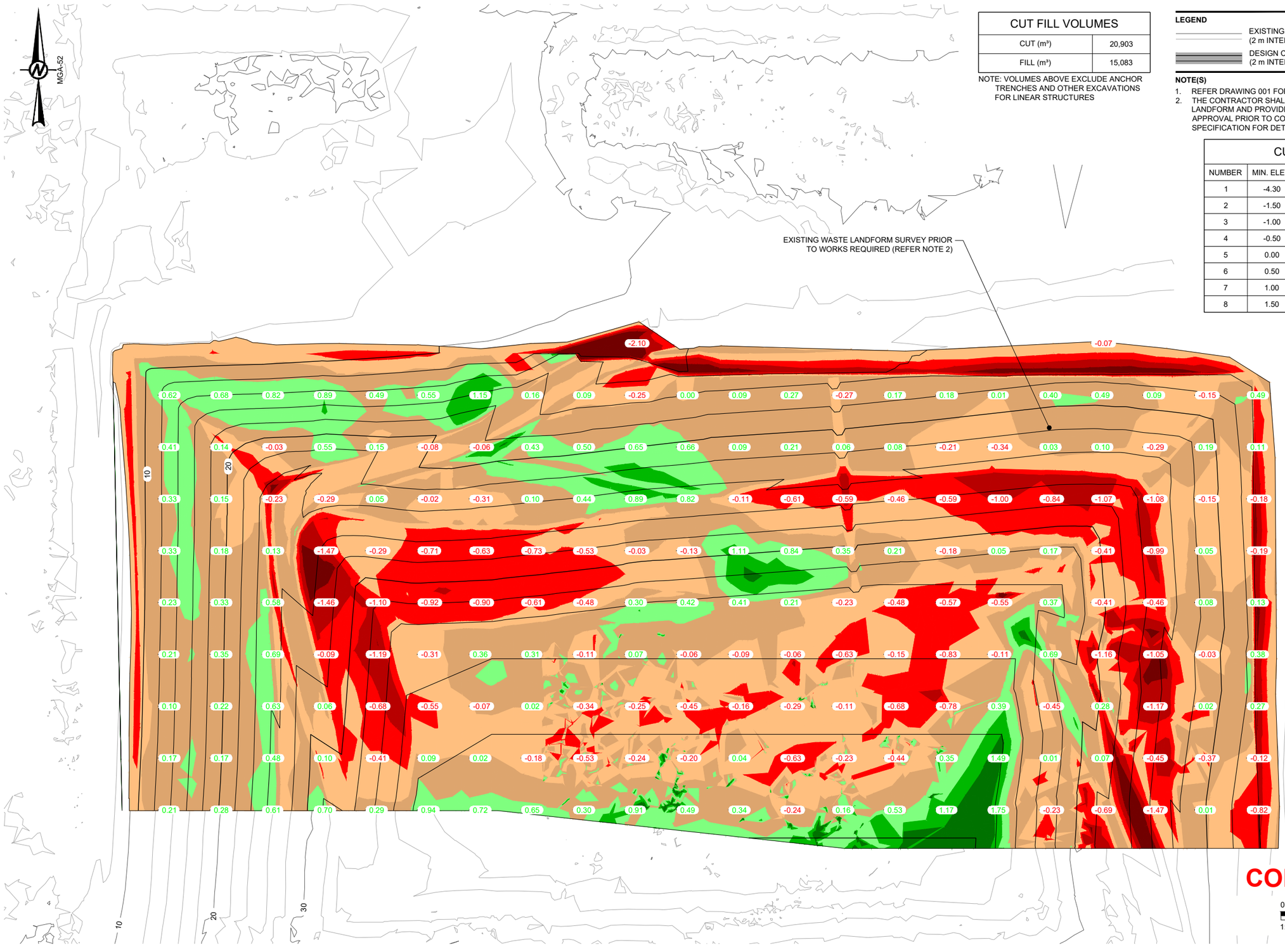
DESIGN CONTOURS (2 m INTERVALS)

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 BREAKDOWN					
NUMBER	MIN. ELEV.	MAX. ELEV.	AREA	COLOR	VOLUME
1	-4.30	-1.50	964.30		360
2	-1.50	-1.00	3441.74		1137
3	-1.00	-0.50	12687.02		4791
4	-0.50	0.00	26637.50		14625
5	0.00	0.50	28465.30		11498
6	0.50	1.00	8427.89		2737
7	1.00	1.50	1637.01		614
8	1.50	2.68	662.56		234

EXISTING WASTE LANDFORM SURVEY PRIOR TO WORKS REQUIRED (REFER NOTE 2)



ISSUED FOR

CONSTRUCTION

0 25 50

1:1,500 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
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	

CLIENT
CITY OF DARWIN

CONSULTANT

GOLDER
MEMBER OF WSP

BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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

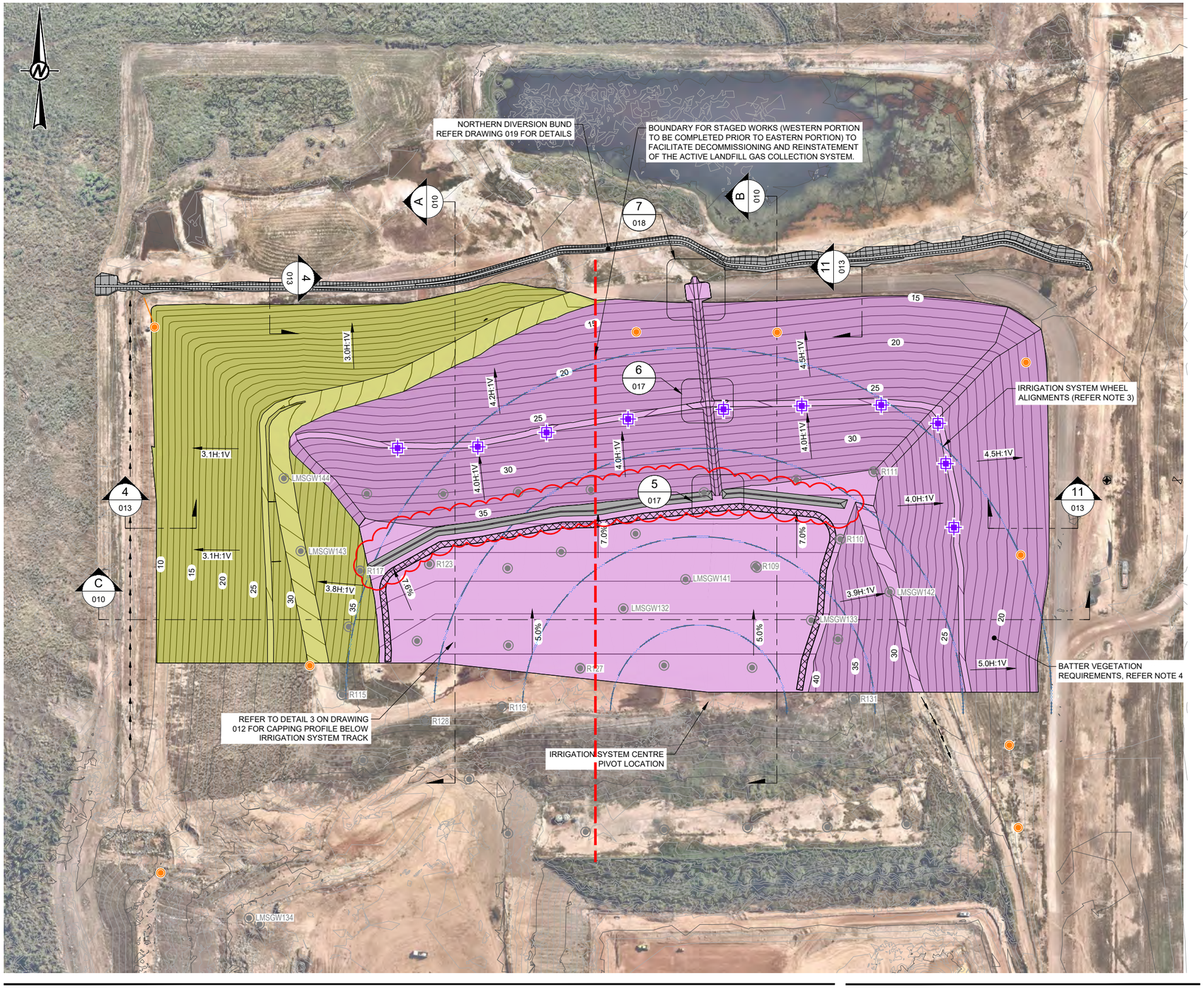
TITLE
CUT FILL PLAN - TOP OF RESHAPED WASTE

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	3	4 of 20	004

Path: \\golder.gtsh\ges\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\99_PROJECTS\20145676 - Stage 3-4 Capping\Concept Design\r013-Stage3-4_Capping\DetailedDesign\02_PRODUCTION\DWG\ | File Name: 20145676-013-004.dwg | Last Edited By: bkanther Date: 2021-06-11 Time:10:35:18 AM | Printed By: BKanther Date: 2021-06-11 Time:10:47:01 AM

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 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	
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	

CLIENT
CITY OF DARWIN

CONSULTANT
GOLDER
MEMBER OF WSP

BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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	3	5 of 20	005

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\CappingConceptDesign\013-Stage3-4_CappingDetailedDesign\02_PRODUCTION\DWGS | File Name: 20145676-013-005.dwg | Last Edited By: bkanther Date: 2021-06-11 Time:10:37:23 AM | Printed By: BKanther Date: 2021-06-11 Time:10:47:08 AM

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

ISSUED FOR

CONSTRUCTION

0 25 50

1:1,500 METRES

NOTE(S)

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

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
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	

CLIENT
CITY OF DARWIN

CONSULTANT
GOLDER
MEMBER OF WSP

BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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	3	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: bkanther Date: 2021-06-11 Time:10:38:20 AM | Printed By: BKanther Date: 2021-06-11 Time:10:47:16 AM

LEGEND

- EXISTING GROUND CONTOURS (1 m INTERVALS)
- DESIGN CONTOURS (1 m INTERVALS)
- EXISTING GAS WELL
- EXISTING DRAIN
- EXISTING LEACHATE SUMP
- UNIT 12 - LFG PANEL DRAIN
- UNIT 11 - LFG GEOCOMPOSITE STRIP DRAIN
- UNIT 24 - PASSIVE GAS VENT
- UNIT 23 - PROPOSED FUTURE GAS WELLS (LOCATIONS TO BE CONFIRMED BY THE PRINCIPAL IN CONSULTATION WITH THE LANDFILL GAS CONTRACTOR PRIOR TO CAPPING CONSTRUCTION)

NOTE(S)

1. PANEL DRAINS TO BE LOCATED DOWNSLOPE OF ANCHOR TRENCHED.

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.

1 m BY 1 m BY 0.3 m THICK AGGREGATE PAD FOR CONDENSATE SOAK AWAY

UNIT 12 - LFG PANEL DRAIN

PASSIVE GAS VENT
REFER DRAWING 014 FOR TYPICAL DETAILS

UNIT 11 - LFG GEOCOMPOSITE STRIP DRAIN

ISSUED FOR
CONSTRUCTION

0 25 50
1:1,500 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
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	

CLIENT
CITY OF DARWIN

CONSULTANT
GOLDER
MEMBER OF WSP

BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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

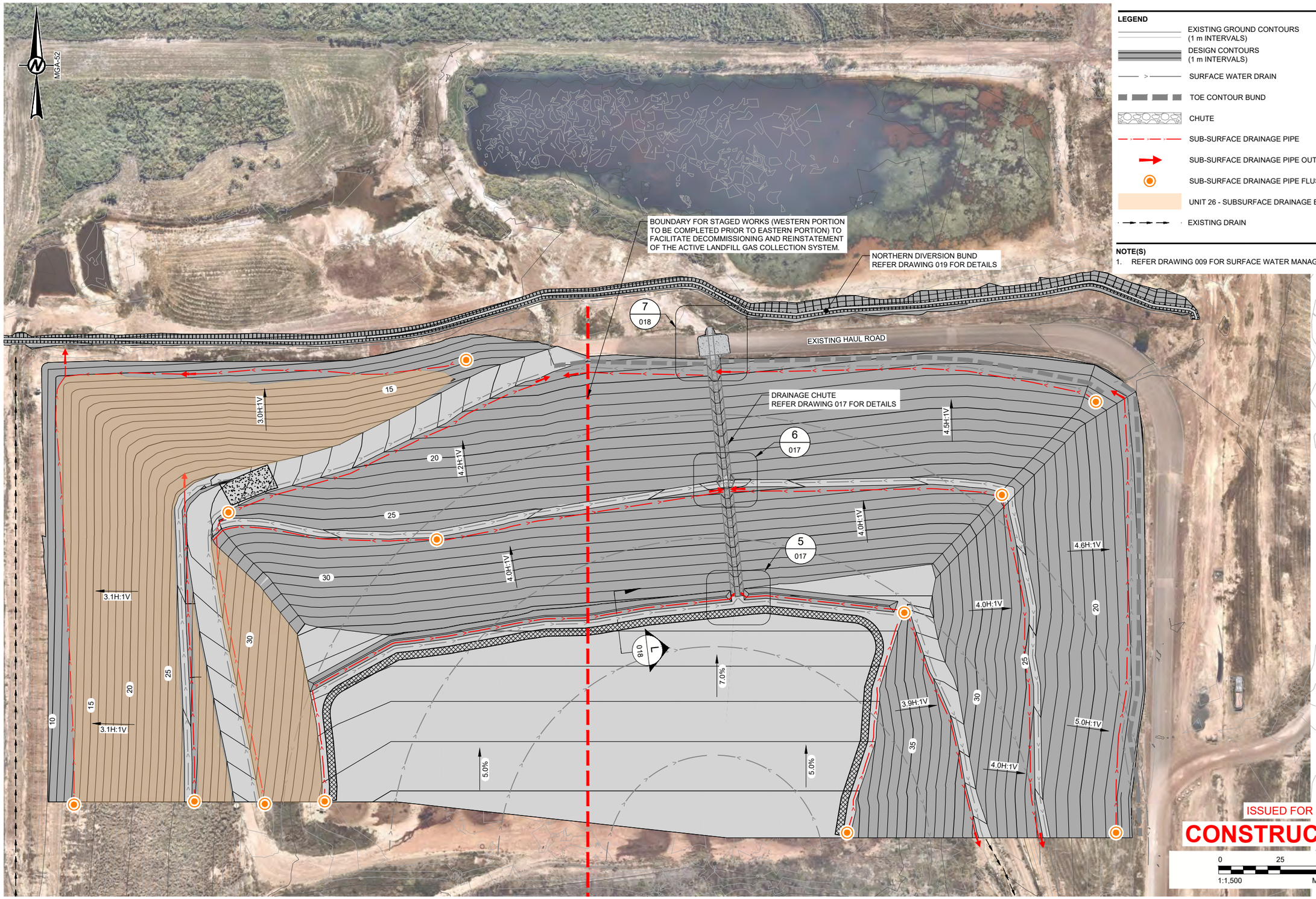
TITLE
GENERAL ARRANGMENT PLAN - PASSIVE GAS

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	3	7 of 20	007

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: 20145676-013-007.dwg | Last Edited By: bkanther Date: 2021-06-11 Time:10:39:16 AM | Printed By: BKanther Date: 2021-06-11 Time:10:47:38 AM



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

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
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

CLIENT
CITY OF DARWIN

CONSULTANT
GOLDER
MEMBER OF WSP
BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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

TITLE
GENERAL ARRANGMENT PLAN - SUB-SURFACE WATER MANAGEMENT

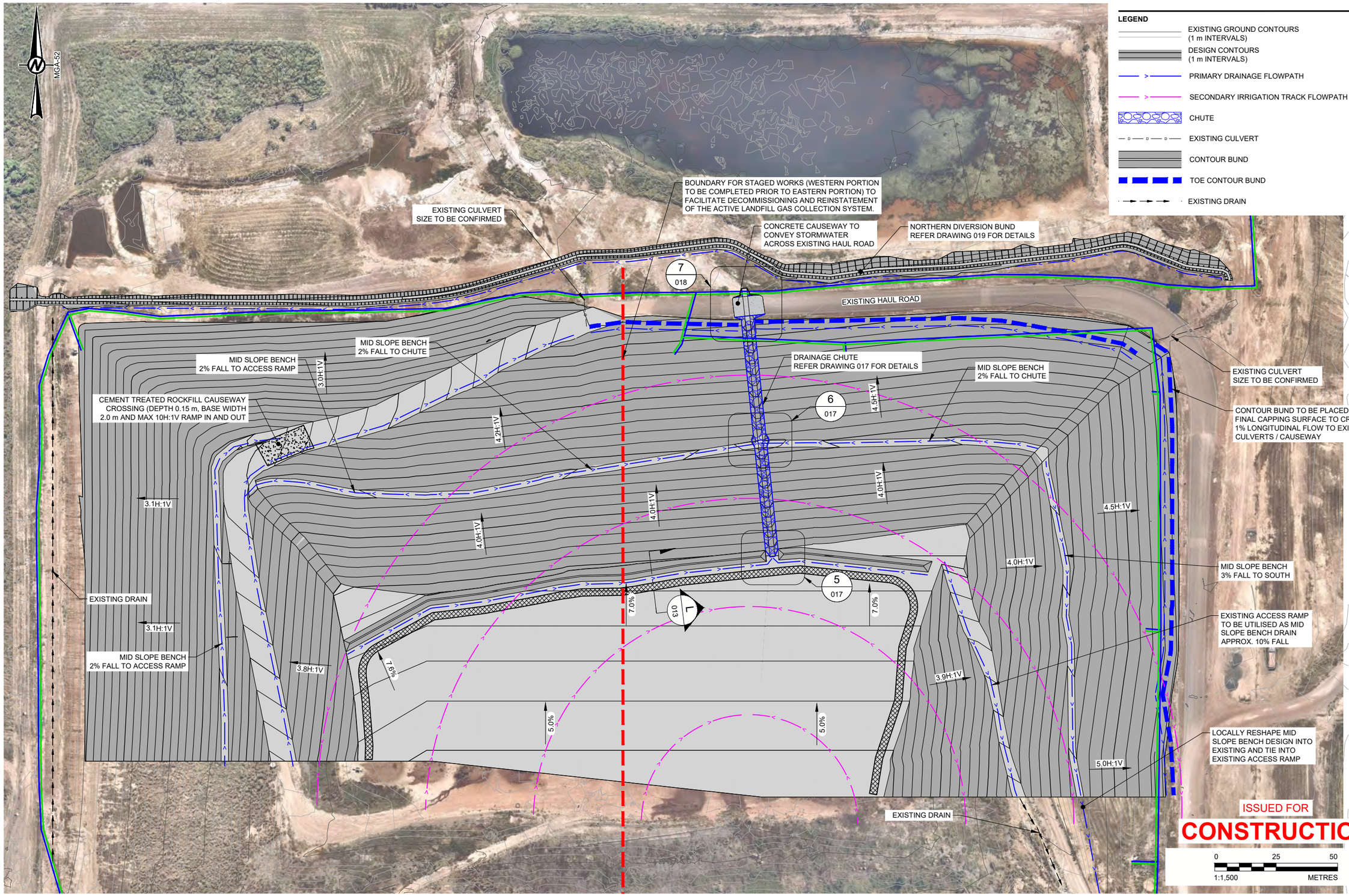
PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	3	8 of 20	008

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

25 mm

0

Path: \\golder.gds\gan\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\DWG\ | File Name: 20145676-013-008.dwg | Last Edited By: bkanther Date: 2021-06-11 Time:10:40:03 AM | Printed By: BKanther Date: 2021-06-11 Time:10:47:48 AM



REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
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	

CLIENT
CITY OF DARWIN

CONSULTANT
GOLDER
MEMBER OF WSP
BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

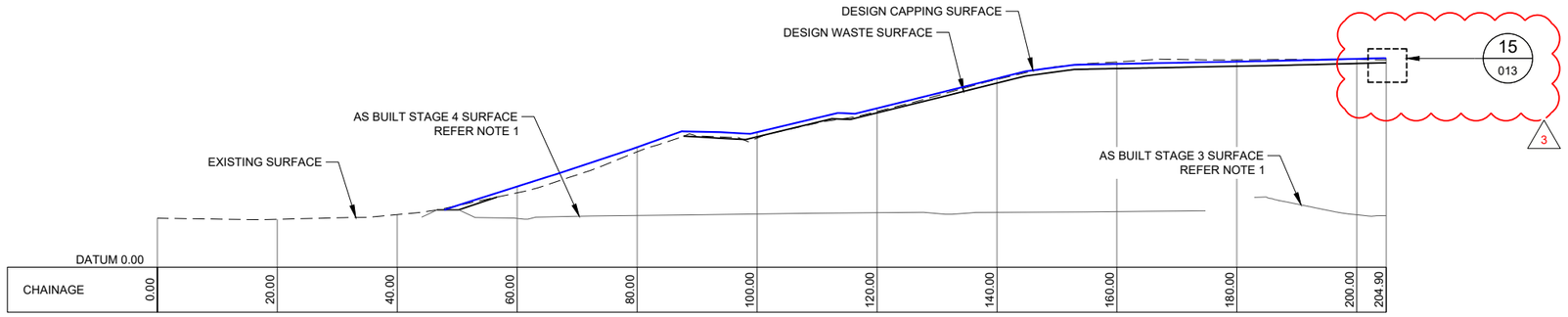
PROJECT
SHOAL BAY WASTE MANAGEMENT FACILITY
STAGE 3 / STAGE 4 CAPPING PROJECT

TITLE
GENERAL ARRANGMENT PLAN - SURFACEWATER MANAGEMENT

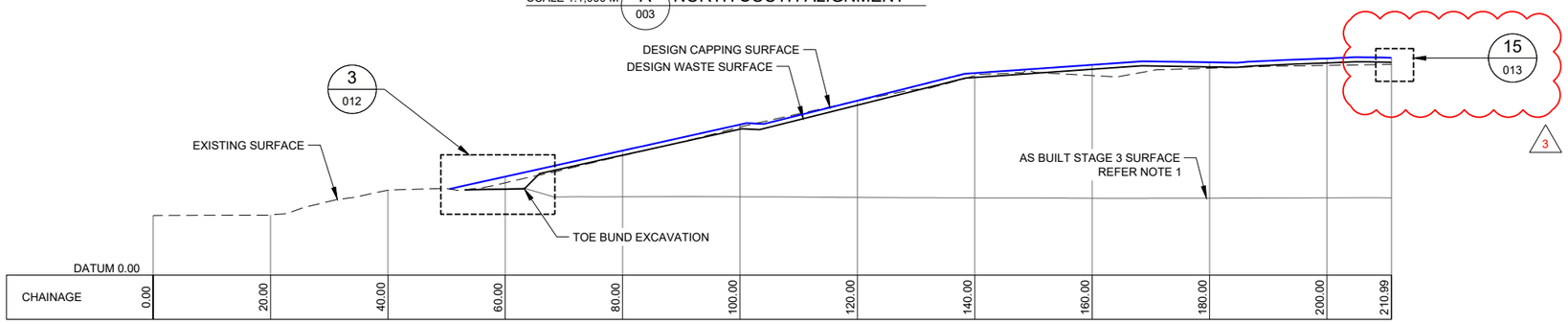
PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	3	9 of 20	009

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

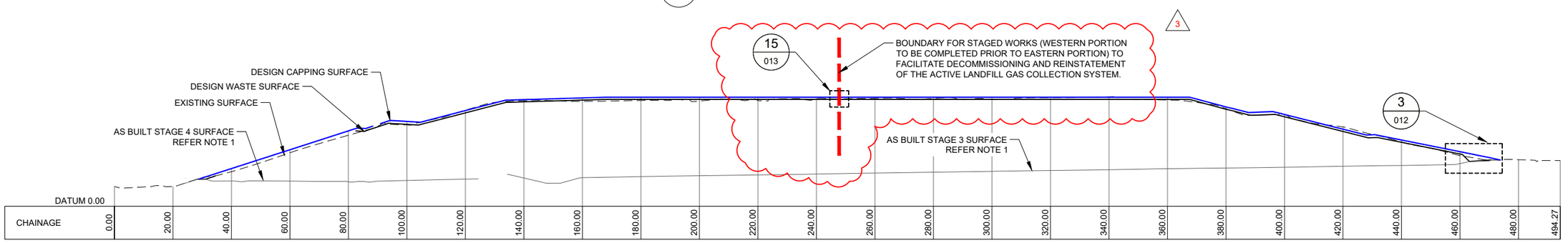
Path: \\golder.gds\gap\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\199_PROJECTS\20145676 - Stage 3,4\Capping\ConceptDesign\013-Stage3-4_Capping\DetailedDesign\02_PRODUCTION\DWG\ | Last Edited By: bkanther Date: 2021-06-11 Time:10:40:29 AM | Printed By: BKanther Date: 2021-06-11 Time:10:47:55 AM | File Name: 20145676-013-009.dwg



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

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
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	

CLIENT
CITY OF DARWIN

CONSULTANT
GOLDER
MEMBER OF WSP

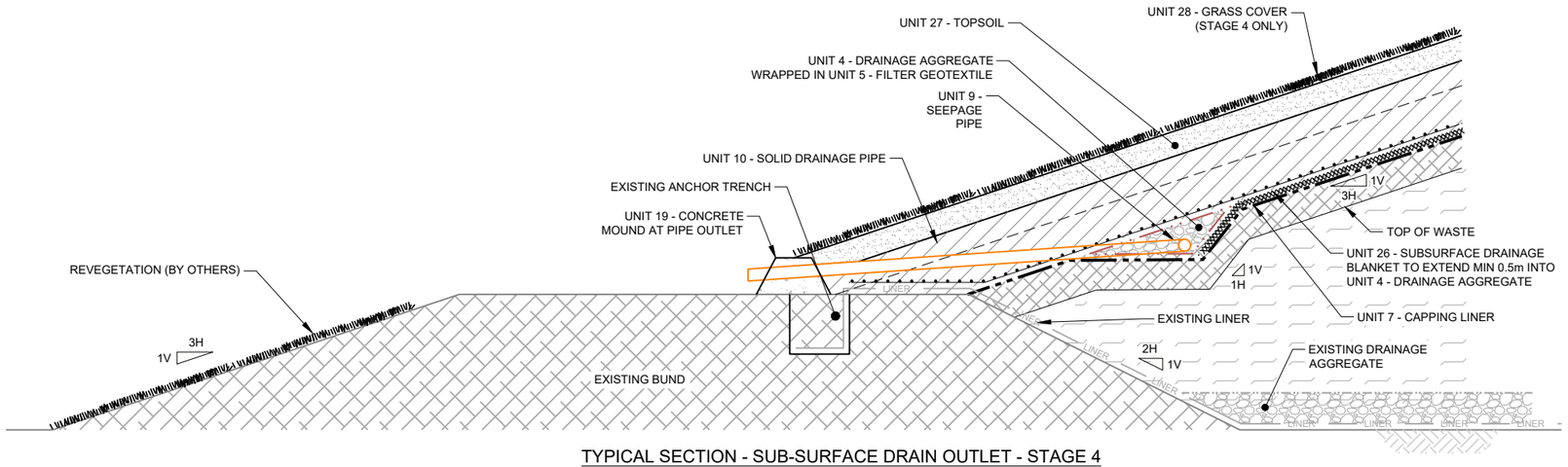
BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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

TITLE
LANDFILL SITE SECTIONS

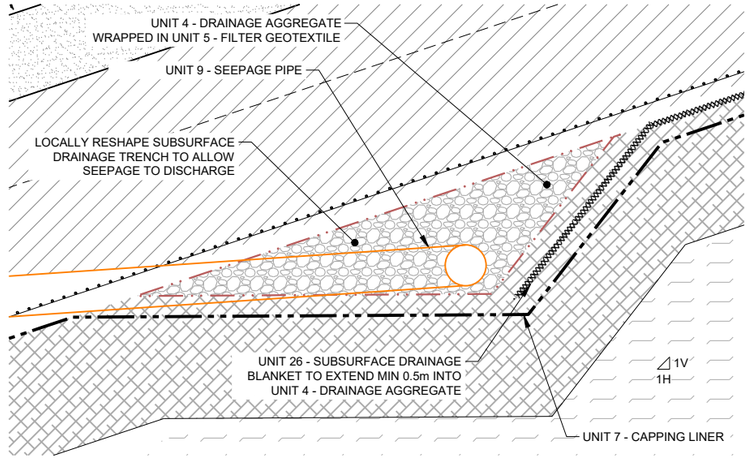
PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	3	10 of 20	010

Path: \\golder.gds\gan\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\DWG\ | File Name: 20145676-013-010.dwg | Last Edited By: bkanther Date: 2021-06-11 Time:10:30:53 AM | Printed By: BKanther Date: 2021-06-11 Time:10:48:01 AM
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0



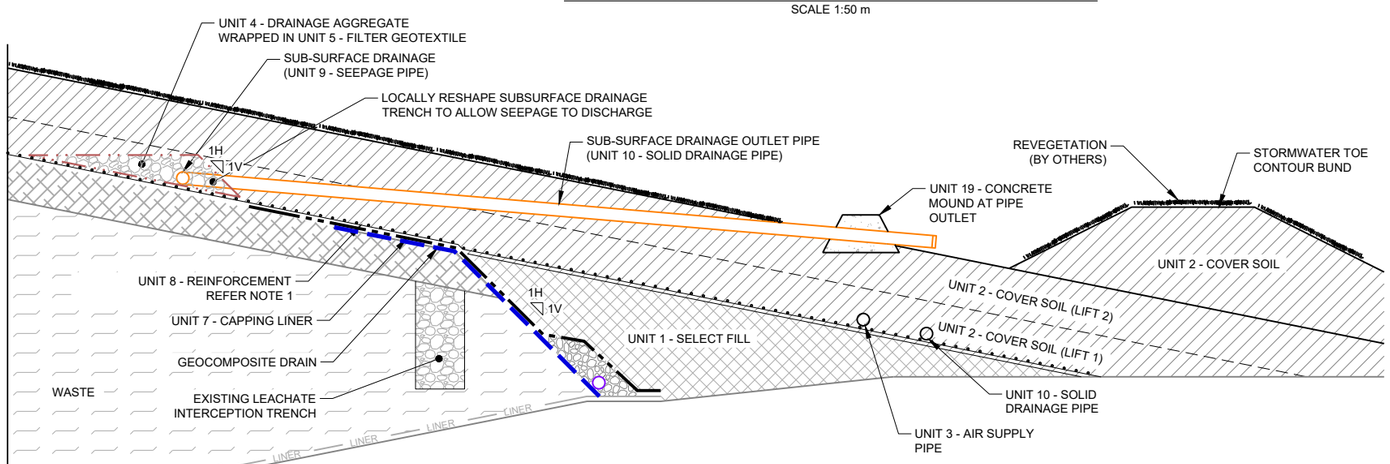
TYPICAL SECTION - SUB-SURFACE DRAIN OUTLET - STAGE 4

SCALE 1:50 m



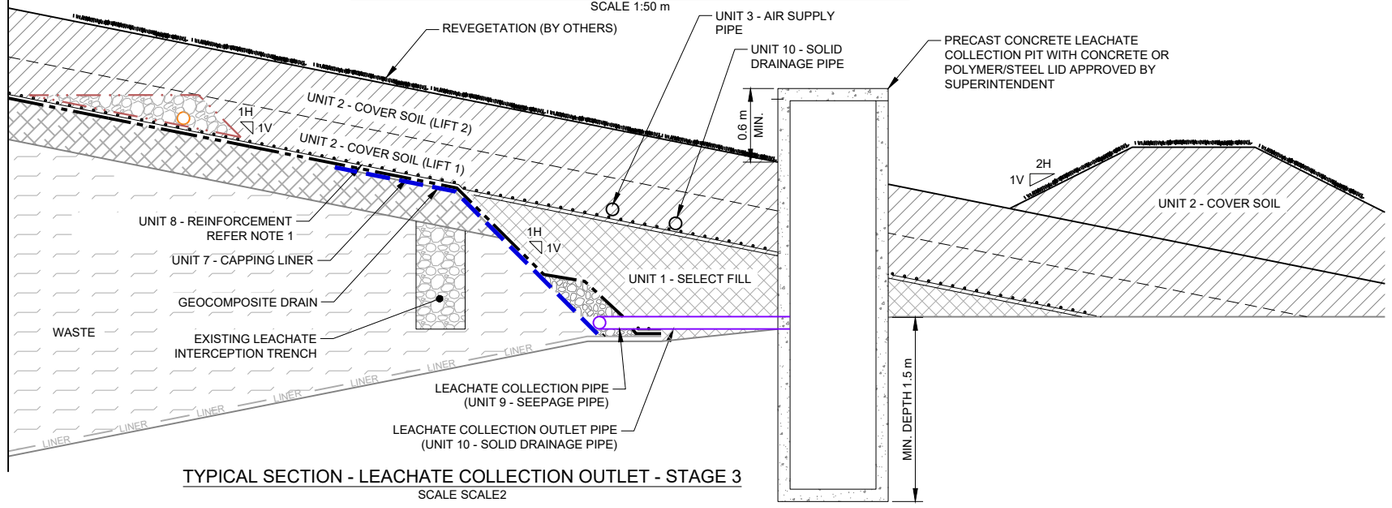
TYPICAL DETAIL - SUB-SURFACE DRAIN COLLECTION TRENCH - STAGE 4 TOE

SCALE 1:15 m



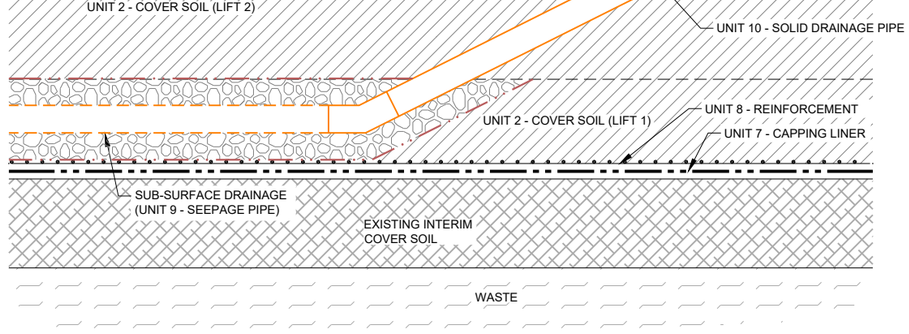
TYPICAL SECTION - LEACHATE COLLECTION OUTLET - STAGE 3

SCALE 1:50 m



TYPICAL SECTION - LEACHATE COLLECTION OUTLET - STAGE 3

SCALE SCALE2



TYPICAL DETAIL - SUB-SURFACE DRAIN FLUSH POINT

SCALE 1:20 m

0 1 2
1:50 METRES

0 0.5 1
1:20 METRES

0 0.25 0.5
1:15 METRES

ISSUED FOR

CONSTRUCTION

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
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	

CLIENT
CITY OF DARWIN

CONSULTANT
GOLDER
MEMBER OF WSP

BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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

TITLE
SUB-SURFACE WATER MANAGEMENT - SECTIONS AND DETAILS

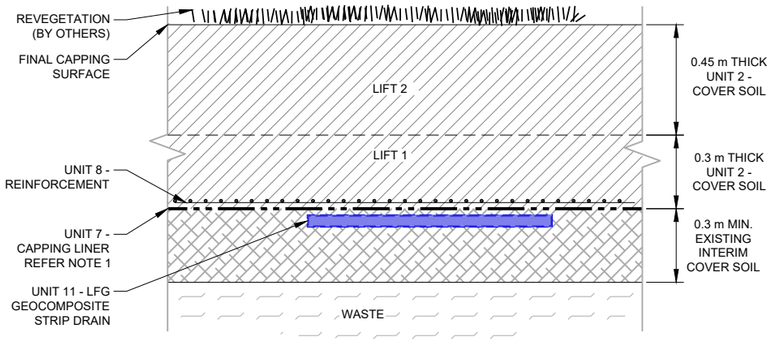
PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	3	11 of 20	011

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

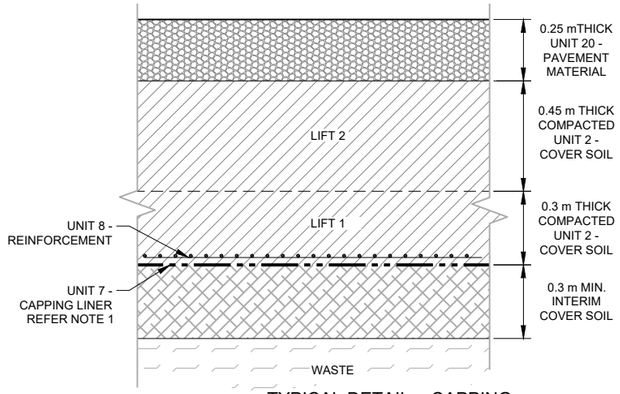
25 mm

0

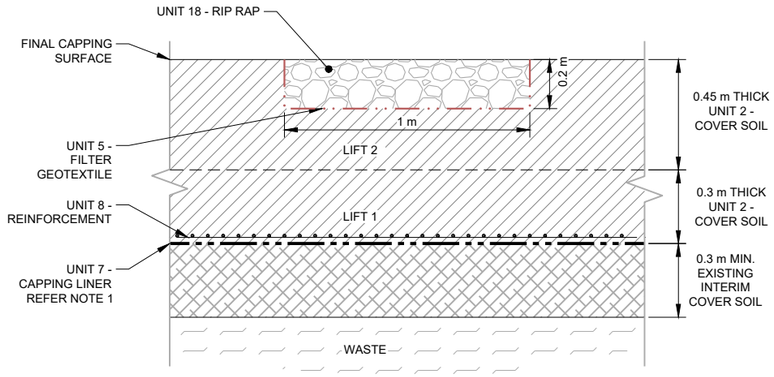
Path: \\golder.gds\gap\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\99_PROJECTS\20145676 - Stage 3-4CappingConceptDesign\013-Stage3-4_CappingDetailedDesign\02_PRODUCTION\DWG\ | File Name: 20145676-013-011_017_018.dwg | Last Edited By: bkanther Date: 2021-05-11 Time:10:43:25 AM | Printed By: BKanther Date: 2021-05-11 Time:10:48:07 AM



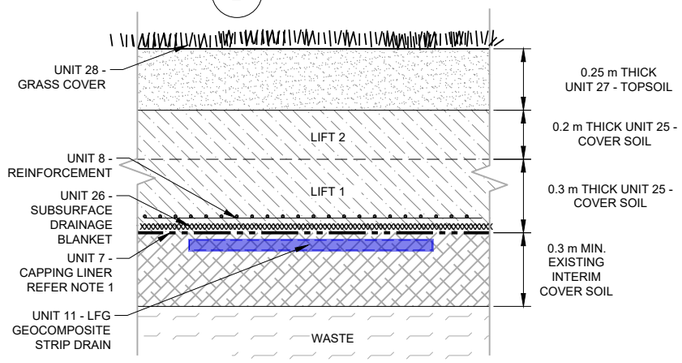
SCALE 1:25 m (1) TYPICAL DETAIL - CAPPING PROFILE TYPE A



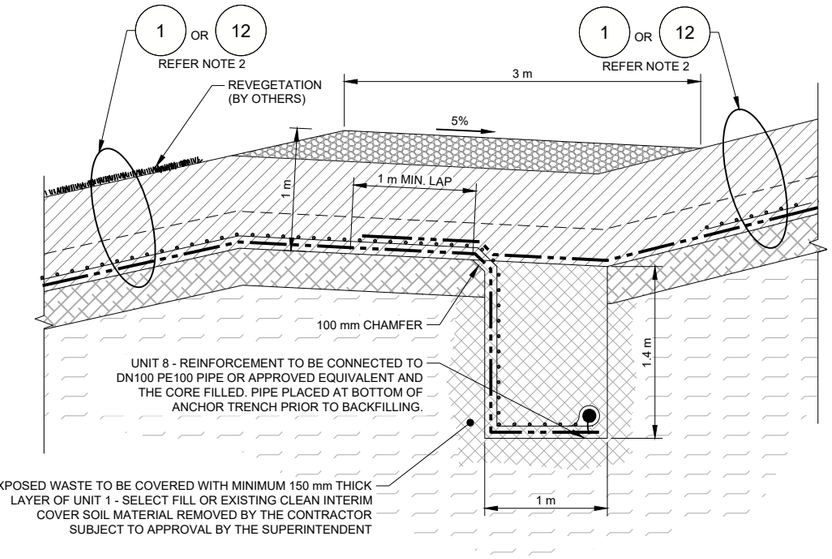
SCALE 1:25 m (2) TYPICAL DETAIL - CAPPING PROFILE ON BENCHES AND RAMP



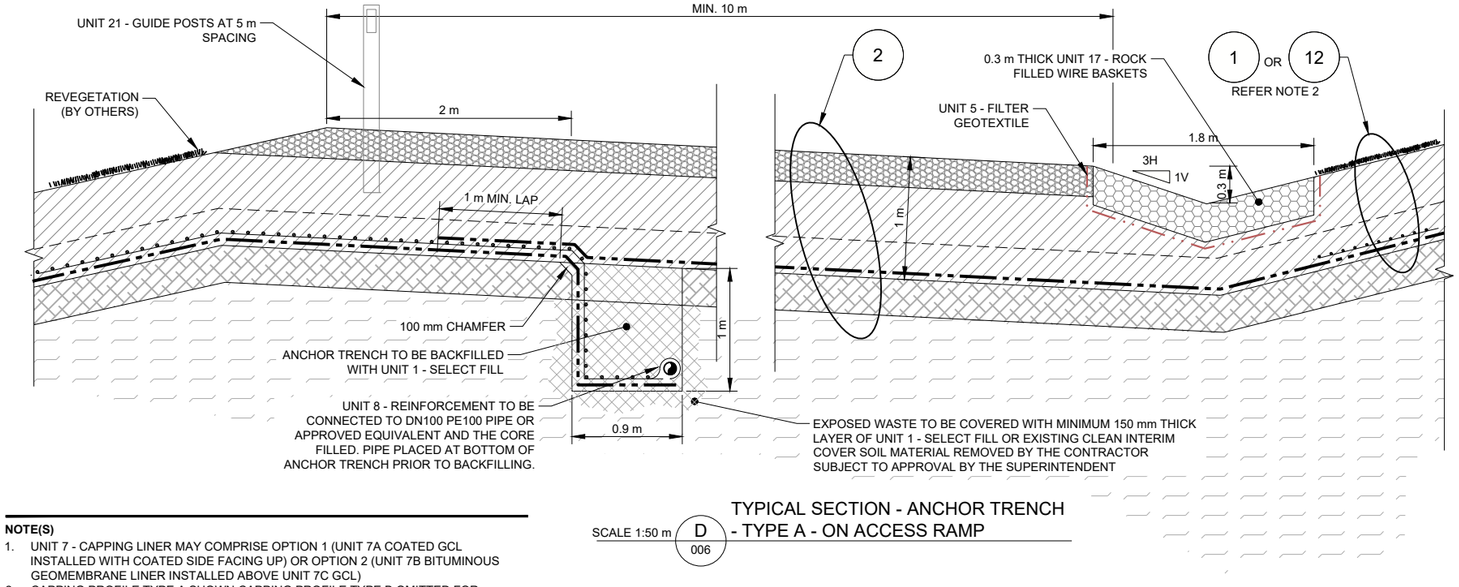
SCALE 1:25 m (3) TYPICAL DETAIL - CAPPING PROFILE UNDER IRRIGATION SYSTEM WHEEL TRACK



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

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
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

CLIENT
CITY OF DARWIN

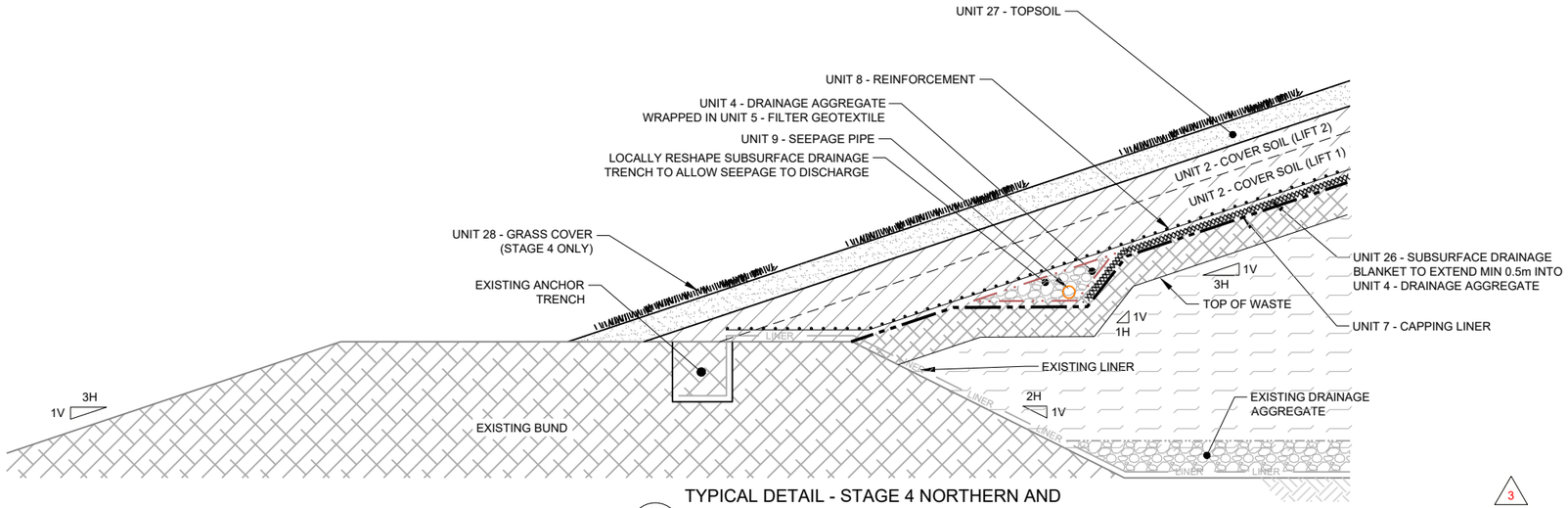
CONSULTANT
GOLDER
MEMBER OF WSP
BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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

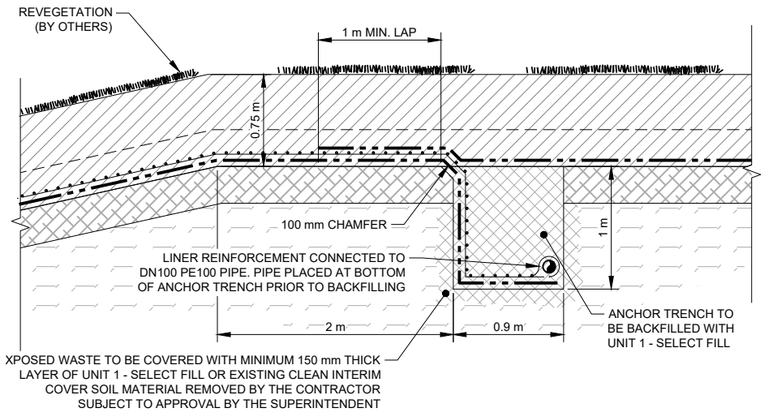
TITLE
ANCHOR TRENCH AND LINER CONNECTION SECTIONS AND DETAILS - (SHEET 1 OF 2)

PROJECT NO.	CONTROL	REV.	12 of 20	DRAWING
20145676	013	3		012

Path: \\golder.gds\gap\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\99_PROJECTS\20145676 - Stage 3-4 Capping\ConceptDesign\013-Stage3-4_CappingDetailedDesign\02_PRODUCTION\DWGS\ | File Name: 20145676-013-012_013.dwg | Last Edited By: bkenther Date: 2021-06-11 Time:10:31:03 AM | Printed By: BKenther Date: 2021-06-11 Time:10:48:15 AM
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0

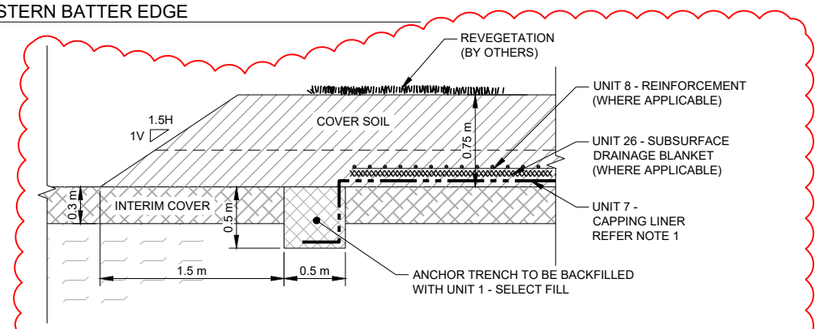


SCALE 1:50 m (4 / 012) TYPICAL DETAIL - STAGE 4 NORTHERN AND WESTERN BATTER EDGE

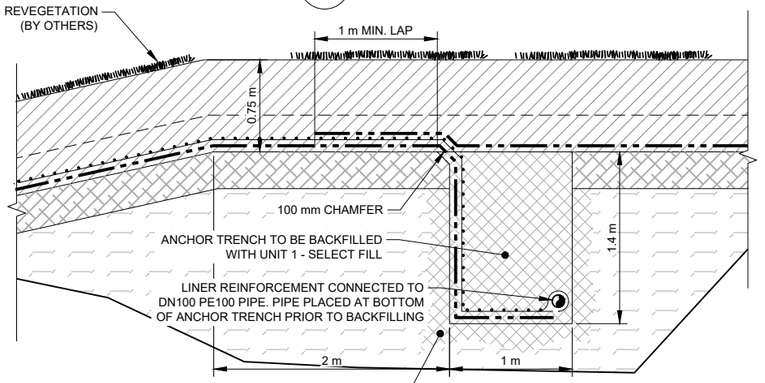


SCALE 1:50 m (G / 006) TYPICAL SECTION - ANCHOR TRENCH - TYPE A - AT CREST

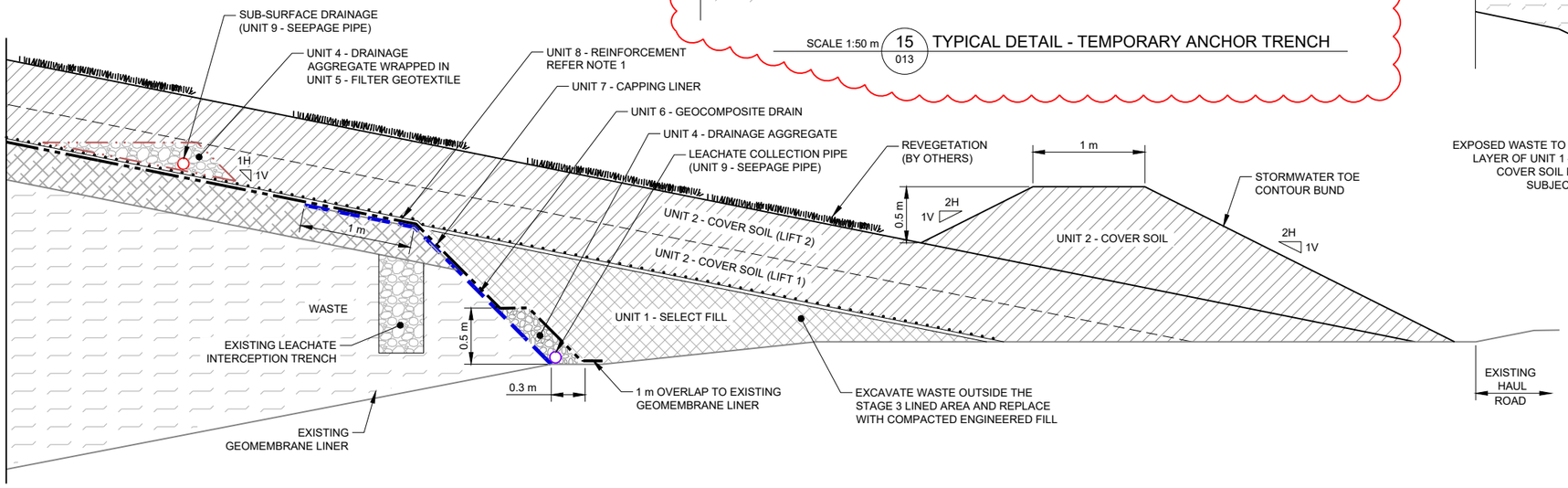
3



SCALE 1:50 m (15 / 013) TYPICAL DETAIL - TEMPORARY ANCHOR TRENCH



SCALE 1:50 m (H / 006) TYPICAL SECTION - ANCHOR TRENCH - TYPE B AND C - AT CREST



SCALE 1:50 m (11 / 012) TYPICAL DETAIL - STAGE 3 NORTHERN AND EASTERN BATTER EDGE

ISSUED FOR
CONSTRUCTION

0 1 2
1:50 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
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

CLIENT
CITY OF DARWIN

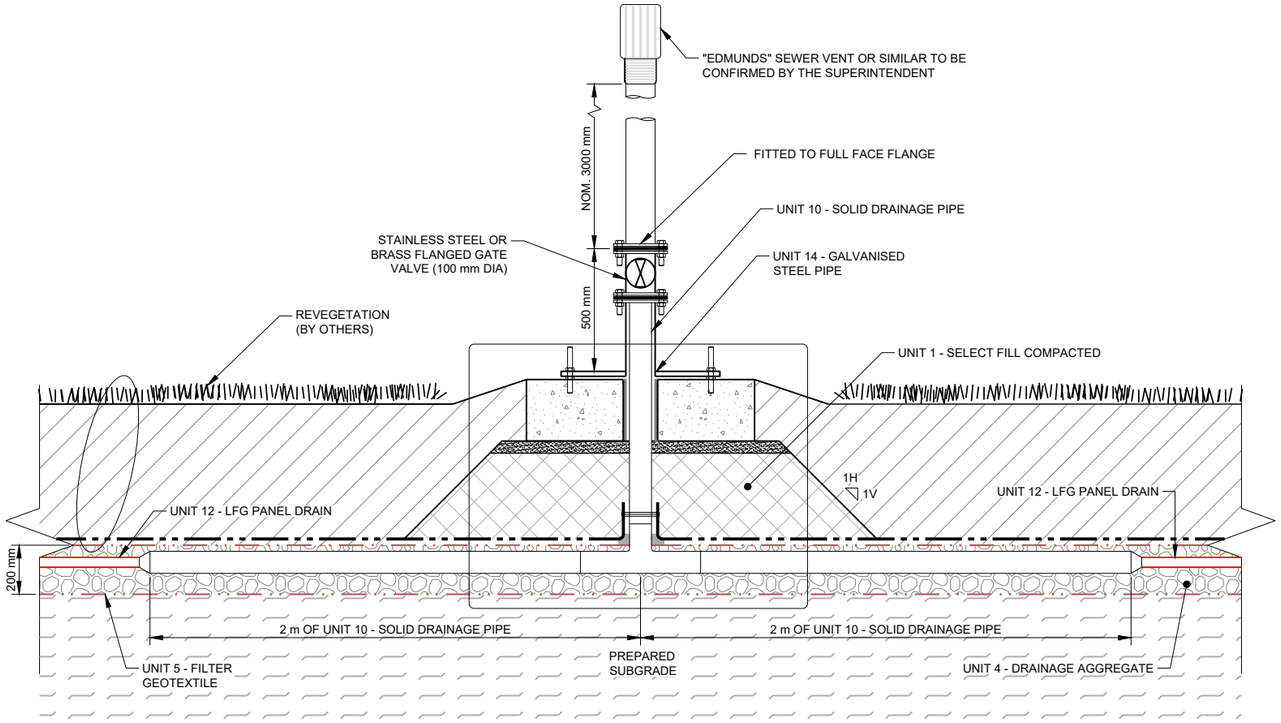
CONSULTANT
GOLDER
MEMBER OF WSP
BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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	3		013

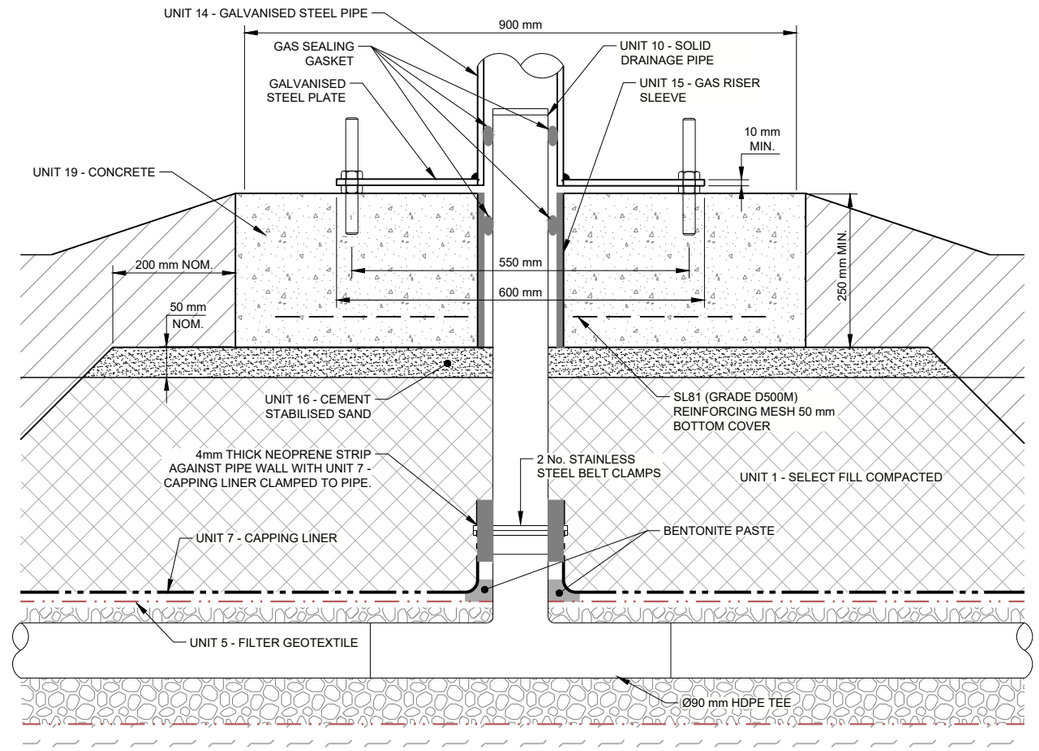
Path: \\golder.gds\gpo\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\99_PROJECTS\20145676 - Stage 3-4CappingConceptDesign\013-Stage3-4_CappingDetailedDesign\02_PRODUCT\DWG\ | File Name: 20145876-013-012_013.dwg | Last Edited By: bkenther Date: 2021-06-11 Time:10:31:03 AM | Printed By: BKenther Date: 2021-06-11 Time:10:48:22 AM
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

9
014

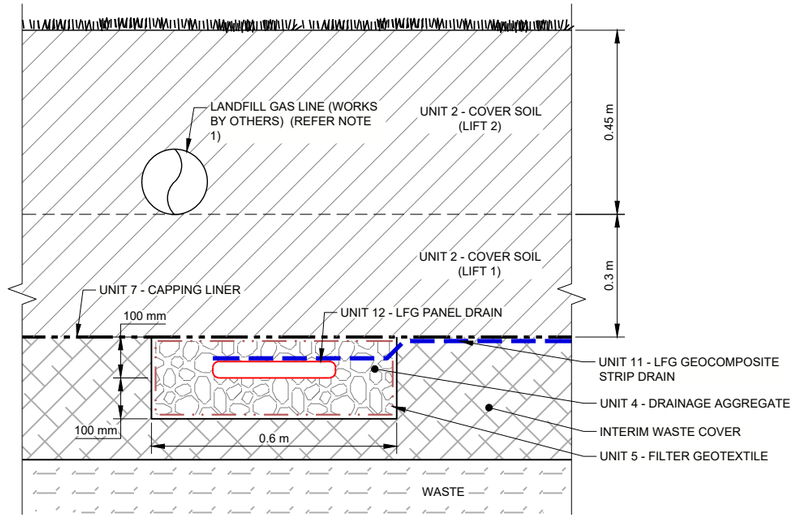
TYPICAL DETAIL - GAS RISER PENETRATION AND UNIT 24 - PASSIVE GAS VENT



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	
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	

CLIENT
CITY OF DARWIN

CONSULTANT
GOLDER
MEMBER OF WSP

BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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

TITLE
PASSIVE GAS SECTIONS AND DETAIL - SHEET 1 OF 2

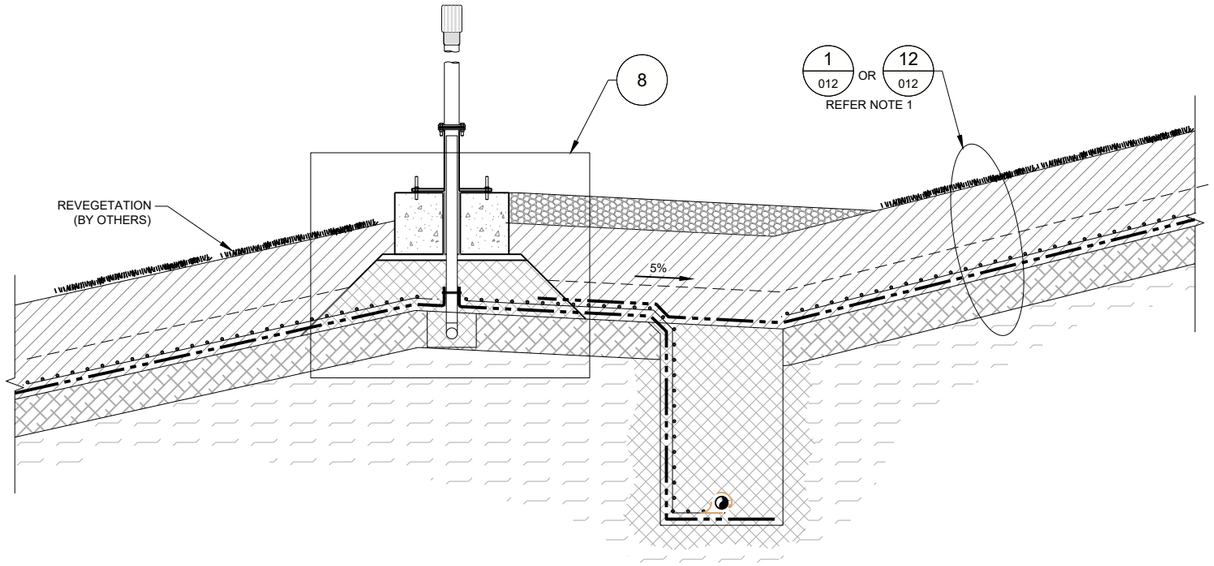
PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	3	14 of 20	014

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

25 mm

0

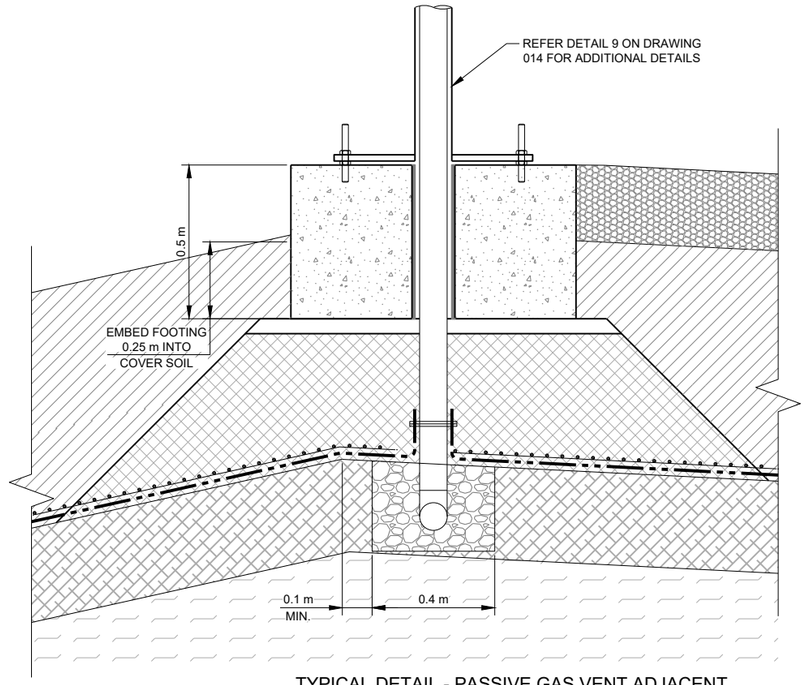
Path: \\golder.gds\gan\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\99_PROJECTS\20145676 - Stage 3-4 Capping\Concept\Design\013-Stage3-4_Capping\Detailed\Design\02_PRODUCTION\DWG\ | File Name: 20145676-013-014_015.dwg | Last Edited By: bkeither Date: 2021-06-11, Time: 10:44:09 AM | Printed By: BKeither Date: 2021-06-11, Time: 10:48:28 AM



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

SCALE 1:50 m

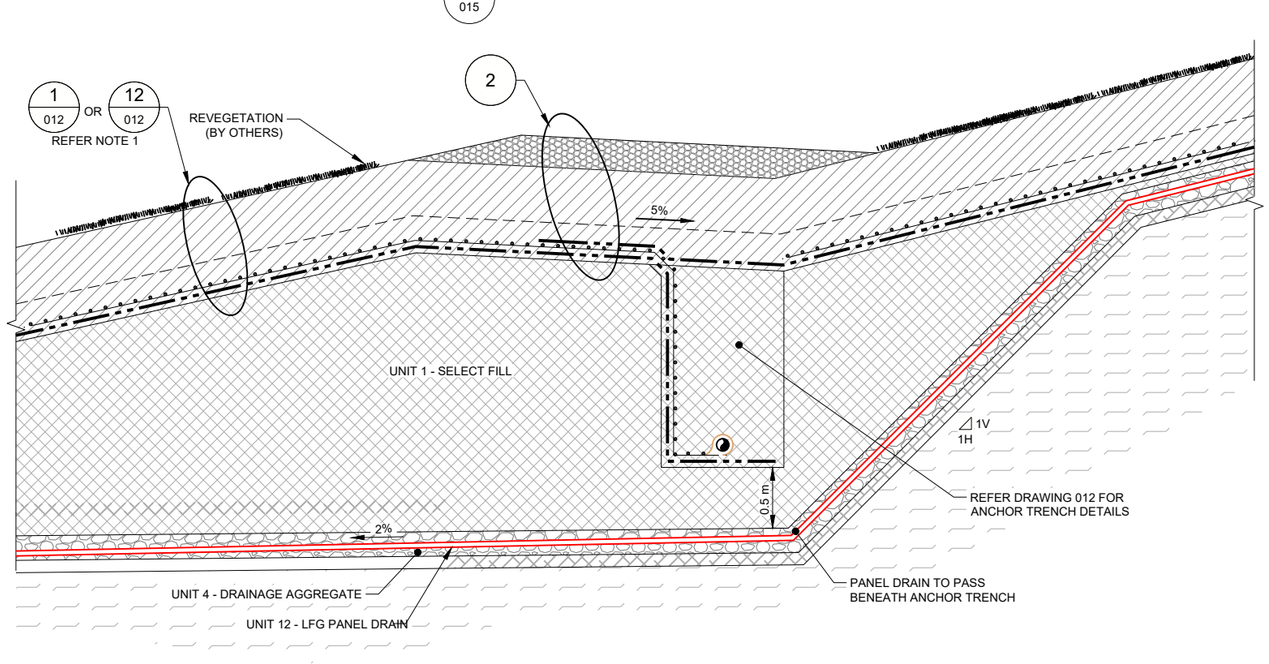
O
015



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	
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	

CLIENT
CITY OF DARWIN

CONSULTANT
GOLDER
MEMBER OF WSP

BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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

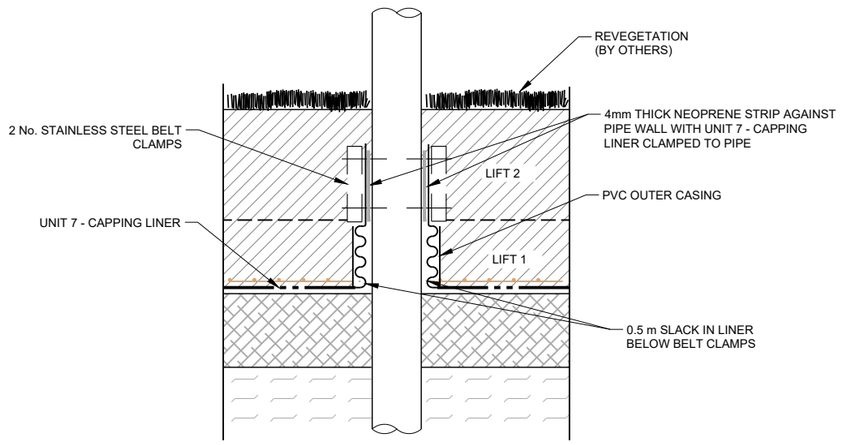
TITLE
PASSIVE GAS SECTIONS AND DETAIL - SHEET 2 OF 2

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	3	15 of 20	015

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

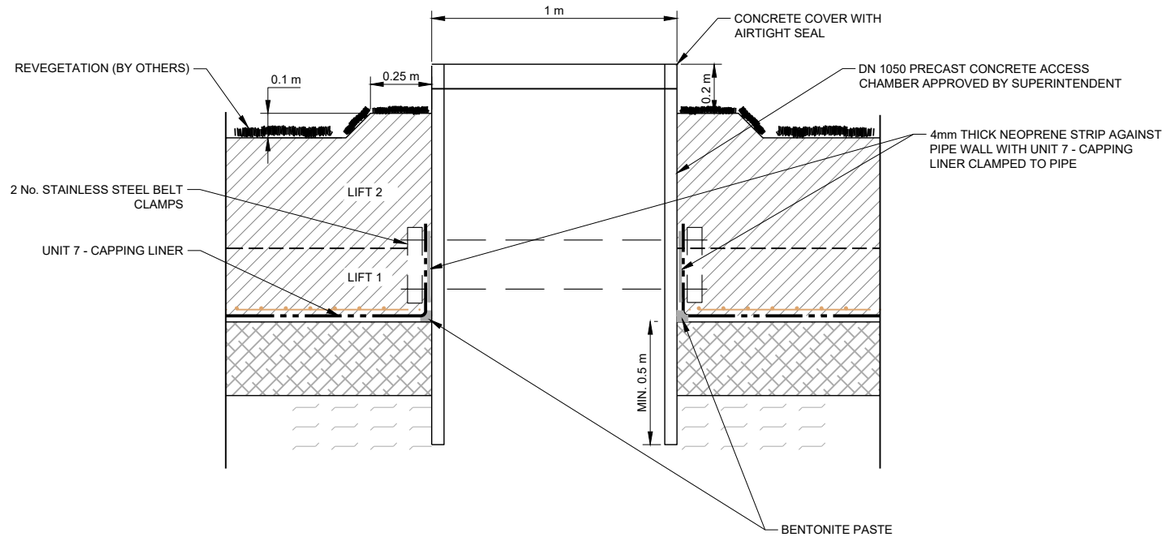
0 25 mm

Path: \\golder.gds\gan\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\DWG\ | File Name: 20145676-013-014_015.dwg | Last Edited By: bkeither Date: 2021-06-11 Time: 10:44:09 AM | Printed By: BKeither Date: 2021-06-11 Time: 10:48:34 AM



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	
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

CLIENT
CITY OF DARWIN

CONSULTANT
GOLDER
MEMBER OF WSP

BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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

TITLE
CAPPING SYSTEM PENETRATION DETAILS

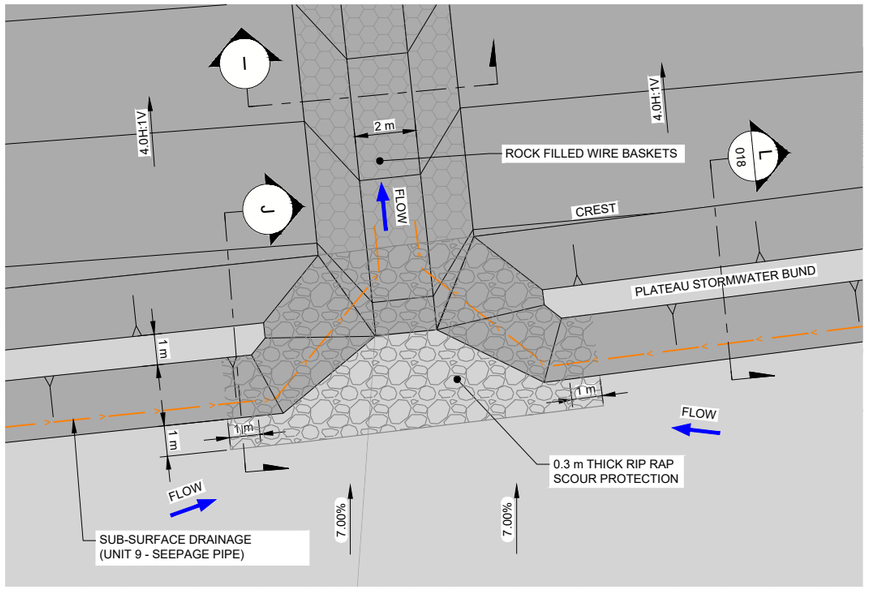
PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	3	16 of 20	016

Path: \\golder.gds\gan\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\99_PROJECTS\20145676 - Stage 3-4 Capping\Concept\Design\013_Stage3-4_Capping\DetailedDesign\02_PRODUCTION\DWG\ | File Name: 20145676-013-016.dwg | Last Edited By: bkanther Date: 2020-12-22 Time:3:31:38 PM | Printed By: BKanther Date: 2021-06-11 Time:10:48:40 AM

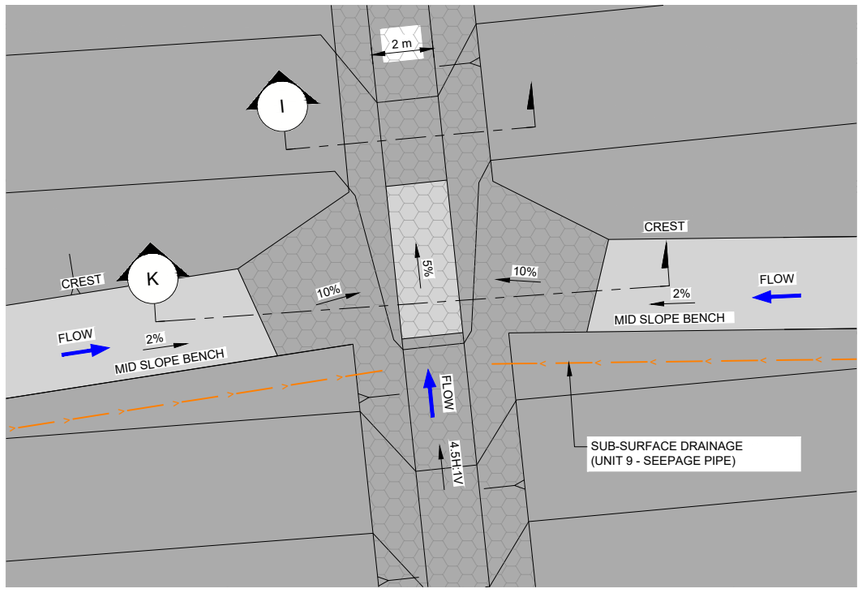
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

25 mm

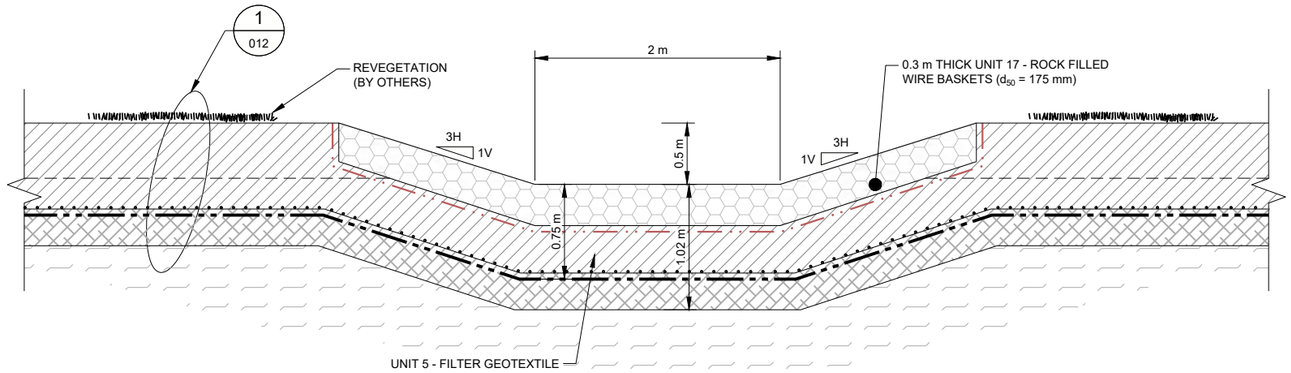
0



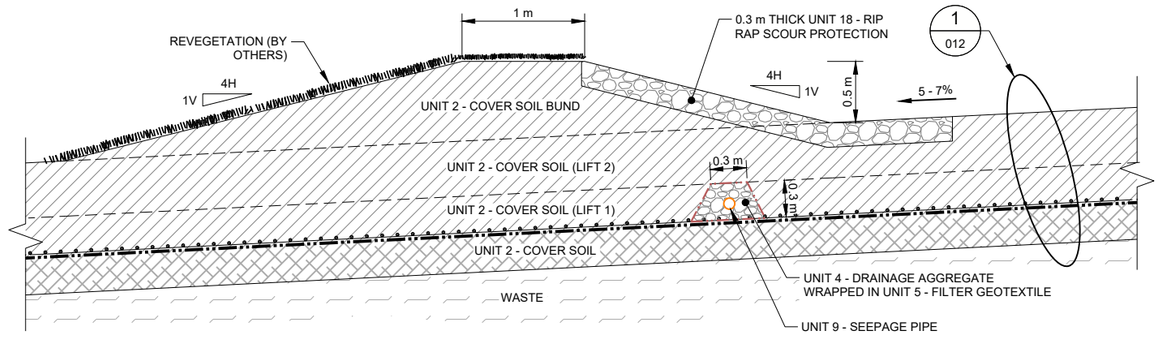
SCALE 1:200 m 5/009 TYPICAL DETAIL - DIVERSION BUND AND CHUTE INTERFACE ON PLATEAU



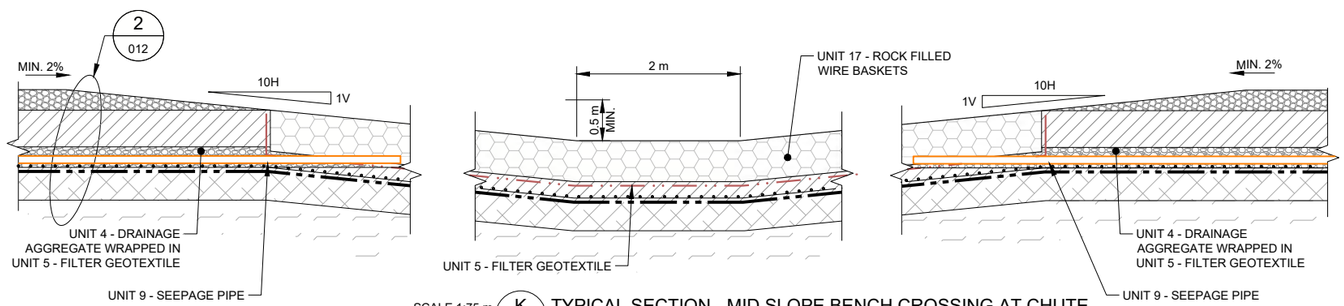
SCALE 1:200 m 6/009 TYPICAL DETAIL - MID SLOPE BENCH AND CHUTE INTERFACE



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
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	

CLIENT
CITY OF DARWIN

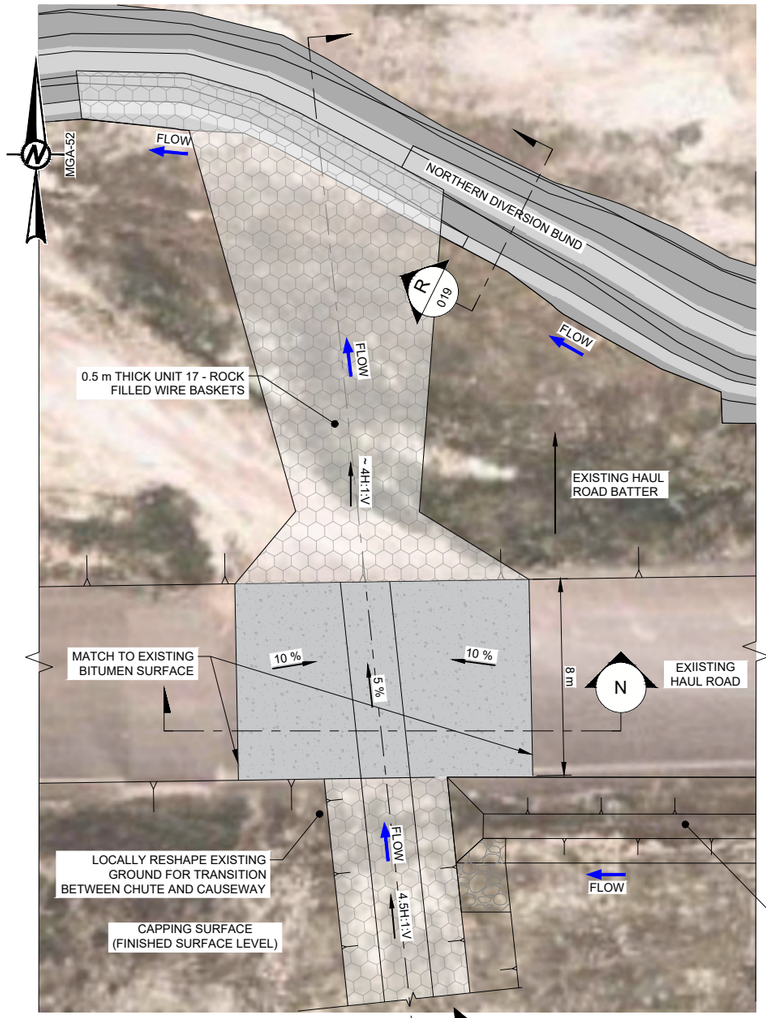
CONSULTANT
GOLDER
MEMBER OF WSP
BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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

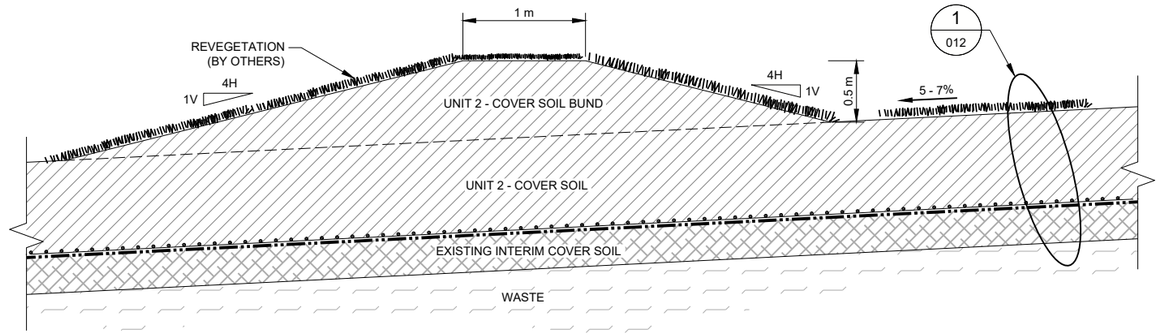
TITLE
STORMWATER CHUTE INLET - SECTIONS AND DETAILS

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	3	17 of 20	017

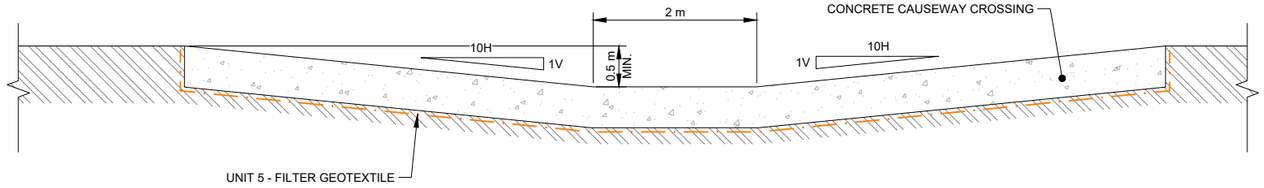
Path: \\golder.gds\gap\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\99_PROJECTS\20145676 - Stage 3-4 Capping\Concept Design\013-Stage3-4_Capping\Detailed Design\02_PRODUCTION\DWG\ | File Name: 20145676-013-011_017_018.dwg | Last Edited By: bkanther Date: 2021-05-11 Time:10:43:25 AM | Printed By: BKanther Date: 2021-05-11 Time:10:48:49 AM
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0



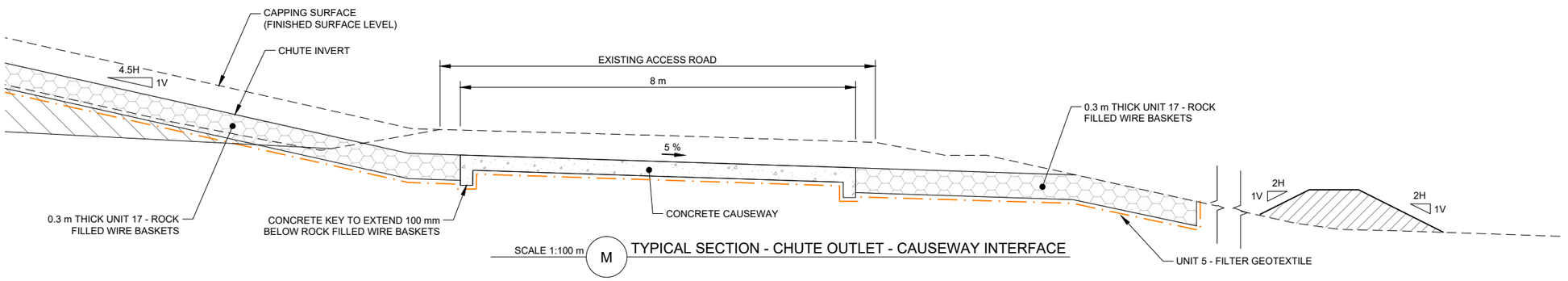
SCALE 1:250 m — 7 / 018 — CAUSEWAY LAYOUT PLAN



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

1:75 — 0 1.25 2.5 METRES

1:100 — 0 2.5 5 METRES

1:250 — 0 5 10 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	
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	

CLIENT
CITY OF DARWIN

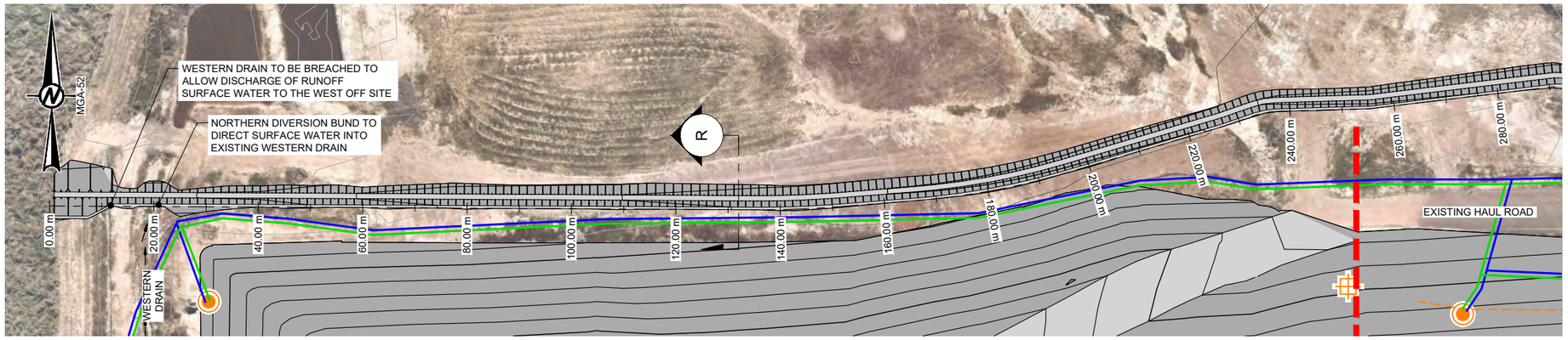
CONSULTANT
GOLDER
MEMBER OF WSP
BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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

TITLE
STORMWATER CHUTE OUTLET - SECTIONS AND DETAILS

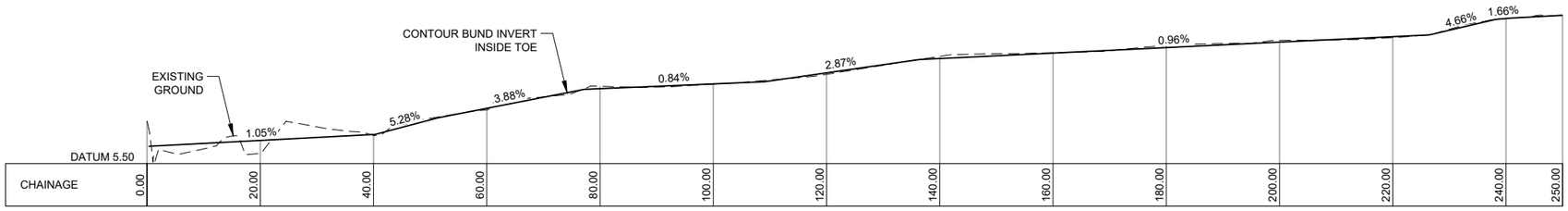
PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	3	18 of 20	018

Path: \\golder.gds\gan\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-D11_017_018.dwg | Last Edited By: bkanther Date: 2021-06-11 Time:10:43:25 AM | Printed By: BKanther Date: 2021-06-11 Time:10:48:57 AM
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0



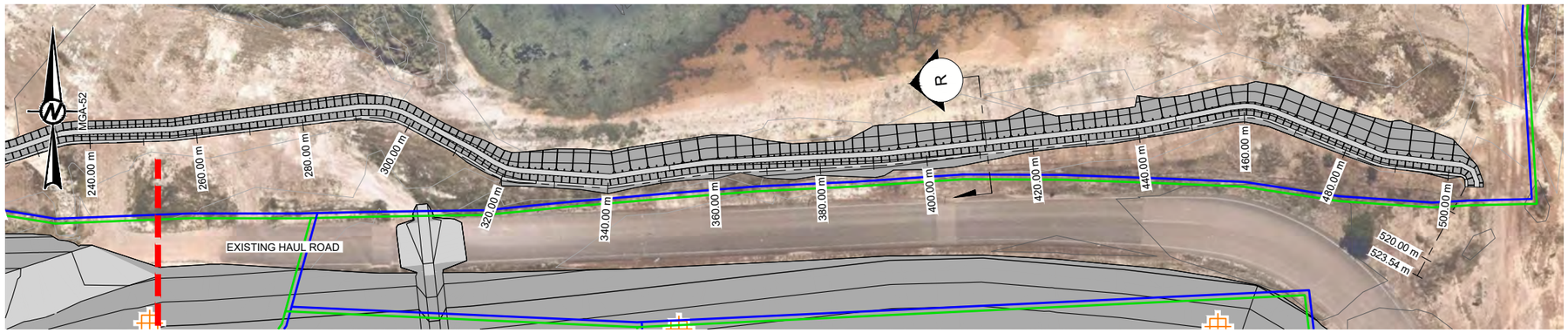
LAYOUT PLAN - NORTHERN DIVERSION BUND - CH 0 - CH 250

SCALE 1:1,000 m



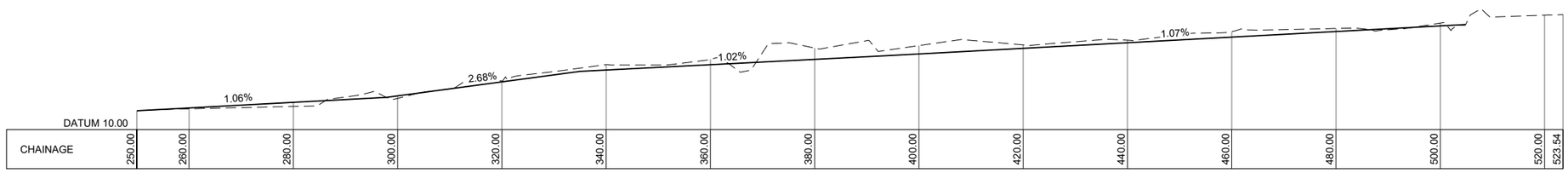
LONGITUDINAL SECTION - NORTHERN DIVERSION BUND - CH 0 - CH 250

SCALE 1:1,000 m



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

SCALE 1:1,000 m

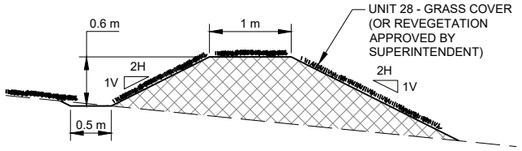


LONGITUDINAL SECTION - NORTHERN DIVERSION BUND - CH 250 - CH 523

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	
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	

CLIENT
CITY OF DARWIN

CONSULTANT
GOLDER
MEMBER OF WSP

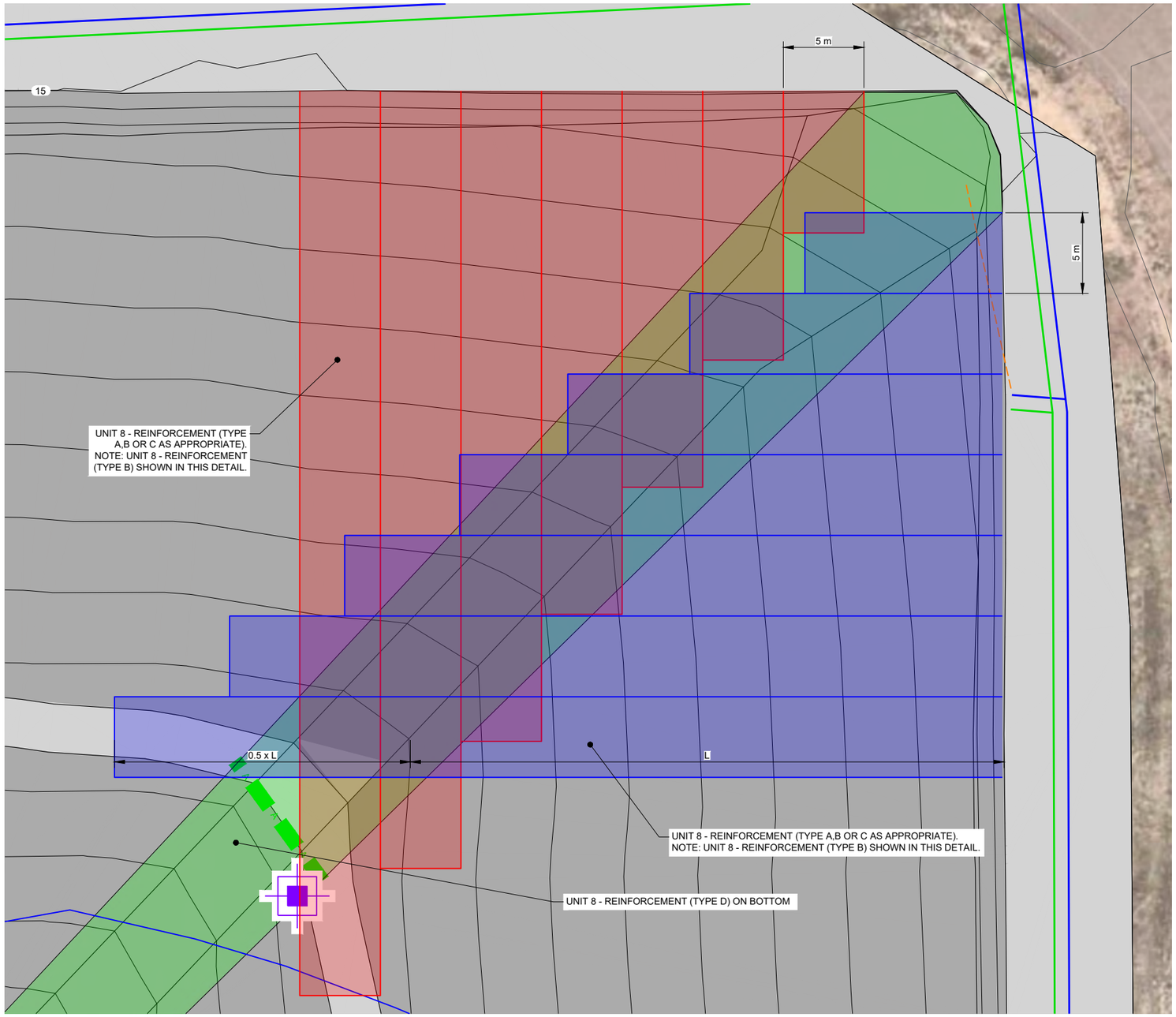
BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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

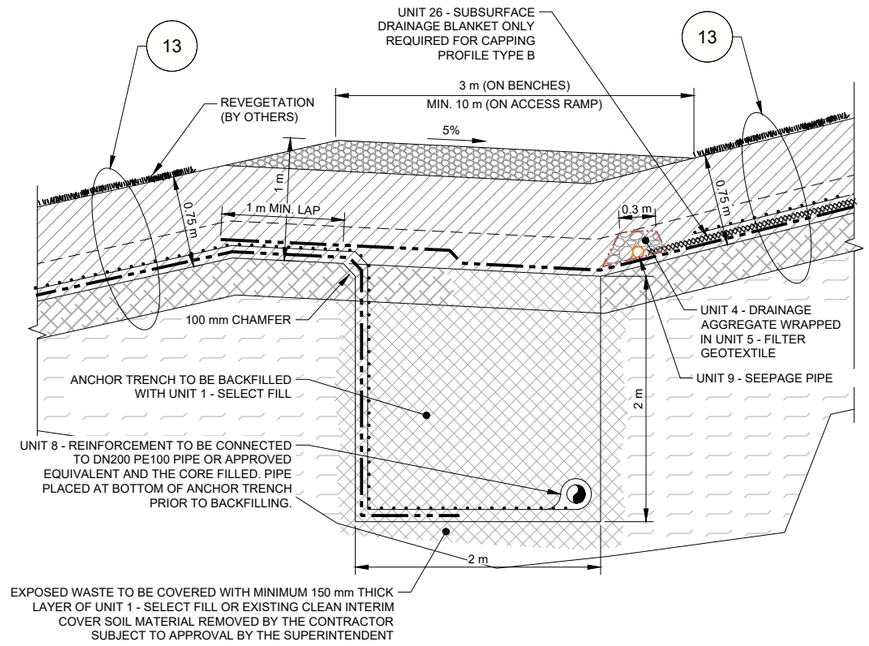
TITLE
NORTHERN DIVERSION BUND - LAYOUT PLAN AND LONGITUDINAL SECTION

PROJECT NO.	CONTROL	REV.		DRAWING
20145676	013	3	19 of 20	019

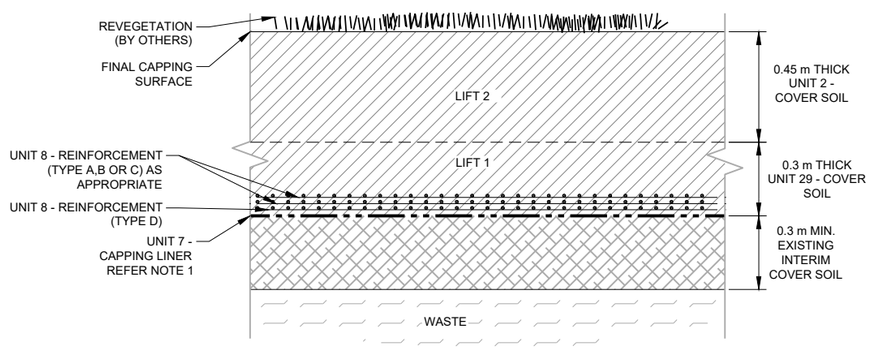
Path: \\golder.gds\gan\Brisbane\Geomatics\CITY_OF_DARWIN\SHOAL_BAY_LANDFILL\99_PROJECTS\20145676 - Stage 3-4 Capping\Concept\Design\013-Stage3-4_Capping\Detailed\Design\02_PRODUCTION\DWG\ | Last Edited By: bkanther Date: 2021-06-11 Time:10:45:14 AM | Printed By: BKanther Date: 2021-06-11 Time:10:49:05 AM | File Name: 20145676-013-019.dwg
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0



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
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				

CLIENT
CITY OF DARWIN

CONSULTANT
GOLDER
MEMBER OF WSP
BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

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	3	20 of 20	020

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: 20145676-013-020.dwg | Last Edited By: bkanther Date: 2021-06-11 Time:10:45:52 AM | Printed By: BKanther Date: 2021-06-11 Time:10:49:14 AM

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

APPENDIX G IRRIGATION MANAGEMENT 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

Table of Contents

1. Introduction 6

1.1. Purpose of Irrigation Management Plan 6

1.2. Scope of Irrigation Management Plan 7

1.3. NT EPA Licence Clauses for Irrigation Area 7

2. System Overview 8

2.1. Leachate Treatment 9

2.2. Treated Leachate Irrigation Area 12

2.3. Treated Leachate Characterisation 13

3. Irrigation Overview 15

3.1. Philosophy, Operation and Control 15

3.2. Irrigation Design 17

3.3. Irrigation Scheduling 18

3.4. Irrigation Maintenance 18

3.5. Supplementary Protocols 19

3.5.1. Surface Runoff 19

3.5.2. Crop Management 19

3.5.3. Weed Management 19

3.5.4. Pest Management 20

4. Irrigation Management and Controls 21

4.1. Soil Moisture Monitoring 21

4.2. Soil Management 21

4.2.1. Soil Sodicity 21

4.2.2. Soil Salinity 22

4.2.3. Available Water Holding Capacity 23

4.2.4. Heavy Metals 23

5. Monitoring 24

5.1. Monitoring 24

5.1.1. Treated Leachate Monitoring 24

5.1.2. Soil Monitoring 25

5.1.3. Groundwater Monitoring 25

Appendices 26

List of Figures

Figure 1: Location of Shoal Bay Waste Management Facility (NearMaps 2020) 8
Figure 2: Shoal Bay Landfill Leachate Treatment Process 9
Figure 3: Map of Irrigation Area 12

List of Tables

Table 1: Summary of Raw Leachate Data from Shoal Bay Landfill (2017 - 2018) 10
Table 2: Summary of PFAS Chemical Family Leachate Data from Shoal Bay Landfill (2017 - 2018) and Adopted Design Values. 11
Table 3: Environmental and Audit Report – Irrigation Parameters 11
Table 4: PFAS effluent requirements (95% species protection) 12
Table 5: Treated Leachate Characterisation from Table 3.1 NSW Effluent via Irrigation Guidelines (2004). 13
Table 6: Treated Leachate Characterisation in accord with Table 3.1 and 3.3 NSW Effluent via Irrigation Guidelines (2004) 14
Table 7: Irrigation Design Criteria for the 6.5ha Vetiver Irrigation Area. 17
Table 8: Average Irrigation Demand vs. Supply 18
Table 9: Salt Tolerance and Vetiver Outputs from the MEDLI model (Appendix A) 22
Table 10: Soil salinity and Vetiver Outputs from the MEDLI model (Appendix A) 22
Table 11: Treated Leachate Monitoring Program 24
Table 12: Soil Monitoring Program 25

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.

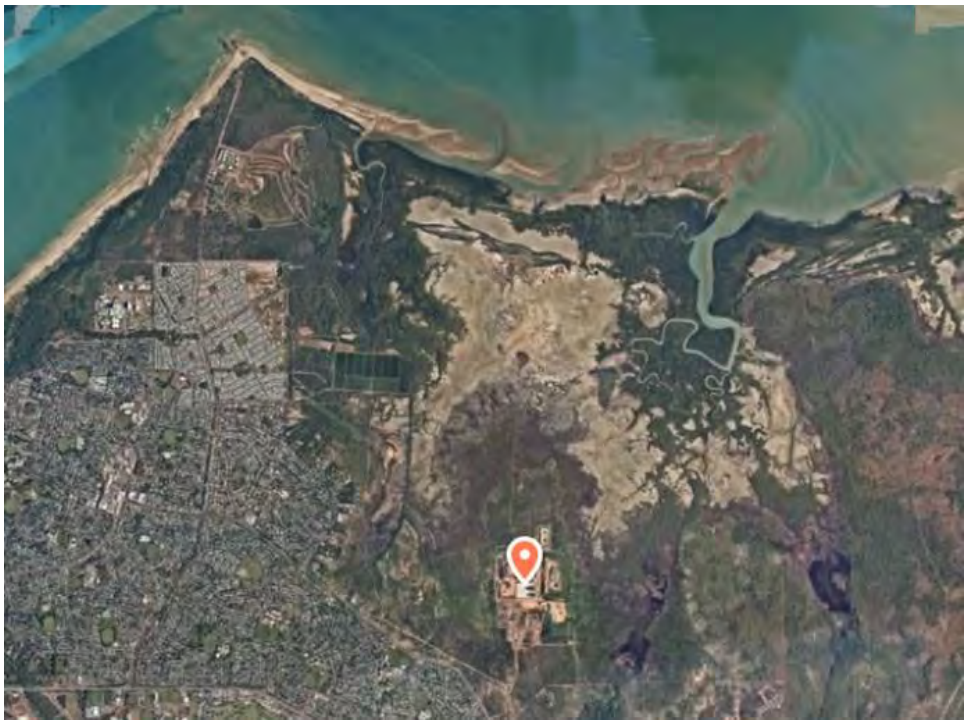


Figure 1: Location of Shoal Bay Waste Management Facility (NearMaps 2020)

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:

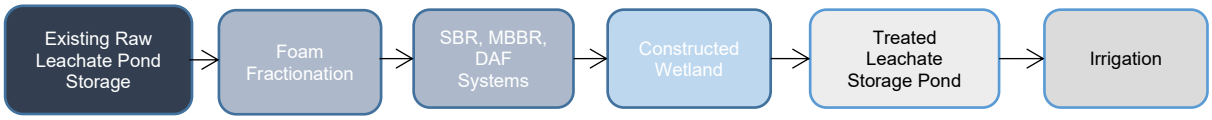


Figure 2: Shoal Bay Landfill Leachate Treatment Process

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.

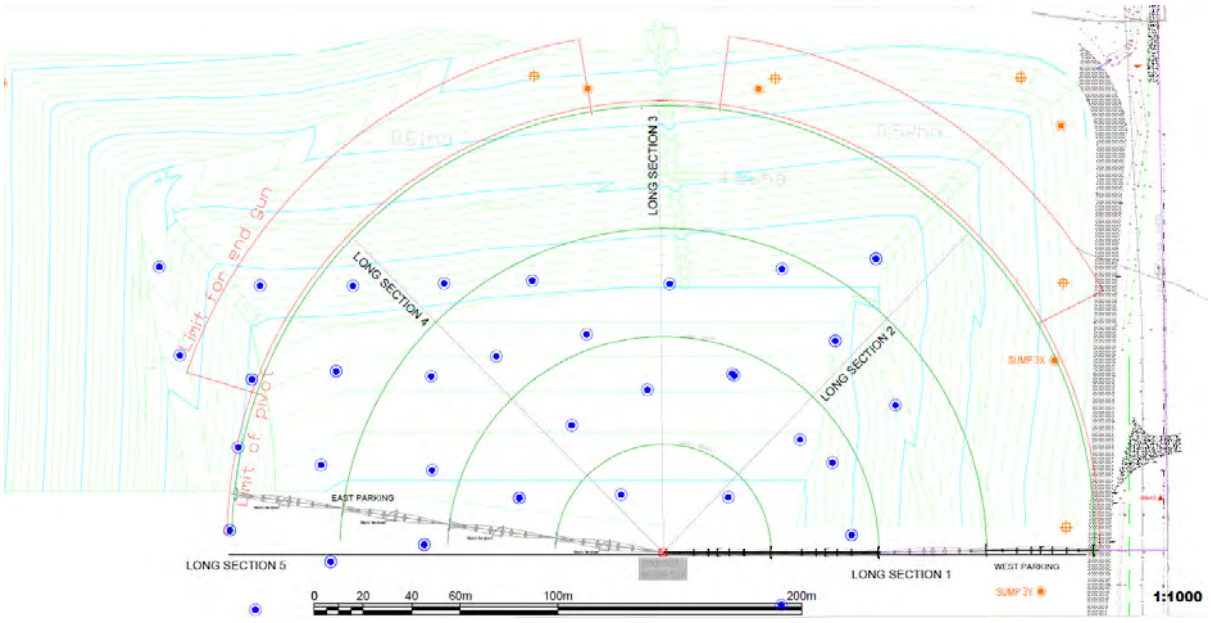


Figure 3: Map of Irrigation Area

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

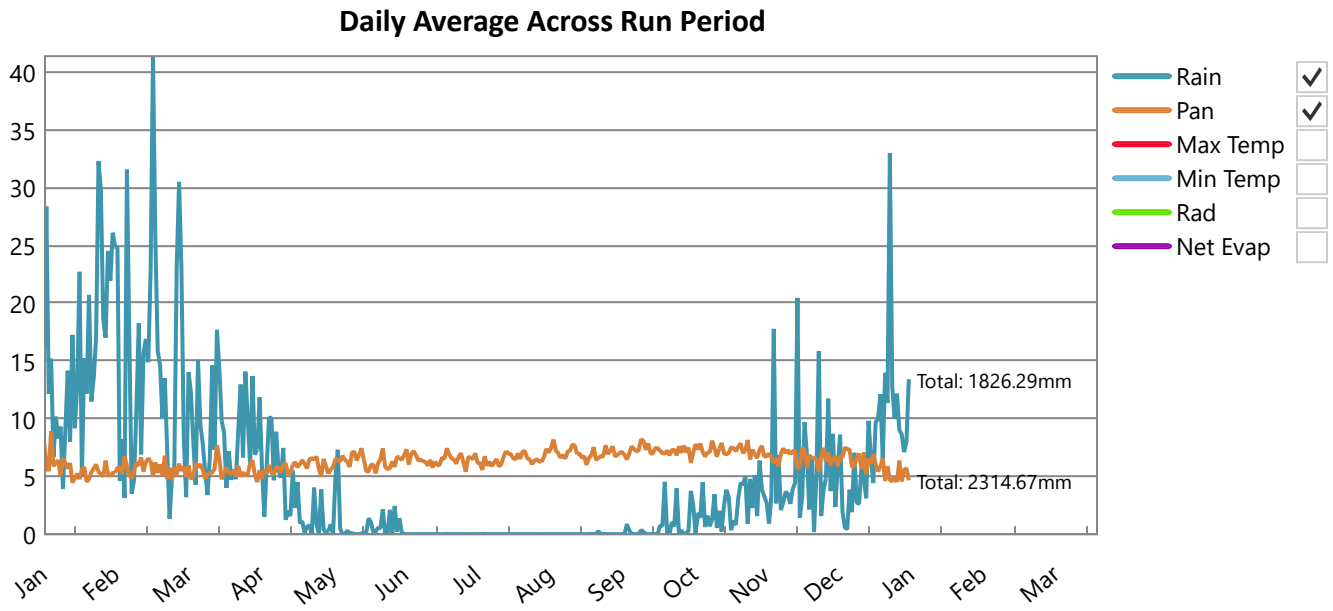
Climate Statistics:

	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

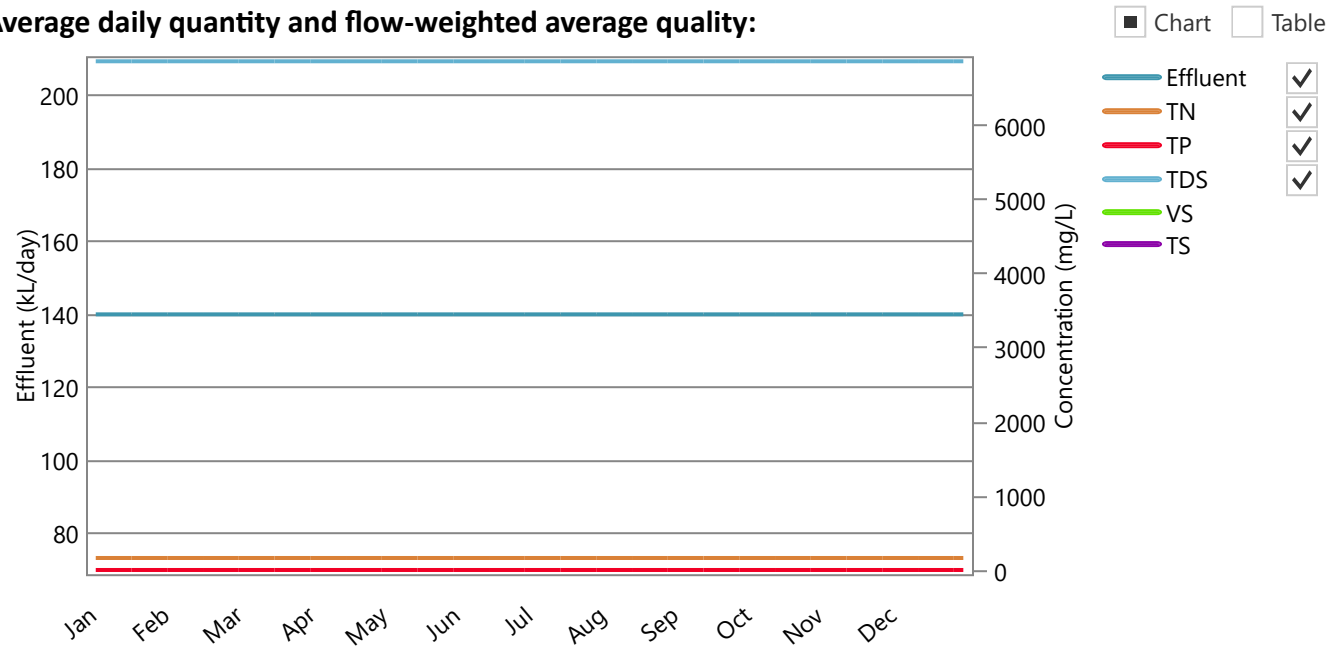


DESCRIPTION

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:

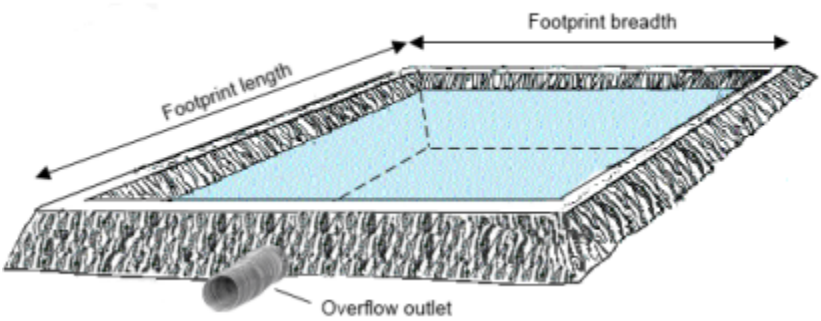
	Concentration (mg/L)	Load (kg/year)
Total Nitrogen	170.00 (170.00 - 170.00)	8691.76 (8687.00 - 8710.80)
Total Phosphorus	8.00 (8.00 - 8.00)	409.02 (408.80 - 409.92)
Total Dissolved Salts	6867.84 (6867.84 - 6867.84)	351138.92 (350946.62 - 351908.12)
Volatile Solids	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)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

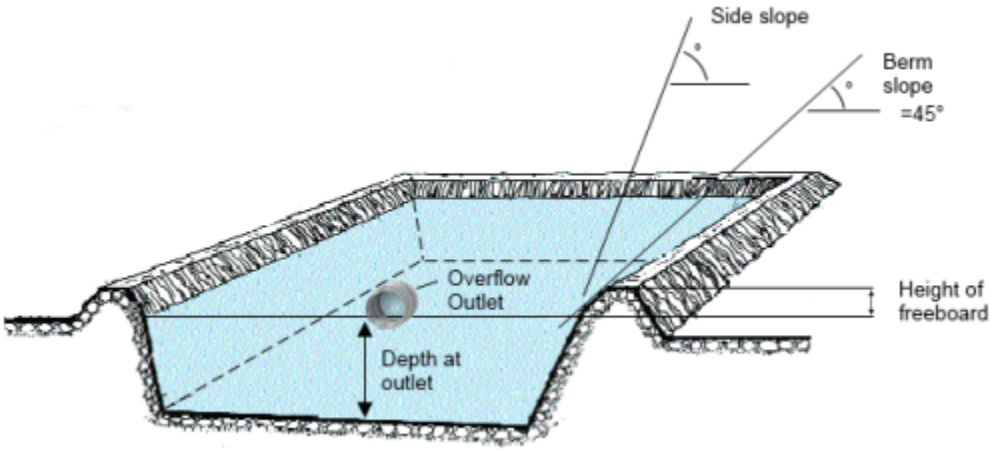
DESCRIPTION

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

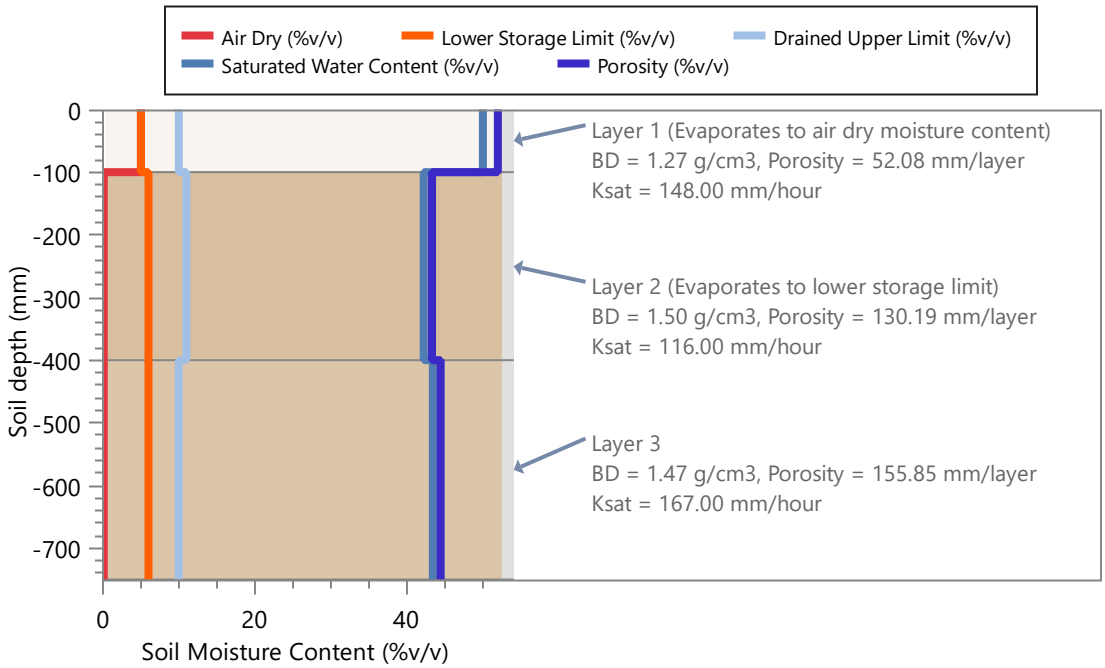
DESCRIPTION

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

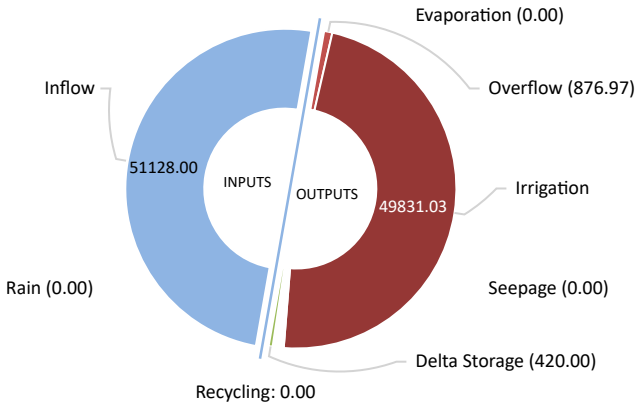
Average monthly cover (fraction) (minimum - maximum)	0.87 (0.78 - 0.94)
Maximum crop factor at 100% cover (mm/mm) (Maximum crop coefficient 0.9 x Pan coefficient 1)	0.90
Total plant cover (both green and dead) left after harvest (fraction)	1.00
Maximum potential root depth in defined soil profile (mm)	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**

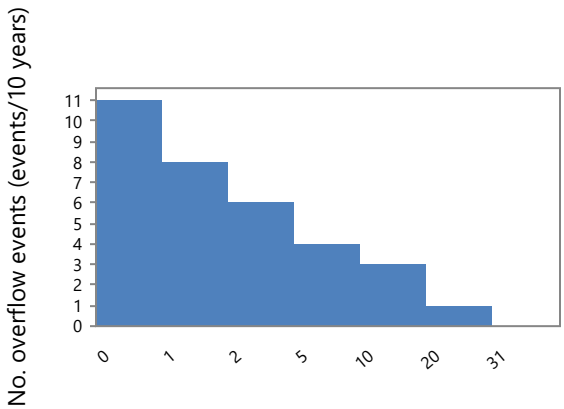
Pond System Water Balance (kL/year)



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

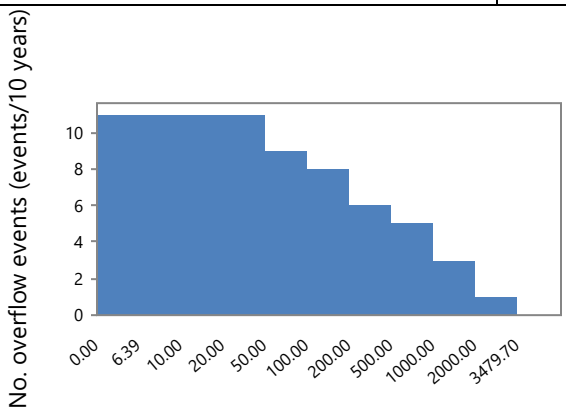
Overflow Diagnostics

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



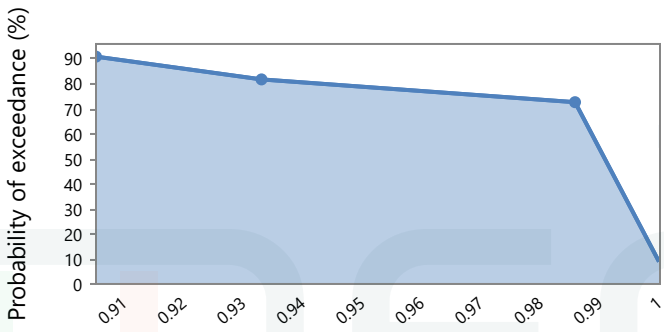
Overflow event duration exceeded (days)

Export plot



Overflow volume exceeded (kL)

Export plot



Annual reuse (fraction)

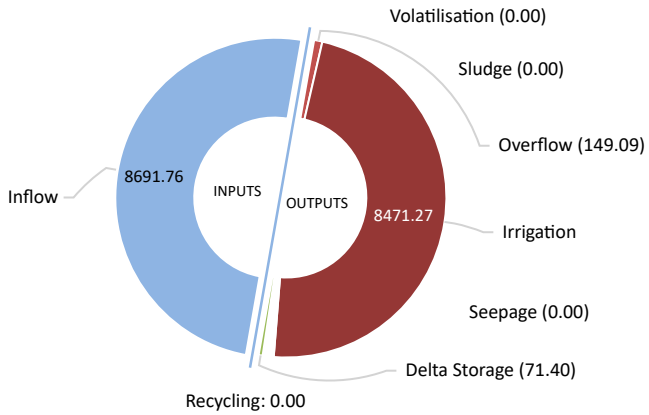
Export plot

PERFORMANCE

Pond System Performance - Nutrient: 1 closed storage tank

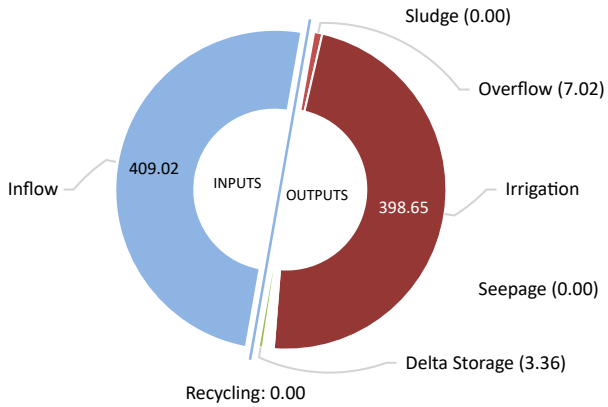
Pond System Nutrients and Salt Balance:

Nitrogen Balance (kg/year)



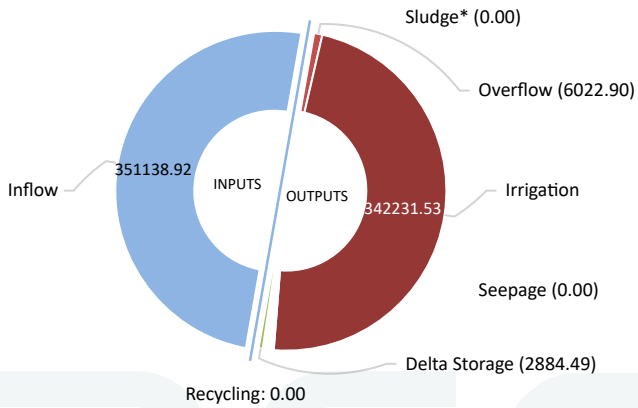
Name	Value
Inflow	8691.76
Recycling	0.00
Volatilisation	0.00
Sludge	0.00
Overflow	149.09
Irrigation	8471.27
Seepage	0.00
Delta Storage	71.40

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

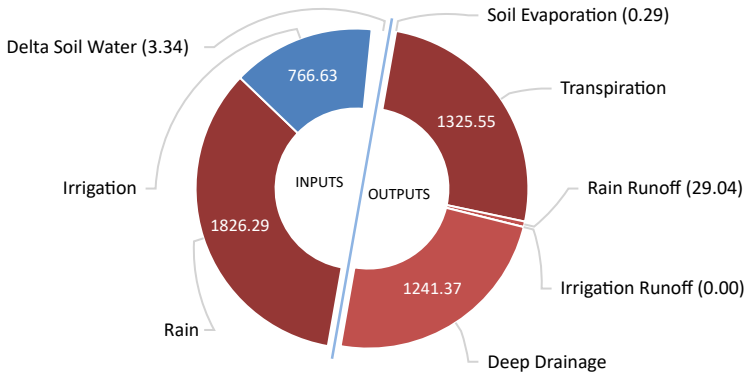
PERFORMANCE

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):

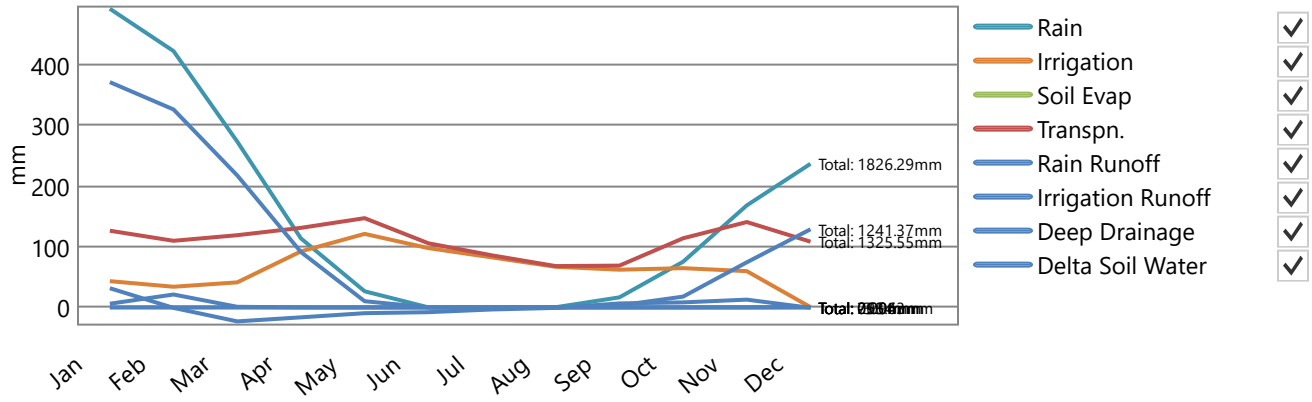
mm/year % Total inputs



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

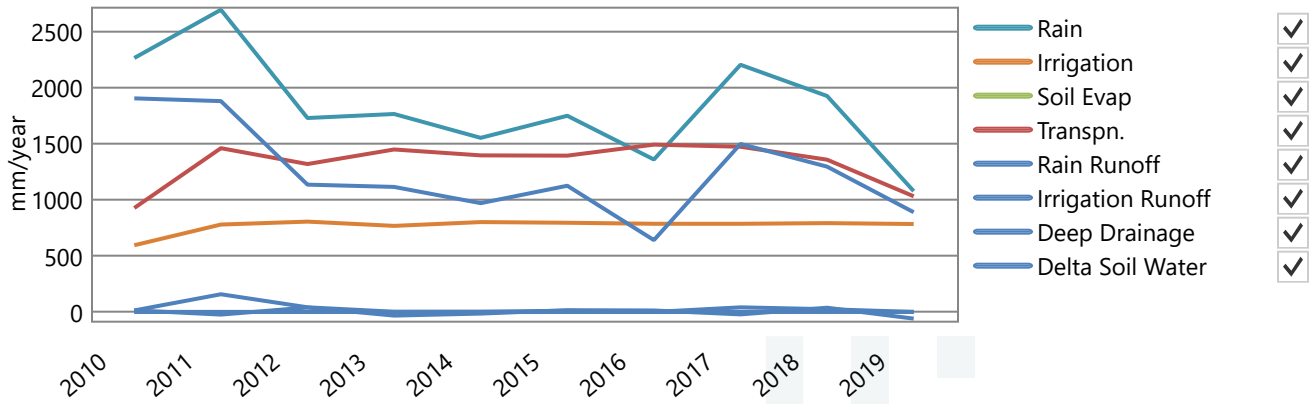
Average Monthly Totals (mm):

Chart Table



Average Annual Totals (mm/year):

Chart Table



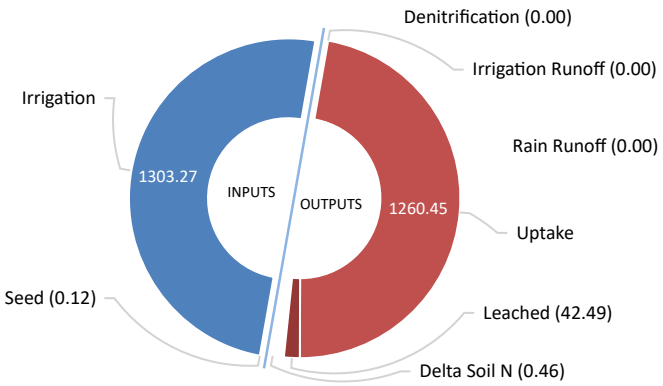
PERFORMANCE

Land Performance - Soil Nutrient

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

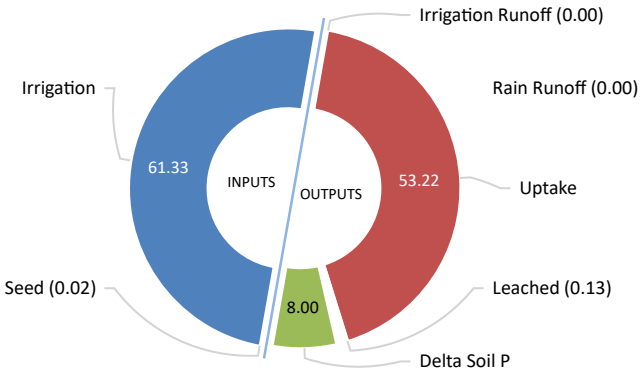
Irrigation ammonium volatilisation losses (kg/ha/year): 0.00
Proportion of total nitrogen in irrigated effluent as ammonium (fraction): 0.00

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

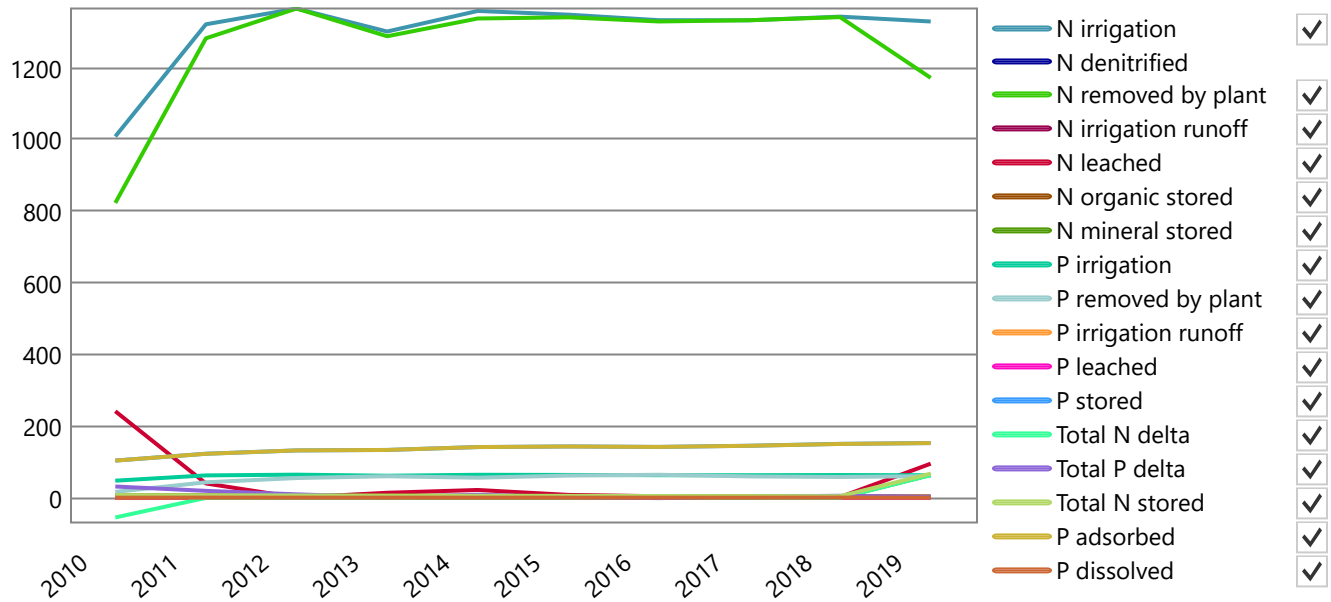
PERFORMANCE

Land Performance - Soil Nutrient

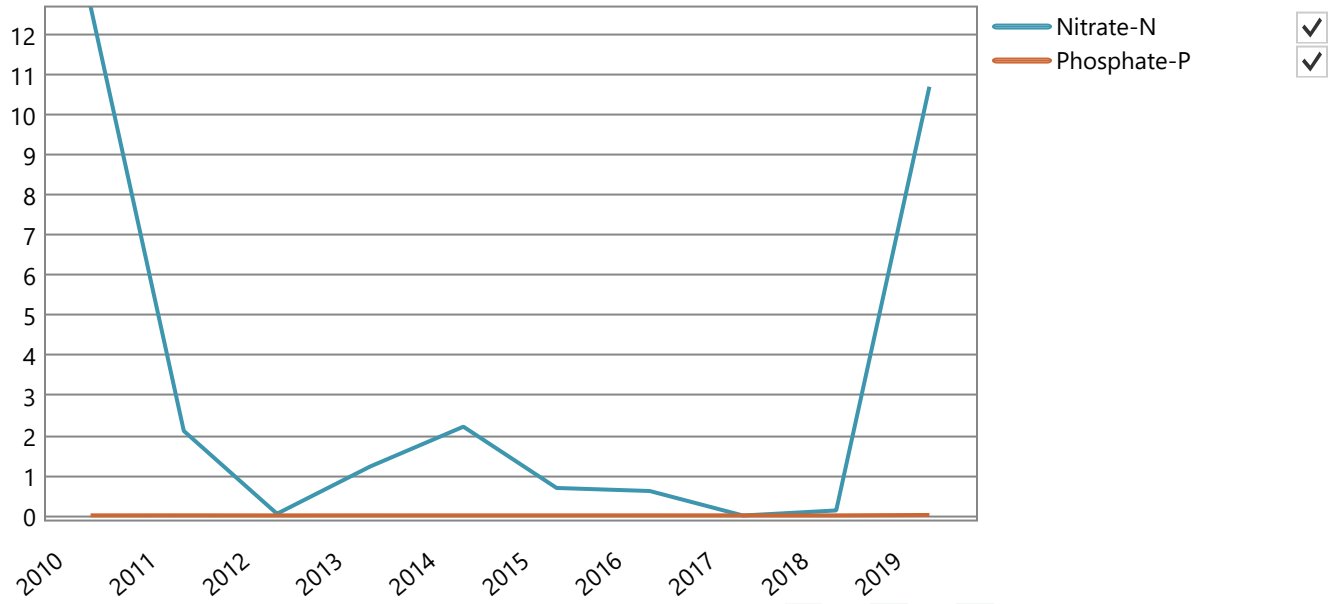
Paddock: New Paddock, 6.5 ha

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

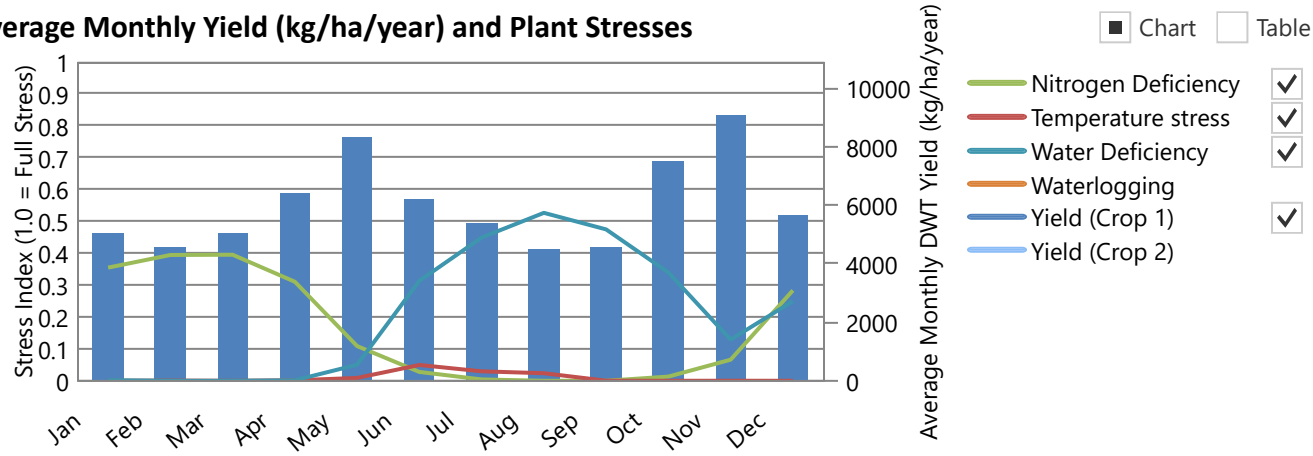
Plant: Continuous Vetiver Pasture, kick started

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)

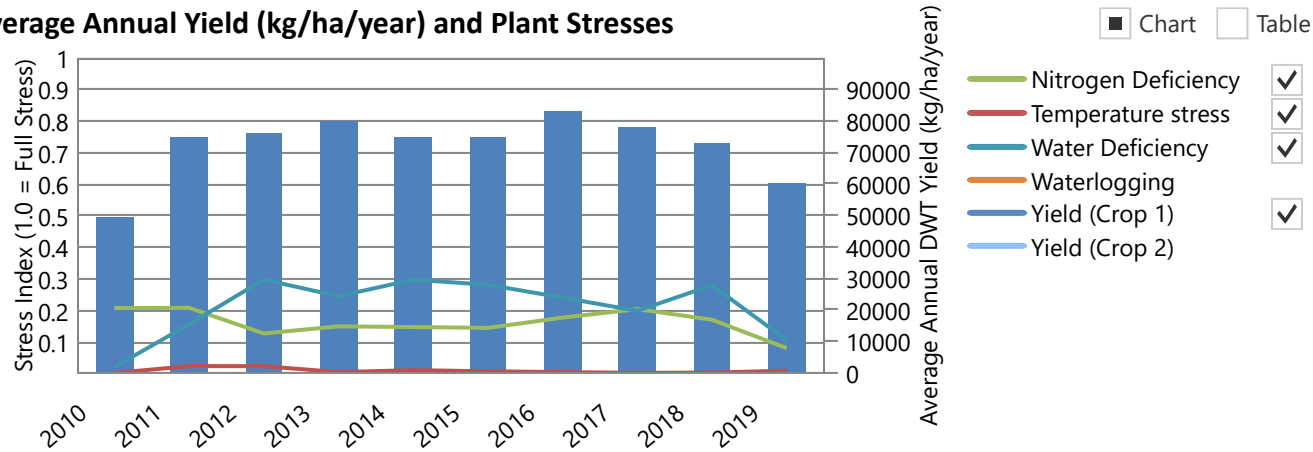
Nutrient Uptake (minimum - maximum):

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

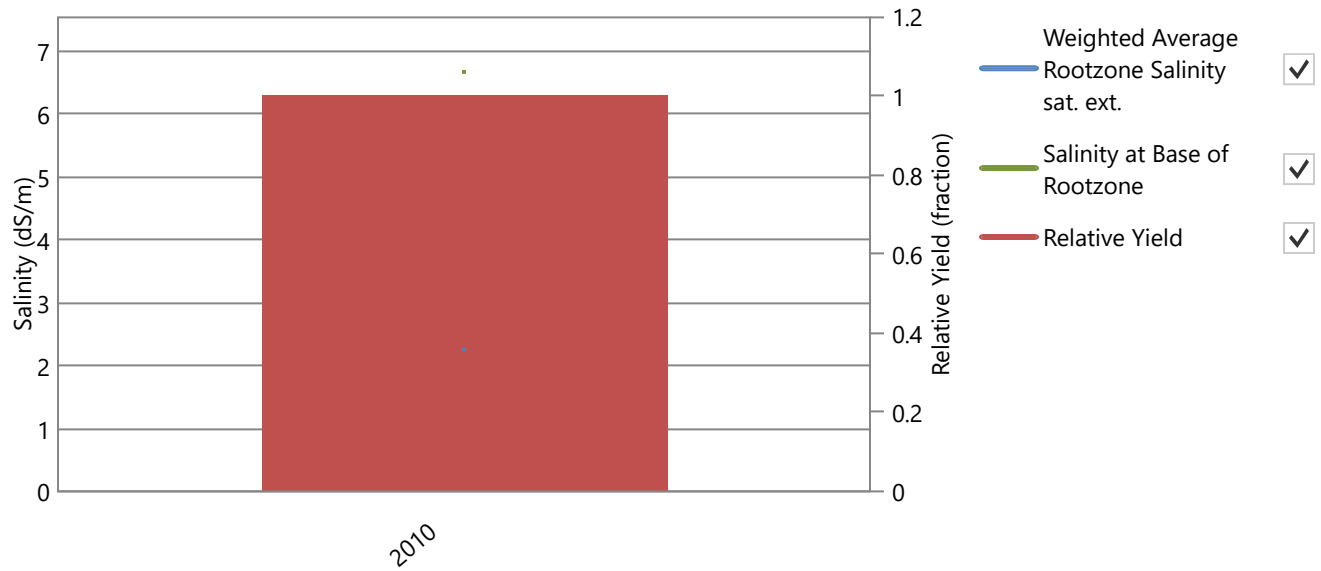
Soil Salinity:

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



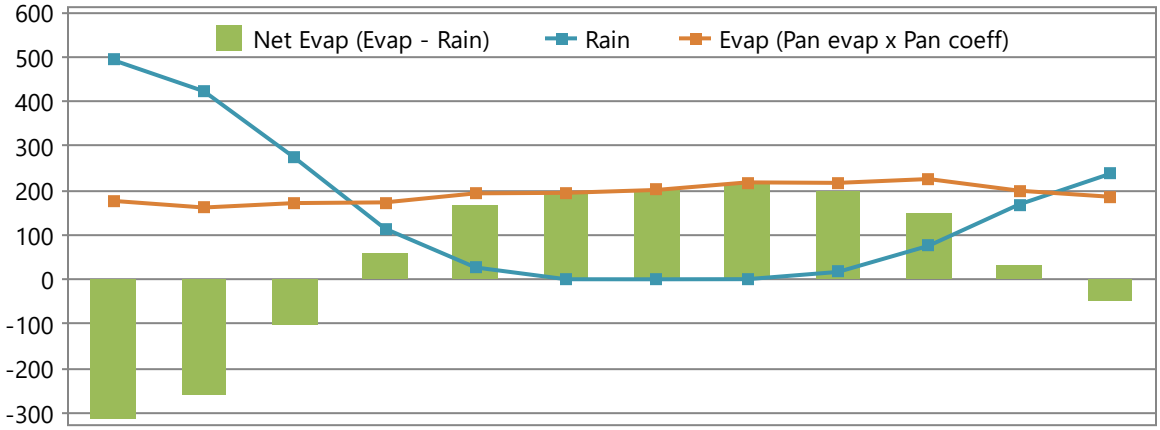
DIAGNOSTICS

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)

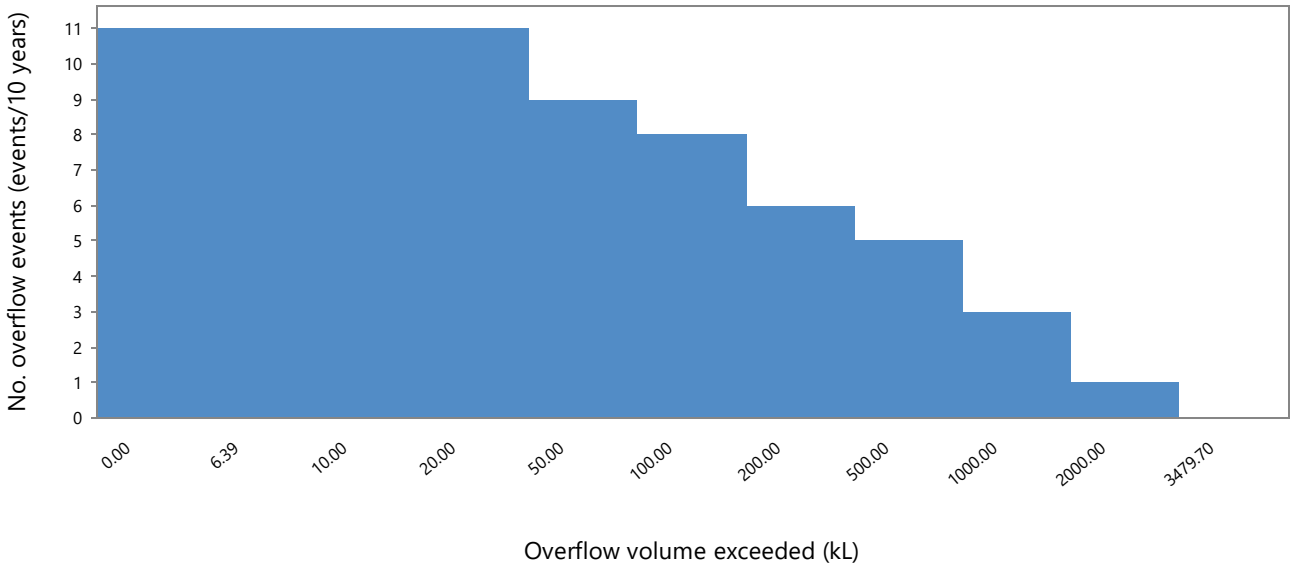
Last pond (Wet weather store): 15000.00 kL

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

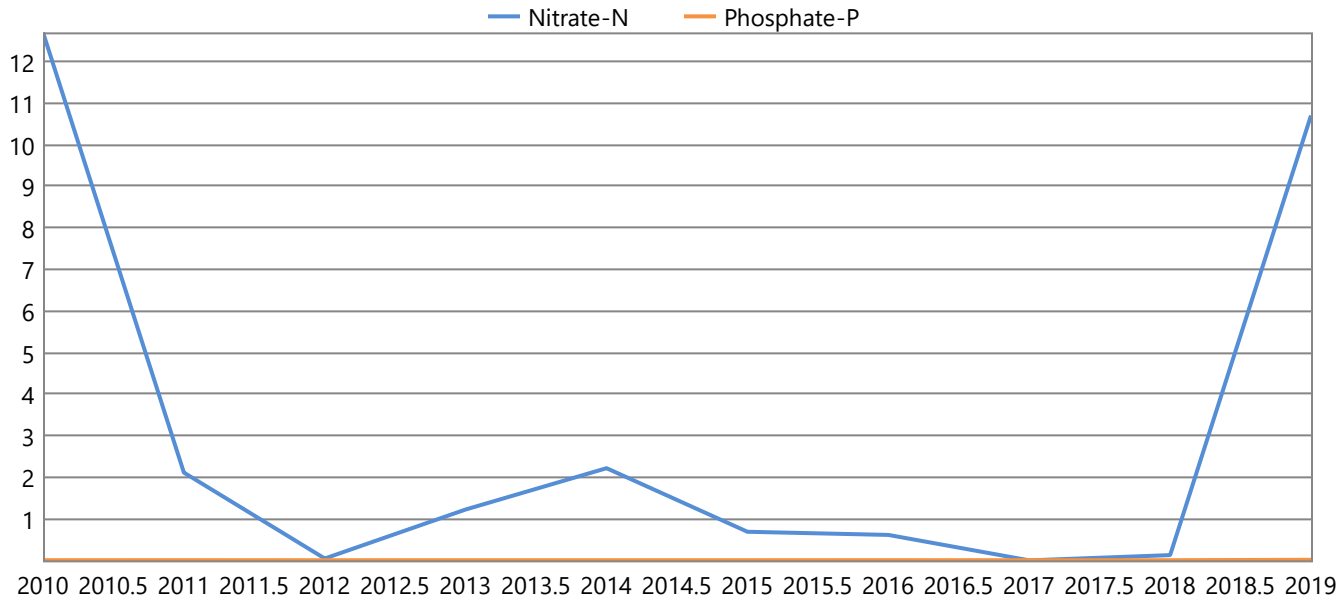
DIAGNOSTICS

Sustainability Diagnostics: New Enterprise

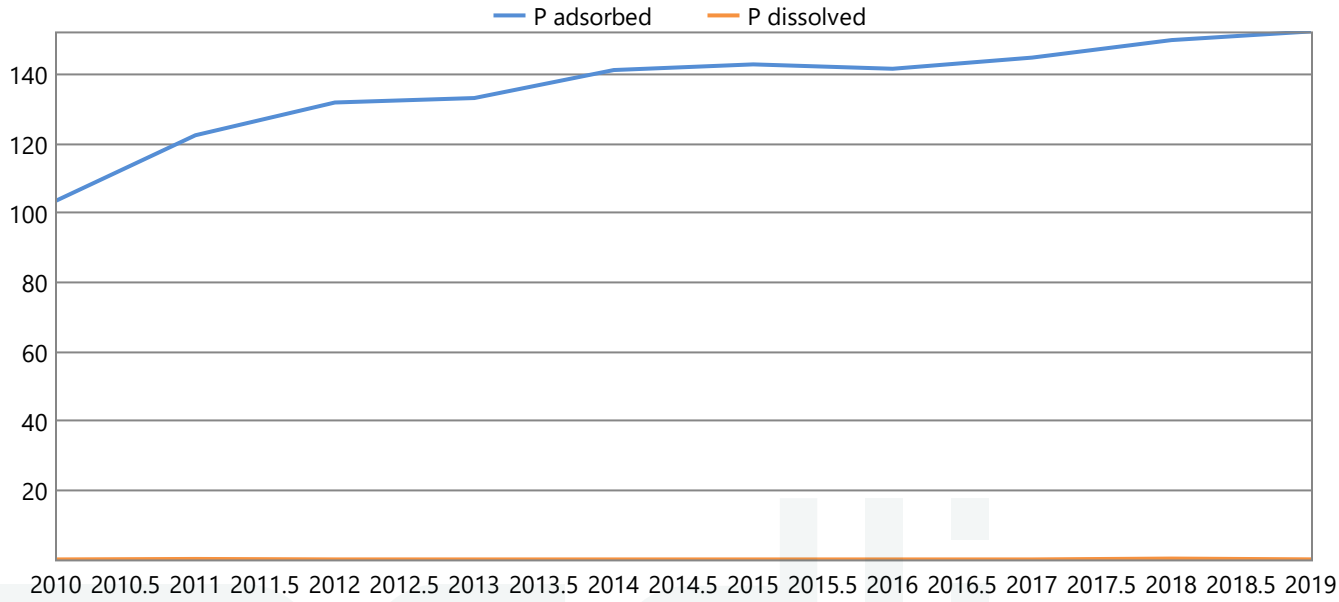
Paddock Land: New Paddock: 6.5 ha

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 H EMERGENCY LEACHATE MANAGEMENT PROCEDURE, SHOAL BAY WASTE MANAGEMENT FACILITY

Emergency Leachate Management Procedure
Shoal Bay Waste Management Facility

1 Purpose

The purpose of this document is to ensure that City of Darwin (CoD) effectively manage leachate in an emergency where there is insufficient leachate storage, for example during extreme weather conditions or leachate treatment equipment failure, to ensure minimal impact to the environment.

2 Scope

This procedure covers all leachate (raw and treated) within the Shoal Bay Waste Management Facility (SBWMF). CoD will lead the implementation of this procedure in consultation with other stakeholders who manage leachate onsite, including Veolia and Water & Carbon Group (WCG).

3 Procedure Statement

The CoD leachate dashboard is updated several times a week to provide data on actual leachate generation, storage and treatment (leachate treatment plant and irrigation and Benevap system).

The leachate dashboard also provides a forecast of leachate generation, based on predicted rainfall events and leachate treatment rates.

In an event where leachate storage capacity is likely to be exceeded, environmental harm will be minimised through adopting the following principles, reflected in the leachate emergency procedure:

1) prioritise the effective storage and management of raw leachate over treated leachate
2) contain surplus leachate to the operational site

The emergency leachate management procedure will be enacted in 2 phases once all listed trigger criteria have been met:

Phase 1: Maintaining raw leachate storage

Phase 1 trigger criteria:

- Leachate storage volumes are above 90% storage capacity;
- An overtopping event of treated leachate is imminent without prioritising the effective storage and management of raw leachate over treated leachate.

Phase 1 actions
1. Notify the EPA of phase 1 emergency procedure to minimise harm to the environment
2. Pump out treated leachate from tank 1 into the lined wetland, making tank 1 available for raw leachate
3. Overflow of treated and diluted leachate may occur from the open wetland into Northern Borrow Pit unlined pond where it will receive further dilution and remain contained onsite.
4. If overflow occurs, take water samples immediately at wetland overflow and within the Northern Borrow Pit/unlined pond at the existing routine surface water sampling site SW14. All water sampling will follow the requirements for surface water sample collection as prescribed in the Water Quality Monitoring Plan (Appendix B of the SBWMF EMP). Sample analysis will be undertaken by a NATA-accredited lab for the routine surface water parameters as per Attachment 3 of EPL188-03.

5. Continue taking weekly water samples at the Northern Borrow Pit/unlined pond (SW14) until discharge of treated leachate into the pond ceases.
6. Maximise the processing of raw leachate through the leachate treatment plant for overflow into the Northern Borrow Pit/unlined pond to maximise capacity for raw leachate storage
7. Provide weekly email updates to the NT EPA that include status of leachate storages and onsite management actions undertaken, and water sampling results with brief assessment of environmental risks. Weekly updates will continue until discharge from the wetland to the Northern Borrow Pit ceases.

Phase 2: Containing raw leachate within the operational site.

Phase 2 trigger criteria:

- Raw leachate storage volumes are reaching an overtopping event
- The forecast generation of raw leachate cannot be stored for more than 96 hours

Phase 2 actions:
1. Notify the EPA of phase 2 emergency procedure to minimise harm to the environment
2. Commence reinjection of raw leachate into stage 5 and 6 where possible
3. Pump out all the diluted treated leachate from the Northern Borrow Pit/unlined pond into the stormwater (S/W) basin
4. Pump a maximum daily leachate generation amount of 150kL of raw leachate into the Northern Borrow Pit/unlined pond for surface containment and rainfall dilution
5. Take an immediate water sample at the Northern Borrow Pit/unlined pond
6. Maintain full capacity of the leachate treatment plant to maximise raw leachate storage
7. Continue to daily monitor leachate storage and generation
8. If additional pumping of raw leachate into the Northern Borrow Pit/unlined pond is required, notify the EPA and maintain a buffer of the maximum daily leachate generation amount of 150kL within the leachate storage system.
9. Take weekly water samples at the Northern Borrow Pit/unlined pond sampling site SW14 until discharge of treated leachate into the pond ceases.
10. Provide weekly email updates to the NT EPA that include status of leachate storages, onsite management actions undertaken, and water sampling results with brief assessment of environmental risks. Weekly updates will continue until discharge of any raw or treated leachate to the Northern Borrow Pit/ unlined pond ceases.

Figure 1: Map of leachate storage and emergency containment areas



APPENDIX I LEACHATE STORAGE POND 3 DETAIL DESIGN

REPORT

Shoal Bay Waste Management Facility - Leachate Storage Pond 3

Technical Specification

Submitted to:

City of Darwin
GPO Box 84
Darwin
NT, 0801

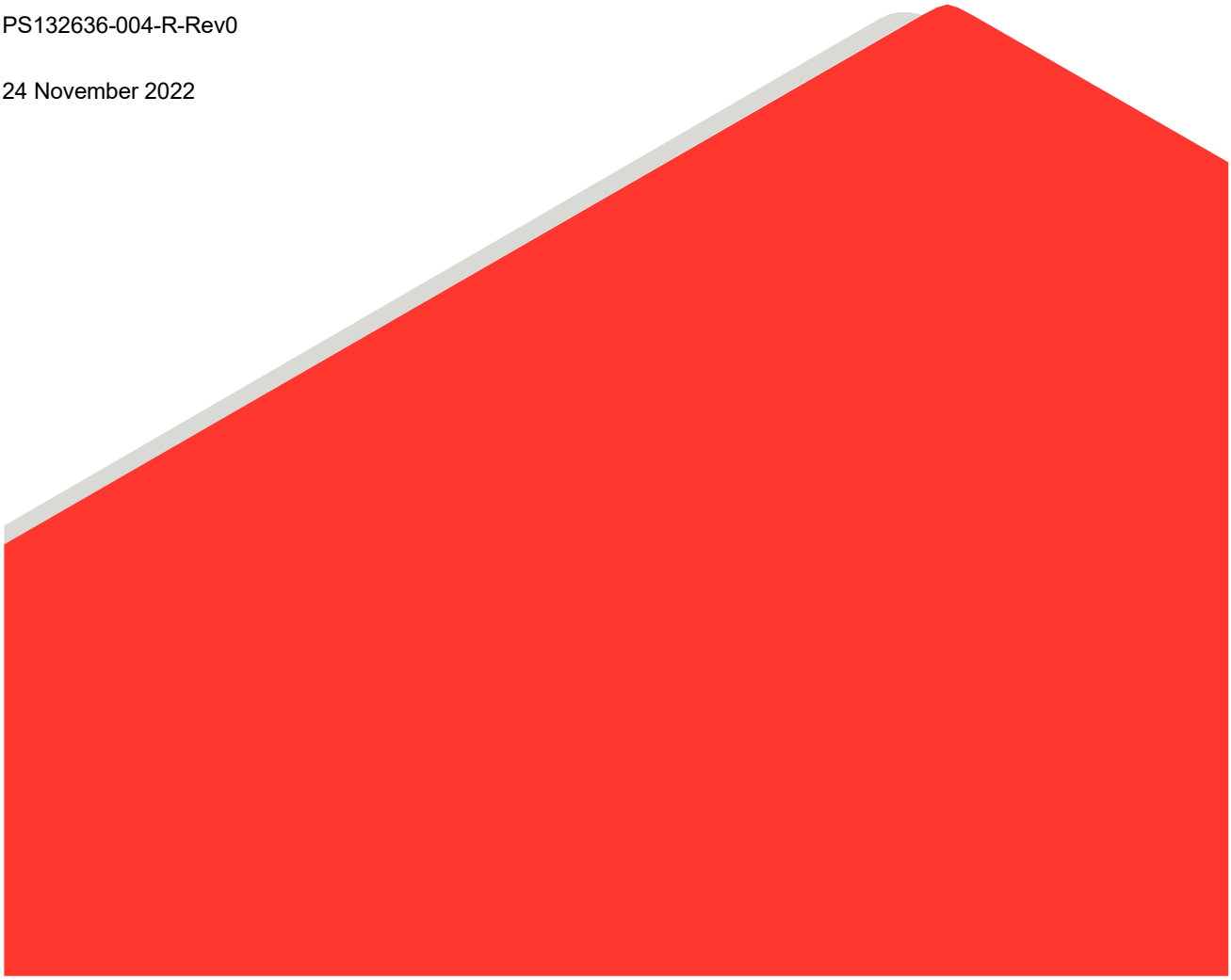
Submitted by:

WSP Australia Pty Limited
900 Ann Street, Level 12, Fortitude Valley, QLD, 4006, Australia

+61 7 3721 5400

PS132636-004-R-Rev0

24 November 2022



Distribution List

City of Darwin - 1 copy (PDF)

WSP Golder - on file

Record of Issue

Company	Client Contact	Version	Date Issued	Method of Delivery
City of Darwin	Mr. Nik Kleine	Rev A **(DRAFT)**	30 August 2022	Electronic (email)
City of Darwin	Mr. Nik Kleine	Rev B **(IFR 90%)**	21 October 2022	Electronic (email)
City of Darwin	Mr. Nik Kleine	Rev C **(IFR 90%)**	1 November 2022	Electronic (email)
City of Darwin	Mr Nik Kleine	Rev0 (**Final)**	24 November 2022	Electronic (email)

Table of Contents

1.0 PRELIMINARIES 10

1.1 General 10

1.2 Definitions 10

1.3 Drawing List 13

1.4 Scope of Works 13

1.5 Hold Points 16

1.6 Inspection Points 20

1.7 Information Supplied to the Contractor 21

1.8 Existing Services 21

1.9 Site Access 21

1.10 Traffic over Constructed Works 22

1.11 Layout of Work Zones 22

1.12 Survey 22

1.12.1 Tolerances and spatial compliance 23

1.13 Construction Management Plan 24

1.14 Safety and Risk Management 24

1.14.1 General 24

1.14.2 Safety Management Plan 25

1.14.3 Induction Training 25

1.14.4 Pre-job Planning 26

1.14.5 Site and Public Security 26

1.15 Environmental Management Plan 27

1.15.1 Noise and Vibration Control 27

1.15.2 Soil Erosion 27

1.15.3 Dust, dirt, water and fumes 27

1.16 Wet Weather Mitigation Plan 27

1.17 Provision for Traffic 27

1.17.1 Traffic Control Devices & Management 27

1.18 Quality Assurance and Quality Systems 28

1.18.1 Quality Objectives 28
1.18.2 Quality Plan 28
1.19 Considerations for Detailed Construction Program 29
1.20 Construction Stormwater Management 29
1.21 Supply of Water for Construction 29
1.22 Geotechnical Inspection and Testing of the Work 29
1.23 Temporary Works 30
1.24 Manufacture and Supply of Material 30
1.25 Non-Conformance 30
1.26 Method Statements 30
1.26.1 Excavation, subgrade preparation and construction of the groundwater drainage system 30
1.26.2 Construction of pond liners 31
1.26.3 Construction of sumps and risers 32
1.26.4 Construction of crest access roads 32
1.26.5 Construction of spillways 33
1.26.6 Construction of external batter protection 33
2.0 MATERIAL PROPERTIES, QUALITY ASSURANCE AND QUALITY CONTROL 34
2.1 Material Specifications and Supply 34
2.2 Unit 1 Engineered Fill 34
2.2.1 Material Properties 34
2.2.2 Pre-construction Compliance Testing 35
2.2.3 As-built Compliance Testing 35
2.3 Unit 2 Select Fill 36
2.3.1 Material Properties 36
2.3.2 Pre-construction Compliance Testing 36
2.3.3 As-built Compliance Testing 37
2.4 Unit 3 Topsoil 37
2.5 Unit 4 Subgrade Drainage Aggregate 38
2.5.1 Material Properties 38
2.5.2 Compliance Testing 38
2.6 Unit 5 Sump Drainage Aggregate 39

2.6.1 Pre-construction Compliance Testing 39
2.7 Unit 6 Cement Stabilised Sand 40
2.8 Unit 7 Riprap 40
2.9 Unit 8 Pavement Material 40
2.9.1 Compliance Testing 40
2.10 Unit 9 Separation Geotextile 41
2.11 Unit 10 Bituminous Geomembrane Liner 41
2.11.1 Material properties 41
2.12 Unit 11 Geonet 42
2.12.1 Testing 42
2.13 Unit 12 HDPE Geomembrane 43
2.14 Unit 13 Cushion Geotextile 44
2.14.1 Testing 45
2.15 Unit 14 Erosion Protection 45
2.16 Unit 15 Groundwater Collection Pipe 46
2.16.1 Material Properties 46
2.16.2 Quality Assurance 46
2.17 Unit 16 Solid Drainage Pipe 46
2.17.1 Material Properties 46
2.17.2 Quality Assurance 46
2.18 Unit 17 Riser Pipe 47
2.18.1 Material Properties 47
2.18.2 Quality Assurance 47
2.19 Unit 18 Leachate Inlet Pipe 47
2.19.1 Quality Assurance 48
2.20 Unit 19 Overflow Pipe 48
2.20.1 Quality Assurance 48
2.21 Unit 20 Concrete 48
2.22 Unit 21 – Geocomposite Drain 48
2.22.1 Testing 50
3.0 EXCAVATION, SUBGRADE PREPARATION AND PLACEMENT OF ENGINEERED FILL 51

3.1 General 51
3.2 Subgrade preparation 51
3.3 Placement of Unit 1 Engineered Fill and Unit 2 Select Fill 51
4.0 CONSTRUCTION OF THE GROUNDWATER DRAINAGE SYSTEM 53
4.1 General 53
4.2 Fabrication and Installation of Unit 15 Groundwater Collection Pipe and Unit 16 Solid Drainage Pipe 53
4.3 Unit 4 Subgrade Drainage Aggregate 53
4.4 Unit 9 Separation Geotextile 54
4.4.1 General 54
4.4.2 Seams and Overlaps 54
4.4.3 Repairs 55
4.5 Unit 21 Geocomposite Drain 55
4.5.1 Installation by Subcontractor 55
4.5.2 Transportation, Labelling, Handling and Storage 56
4.5.3 Repairs 56
4.6 Unit 6 Cement Stabilised Sand 56
4.7 Unit 1 Engineered Fill 56
5.0 CONSTRUCTION OF THE LINER 57
5.1 Construction of Unit 2 Select Fill for the Pond Liner 57
5.1.1 Unit 2 Select Fill Placement 57
5.1.2 Compacted Unit 2 Select Fill Surface Preparation and Maintenance 58
5.1.2.1 Erosion Management of Compacted Unit 2 Select Fill 58
5.2 Unit 10 BGM 58
5.2.1 Installation 58
5.2.1.1 Field Panel Placement 58
5.2.1.2 Damage and Defects 60
5.2.1.2.1 General 60
5.2.1.2.2 Manufacturing Defects 60
5.2.1.3 Repair of Defects 60
5.2.1.4 Patching 60
5.2.1.5 Capping 60

5.2.1.6 BGM Field Welding 61
5.2.1.6.1 Joining Equipment and Method 61
5.2.1.6.2 Weld Preparation 61
5.2.1.6.3 Field Weld Record 61
5.2.1.6.4 Conditions for Welding 61
5.2.1.6.5 Seams and Overlaps 62
5.2.2 Testing 62
5.2.2.1 Trial Welds 62
5.2.2.1.1 Trial Weld Evaluation Criteria 62
5.2.2.2 Non-Destructive Weld Continuity Testing 62
5.2.2.2.1 General 62
5.2.2.2.2 Non-destructive test of the joined seam 63
5.2.2.3 Destructive Weld Continuity Testing 64
5.2.2.3.1 General 64
5.2.2.3.2 Location and Frequency 64
5.2.2.3.3 Field Destructive Sample Procedures 64
5.2.2.3.4 Size of Samples 64
5.2.2.3.5 Preliminary Field Tests 64
5.2.2.3.6 Laboratory and Field Testing Weld Evaluation Criteria 64
5.2.2.3.7 Failed Destructive Sample Procedure 65
5.3 Unit 11 Geonet 65
5.3.1 Installation by Subcontractor 65
5.3.2 Transportation, Labelling, Handling and Storage 65
5.3.3 Repairs 66
5.4 Unit 12 HDPE Geomembrane Liner 66
5.4.1 Installation by Subcontractor 66
5.4.2 Transportation, Labelling, Handling and Storage 66
5.4.3 Placement 66
5.4.3.1 Layout Drawings 66
5.4.3.2 Panel Identification 67
5.4.3.3 Field Panel Placement 67
5.4.3.4 Installation Schedule 67

5.4.3.5 Method of Placement 67
5.4.4 Damage and Defects 68
5.4.4.1 Fisheye 68
5.4.4.2 Surface Blemishes 68
5.4.4.3 Scratches 68
5.4.4.4 Non-uniform Surface Texture 69
5.4.4.5 Repair of Defects 69
5.4.5 Field Welding 69
5.4.5.1 Requirements of Personnel 69
5.4.5.2 Welding Equipment and Methods 69
5.4.5.2.1 Approved Processes for Field Welding 69
5.4.5.2.2 Fusion Welding Process 70
5.4.5.2.3 Extrusion Welding Process 70
5.4.5.2.4 Protection of Geomembrane 70
5.4.5.3 Seam Layout 70
5.4.5.4 Weather Conditions for Welding 70
5.4.5.5 Weld Preparation 70
5.4.5.6 Overlapping and Temporary Bonding 71
5.4.5.7 General Welding Procedures 71
5.4.6 Testing 72
5.4.6.1 Trial Welds 72
5.4.6.1.1 Trial weld acceptance criteria for Unit 12 HDPE Geomembrane 72
5.4.6.2 Non-destructive Weld Continuity Testing 73
5.4.6.2.1 General 73
5.4.6.2.2 Spark Testing 73
5.4.6.2.3 Vacuum Testing 74
5.4.6.2.4 Air Pressure Testing 74
5.4.6.3 Destructive Weld Continuity Testing 75
5.4.6.3.1 Location and Frequency 75
5.4.6.3.2 Sampling Procedure 75
5.4.6.3.3 Size of Samples 75
5.4.6.3.4 Weld Destructive Tests 75

5.4.6.3.5 Destructive weld acceptance criteria....76
5.4.6.3.6 Failed Destructive Sample Procedure....77
5.4.7 Repairs....77
5.4.7.1 General....77
5.4.7.2 Patching....77
5.4.7.2.1 Capping....78
5.4.7.2.2 Grinding and Welding....78
5.4.7.2.3 Geomembrane Wrinkles and Bridging....78
5.4.8 Site Management....79
5.5 Anchor Trenches....79
5.6 Backfill of Anchor Trenches with Unit 6 Cement Stabilised Sand....79
6.0 CONSTRUCTION OF THE SUMPS AND RISERS....80
6.1 General....80
6.2 Unit 13 Cushion Geotextile....81
6.2.1 Transportation, Handling and Storage....81
6.2.2 Seams and Overlaps....82
6.2.3 Repairs....82
6.3 Unit 5 Sump Drainage Aggregate Placement....82
7.0 CONSTRUCTION OF THE LEACHATE INLET PIPE....83
7.1 General....83
8.0 CONSTRUCTION OF THE EMERGENCY LEACHATE OVERFLOW SYSTEM....84
9.0 CONSTRUCTION OF ACCESS RAMP AND CREST PROTECTION SURFACE....85
10.0 CONSTRUCTION OF SPILLWAYS AND SURFACE WATER DRAINS....86
10.1 General....86
10.2 Unit 7 Riprap Placement....86

TABLES

Table 1: Definitions....10
Table 2: Materials....12
Table 3: Drawing List....13
Table 4: Works Description and Suggested Sequence of Construction....14
Table 5: Summary of Hold Points....16

Table 6: Summary of Inspection Points 20
Table 7: Unit 1 Engineered Fill Material Properties 34
Table 8: Unit 1 Engineered Fill as-built compliance testing acceptance criteria 35
Table 9: Unit 2 Select Fill Material Properties 36
Table 10: Unit 2 Select Fill as-built compliance testing acceptance criteria, method and frequency 37
Table 11: Unit 4 Subgrade Drainage Aggregate Material Properties 38
Table 12: Frequency of Compliance Testing - Unit 4 Drainage Aggregate 38
Table 13: Unit 5 Sump Drainage Aggregate Material Properties 39
Table 14: Unit 7 Riprap Material Properties 40
Table 15: Unit 9 Separation Geotextile Properties 41
Table 16: BGM Liner Material Property Requirements 41
Table 17: Required properties of Unit 11 Geonet 42
Table 18: Required Testing of Unit 11 Geonet 43
Table 19: Required properties and Testing of Unit 12 HDPE Geomembrane 44
Table 20: Unit 13 Cushion Geotextile Material Properties 45
Table 21: Required properties of Unit 21 Geocomposite Drain 50
Table 22: Required Testing of Unit 21 Geocomposite Drain 50

1.0 PRELIMINARIES

1.1 General

The City of Darwin commissioned WSP Australia Pty Ltd (WSP Golder) as the Principal Contractor (the Contractor) to prepare design documentation and manage the construction of a 15ML covered leachate pond at the Shoal Bay Waste Management Facility (SBWMF), Darwin, Northern Territory. The leachate pond is to be located to the north of the existing leachate ponds within the boundaries of the SBWMF.

The pond will have a floating geosynthetic cover (the pond cover) (Design by Others) and constructed by a Geosynthetic Installer nominated by the Principal Contractor. It is desired that the pond be constructed and operational (including the pond covers) before commencement of the Wet Season in December 2022.

The Contractor shall consider the City of Darwin's goals, outlined below, in its construction program.

1) The pond is intended to be constructed and operational (including the pond covers) before commencement of the Wet Season in November 2022.

2) The opportunity to stage construction activities to manage the risk of adverse impacts of weather causing disruption and delays to the construction program.

This Technical Specification (the Specification) details the construction requirements for the embankments, groundwater drainage system, composite geosynthetic liners, and ancillary infrastructure of the Leachate Pond; it does not include the pond covers, stormwater drains, access roads and size of leachate inlet pipes. The Specification shall be read in conjunction with the Design Drawings and any subsequent amendments. The Works shall be constructed in accordance with the requirements of the Specification.

A Geosynthetics Installer nominated by the Contractor shall be appointed by the Contractor for the installation of the geosynthetic components of the Works, which is considered to be a specialist activity.

1.2 Definitions

The key parties and terms referred to in the Specification are described in Table 1. Works materials are defined in Table 2.

Table 1: Definitions

Party / Term	Description
Principal	City of Darwin
Contractor	WSP Australia Pty Ltd (WSP Golder). Company that is responsible for the construction of the Works including management of subcontractors.
Site	Area of the North of the current Leachate Ponds located to the north of the Landfill Site, as shown on Drawing D002 and D003.
Landfill Site	Shoal Bay Waste Management Facility, Darwin, Northern Territory, as shown on Drawing D001.
Works	All works described in the Specification and Drawings, including those listed in Table 3.
Superintendent	Individual appointed by Principal to act as the Principal's Authorised Person.
Designer	WSP Australia Pty Ltd (WSP Golder)
Environmental Auditor (Qualified Person)	Tony Kortegast The Qualified Person approved by the NTEPA and commissioned by the Client to oversee and verify whether the WUC comply with the Specification

Party / Term	Description
	in accordance with the NTEPA Guidelines for the siting, design and management of solid waste disposal sites in the Northern Territory (January 2013). The term Environmental Auditor is used for the purposes of the project.
Geotechnical Inspection and Testing Authority (GITA)	Shall be engaged by the Client to undertake inspection of Unit 1 Engineered Fill and Unit 2 Select Fill and inspection of Unit 10 BGM, Unit 11 Geonet and Unit 12 HDPE Geomembrane indicated in the Specification, and to provide an opinion on the compliance of those works with the Specification and Construction Quality Assurance (CQA) Plan. The GITA shall be on Site on a full-time basis when works for which they are engaged to inspect are being undertaken.
Geotechnical Testing Authority (GTA)	Shall be engaged by the Contractor and approved by the Superintendent to undertake quality assurance testing of Unit 1 Engineered Fill, Unit 2 Select Fill, Unit 4 Subgrade Drainage Aggregate, Unit 5 Sump Drainage Aggregate and Unit 7 Riprap as indicated in the Specification.
Veolia	Current operator of the landfill at the Landfill Site.
Landfill Management Services (LMS)	Current operator of the Shoal Bay Renewable Energy Facility which generates electricity from landfill gas collected at the Landfill Site
NATA Laboratory	National Association of Testing Authorities (NATA) accredited geotechnical testing laboratory appointed by the Contractor and approved by the Superintendent to undertake independent testing of earthworks and construction materials for Unit 1 Engineered Fill, Unit 2 Select Fill, Unit 4 Subgrade Drainage Aggregate, Unit 5 Sump Drainage Aggregate and Unit 7 Riprap
Surveyor	Licensed surveyor appointed by the Contractor and approved by the Superintendent to undertake the set-out of the Works and measurement of selected material quantities.
Geosynthetics Supplier	Shall be a geosynthetics supplier to be engaged by the Principal and approved by the Superintendent.
Geosynthetics Installer	Shall be a specialist lining installer nominated engaged by the Contractor and approved by the Superintendent.
Pipe Installer	Shall be a specialist pipe installer to be engaged by the Contractor.
Hold Point	Contractor to halt work on identified items, and on any related or dependent items, until the Hold Point is released in writing by the Superintendent. Release of Hold Points shall be dependent on the Contractor providing the required information to the satisfaction of the Superintendent or its appointed representative.
Inspection Point	Contractor to provide notification in advance of commencing work on identified items to allow the opportunity for inspection by the Superintendent or its appointed representative. Notice to be provided as indicated but in no case shall be less than 2 hours in advance of starting or completing the required stage of works.
Specification	Shall include this Technical Specification, Design Drawings and any subsequent amendments.
Drawings	Design drawings listed in Table 3 (Section 1.3) of the Specification and any subsequent amendments to those drawings.
Design by Others	Design by another consultant engaged by the Principal or Designer.

Table 2: Materials

Unit	Description
Soil Materials	
Unit 1 Engineered Fill	Suitable soil material with a minimum fines content of 30% and maximum particle size of 130 mm (refer to Section 2.2) that is excavated, transported, moisture conditioned, compacted and tested according to the performance standards in the Specification.
Unit 2 Select Fill	Clay rich soil sourced by the Contactor with a minimum fines content of 30% and a maximum particle size of 37.5 mm (refer to Section 2.3) that is excavated, transported, placed, moisture conditioned, compacted and tested according to the performance standards in the Specification.
Unit 3 Topsoil	Soil to establish and maintain grass cover that is placed according to the Specification.
Granular Materials	
Unit 4 Subgrade Drainage Aggregate	Low fines content aggregate.
Unit 5 Sump Drainage Aggregate	Low fines content aggregate.
Unit 6 Cement Stabilised Sand	5% cement stabilised sand pre-mixed at a concrete batch plant of type approved by the Superintendent.
Unit 7 Rip Rap	D50 of 100 mm for erosion protection.
Unit 8 Pavement Material	Recently quarried Type II Gravel in accordance with Northern Territory Government's Department of Infrastructure Technical Specification for Pavement Materials. The Unit 8 Pavement Material is to provide erosion protection and a surface for controlled traffic access on selected portions of the crests of the ponds, as indicated on the Drawings.
Geosynthetics	
Unit 9 Separation Geotextile	Medium to separate materials.
Unit 10 BGM	Bituminous Geomembrane liner (BGM)
Unit 11 Geonet	Continuous leakage collection layer installed across the pond footprint.
Unit 12 HDPE Geomembrane	2.0 mm thick High Density Polyethylene (HDPE) geomembrane to be installed by the Geosynthetics Installer.
Unit 13 Cushion Geotextile	Medium to protect underlying/overlying geosynthetics materials.
Unit 21 Geocomposite Drain	Continuous groundwater seepage collection layer installed on the internal batters around the pond up to existing ground level
Pipes	
Unit 15 Groundwater Collection Pipe	Perforated Nominal Diameter 90 mm pipe approved by the Superintendent, to be installed by the Pipe Installer. Used to collect and convey groundwater seepage.
Unit 16 Solid Drainage Pipe	Solid Nominal Diameter 110 mm pipe approved by the Superintendent, to be installed by the Pipe Installer. Used to convey groundwater seepage collected in the system to the outlet location.
Unit 17 Riser Pipe	Nominal Diameter 450 mm HDPE PE100 pipe to be installed by the Pipe Installer. Used for the seepage extraction and leachate extraction systems.

Unit	Description
Unit 18 Leachate Inlet Pipe	Pipe installed above the liner system to allow leachate discharge into the pond (below the floating cover).
Other Materials	
Unit 14 – Erosion Protection	Hydromulch mix placed on the outer batters of leachate storage pond, stormwater drains and disturbed areas agreed between the Principal and the Contractor.
Unit 19 Overflow Pipe	Solid Nominal Diameter 200 mm pipe approved by the Superintendent, to be installed by the Pipe Installer. Used to convey emergency overflow from the leachate storage
Unit 20 – Concrete	32 MPa concrete (with steel reinforcement where required).

1.3 Drawing List

The design is presented in the following drawings.

Table 3: Drawing List

Drawing number	Drawing title
D001	Locality Plan and Drawing Index
D002	Existing Conditions Plan
D003	Earthworks Cut & Fill Plan
D004	Groundwater Drainage Plan
D005	General Arrangement Plan
D006	Long Sections – Leachate Storage Pond
D007	Long Sections – Spillway and Groundwater Drainage
D008	Typical Details - Embankment
D009	Plan and Details – Emergency Leachate Overflow System
D010	Typical Details – Liner and Drainage
D011	Plan and Sections – Sump and Riser Pipes
D012	Typical Details – Sump and Riser Pipes
D013	Plan and Section – Stormwater Spillway
D014	Typical Details – Stormwater Spillway
D015	Plan and Typical Details – Inlet Pipe
D016	Plan, Section and Typical Details – Diversion Drain

1.4 Scope of Works

The Works involves the construction of one leachate pond at the site. Drawing D001 provides a locality plan and Drawing D002 presents the footprint of leachate pond relative to the Landfill Site.

Table 4 summarises the Works presented on the Drawing Set referenced in Section 1.3 to be executed and completed by the Contractor and provides a suggested sequence of construction for each part of the Works.

The scope shall include for material supply and delivery, construction, testing, reporting of “work as executed” and quality assurance information, and commissioning of the works.

Table 4: Works Description and Suggested Sequence of Construction

Works Part	Suggested Sequence of Construction
Preparation	Prepare and implement Works control measures: Workplace health, safety and environmental management planning. Construction programs. Construction management plans. Construction method statements. Supply and setup site management infrastructure, including access roads, signage, traffic management, Contractor’s facilities, erosion and sediment control and surface water management.
Surface water diversion	Construct diversion drain along western toe of the pond to collect runoff from the catchment west of the pond and drain to the north around the pond. Construct swale drain along southern toe of pond to collect runoff from the catchment south of the pond and drain to the east around the pond.
Bulk Earthworks	Note that construction of the groundwater drainage system prior to completion of the perimeter embankments and access ramps may be preferable to avoid the need for deep excavation for the groundwater drainage pipes and trenches under the embankments, as indicated in the suggested sequence of construction provided below. Prepare subgrade surface: Clear and grub work area, including removal of vegetation and topsoil. Strip granular laterite soils and sand lenses to expose acceptable embankment foundation materials. Excavate to grades and levels indicated on the drawings. Proof roll exposed surfaces prior to fill placement. Stockpile excavated materials by material type for potential re-use, as required. Construct perimeter embankments and access ramps: Construct access ramps as approved by Superintendent with consideration of access track location. Construct perimeter embankments with Unit 1 Engineered Fill in accordance with the Drawings. Proof roll subgrade surface.
Groundwater Drainage System	Excavate groundwater drainage trenches to the lines and levels shown on the drawings. Construct the groundwater drainage system: Place Unit 9 Separation Geotextile, Unit 15 Groundwater Collection Pipe and Unit 4 Subgrade Drainage Aggregate in groundwater drainage trenches. Place Unit 21 Geocomposite Drain on the internal excavated batters and tie-in to the groundwater drainage trenches. Construct the gravel groundwater drainage blanket with Unit 9 Separation Geotextile and Unit 4 Subgrade Drainage Aggregate.
Emergency overflow system	Excavate trench for overflow weir box and Unit 19 Overflow Pipe. Construct concrete overflow weir box, FRP Grate and Unit 19 Overflow Pipe connection. Backfill pipe with Unit 6 Cement Stabilised Sand.
External batter protection	Construct external batter protection: Place Unit 3 Topsoil and Unit 14 Erosion Protection on areas indicated in the Drawings.

Works Part	Suggested Sequence of Construction
	Due to the short timeframe between anticipated completion of the leachate ponds and onset of the wet season, progressive construction of external batter protection (e.g. as perimeter embankments are constructed) is recommended to establish vegetation prior to onset of the wet season, and protect constructed areas during wet weather and high wind conditions.
Secondary Liner	Construct the pond liners: 200 mm thick Unit 2 Select Fill, overlain by Unit 10 BGM, Unit 11 Geonet and Unit 12 HDPE Geomembrane installation.
Leakage Collection System	Install Unit 11 Geonet: Construct Leakage collection sump and riser: Install Unit 17 Riser Pipe with end caps. Place Unit 5 Sump Drainage Aggregate and Unit 13 Cushion Geotextile over the Unit 17 Riser Pipe in accordance with the Drawings.
Primary Liner	Install Unit 12 HDPE Geomembrane
Leachate Extraction Sump and Riser	Construct the pond sumps and risers: Construct concrete slabs and headwall for Unit 17 Riser Pipe placement at the crest of embankments. Place Unit 13 Cushion Geotextile over Unit 12 HDPE Geomembrane on the internal batter and in the sump along the alignment of the Unit 17 Riser Pipe. Install Unit 17 Riser Pipe with end caps. Place Unit 5 Sump Drainage Aggregate over the Unit 17 Riser Pipe in accordance with the Drawings. Place the riser pipe in the pre-cast concrete box penetration. Note the sump is not depressurised by the groundwater drainage system and therefore groundwater could cause potential constructability issues associated with pressure underneath the liner in the sump. The Contractor shall consider construction of the sump components in one sequence to provide the ballast weight from the sump drainage aggregate and the risk of high seasonal groundwater levels in scheduling the works.
Anchor Trench	Secure Unit 10 BGM, Unit 11 Geonet and Unit 12 HDPE Geomembrane in the anchor trenches. The timing and method of backfill of the anchor trench shall be approved by the Superintendent noting that the backfill may need to be staged to allow for installation of the floating cover. The permanent backfill of the anchor trenches shall be using Unit 6 Cement Stabilised Sand.
External Spillway	Construct the external spillway which include the spillway, chute, dissipation basin and channel. Construct concrete slab. Place Unit 7 Rip Rap over Unit 9 Separation Geotextile in the external spillway. Place rock mattress as part of dissipation basin.
Leachate Inlet pipe	Install the leachate inlet pipe: Construct concrete footing and headwall for connection with leachate inlet pipe. Install additional panel of HDPE geomembrane at the toe as shown in the Drawings. Install Unit 13 Cushion Geotextile. Install the leachate inlet pipe including end caps. Place Unit 5 Sump Drainage Aggregate over leachate inlet pipe and encapsulate in Unit 13 Cushion Geotextile.
Crest access	Construct crest access: Place and compact Unit 8 Pavement Material. Construct post and chain marker fence at minimum offset from anchor trench as indicated in the Drawings.

Works Part	Suggested Sequence of Construction
	Install guide posts.

1.5 Hold Points

Hold Points for the Works are summarised in Table 5.

Table 5: Summary of Hold Points

Hold Point Reference	Item	Description
HP1	Construction Management Plan	The Contractor shall submit a Construction Management Plan (CMP) to the Superintendent for review and approval at least 5 working days prior to the commencement of any works on site. The CMP shall conform to the requirements detailed in Section 1.13 of the Specification. Physical works shall not commence on site until this Hold Point is released by the Superintendent.
HP2	Material Quality Assurance	The Contractor shall present documentation that demonstrates that each of the material units listed in Table 2 conform with the Specification to the Superintendent for review and approval prior to delivery to the Site and prior to use on site. Use of each material shall not commence until this Hold Point has been released for that material.
HP3	Method Statement for Excavation, subgrade preparation and construction of the groundwater drainage system	The Contractor shall submit a Method Statement for Excavation, subgrade preparation and construction of the groundwater drainage system to the Superintendent for review and approval at least 2 working days prior to the commencement of earthworks on site. The Method Statement shall conform to the requirements detailed in Section 1.26 of the Specification. Earthworks shall not commence on site until this Hold Point is released by the Superintendent.
HP4	Survey of excavated surface	The Contractor shall submit a survey of the excavated subgrade surface, prepared in accordance with requirements of Section 1.12, to the Superintendent for review and approval prior to commencing construction over the subgrade. Placement of overlying materials shall not commence until this Hold Point is released by the Superintendent.
HP5	Survey of Unit 1 Engineered Fill and Unit 2 Select Fill	The Contractor shall submit a survey, prepared in accordance with requirements of Section 1.12, of the constructed Unit 1 Engineered Fill and Unit 2 Select Fill surface to the Superintendent for review and approval prior to commencing construction of overlying unit materials. Placement of overlying unit materials shall not commence until this Hold Point is released by the Superintendent.
HP6	Construction Compliance Testing of Unit 1 Engineered Fill, and Unit 2 Select Fill	The Contractor shall submit documentation to the Superintendent, prepared by a NATA Laboratory, demonstrating that Unit 1 Engineered Fill and Unit 2 Select Fill complies with the specified criteria and testing requirements for material properties, compaction ratio and moisture content. Placement of overlying unit materials shall not commence until this Hold Point is released by the Superintendent.

Hold Point Reference	Item	Description
HP7	Survey of excavated groundwater drainage trenches, groundwater drainage pipes and groundwater drainage blanket	The Contractor shall submit a survey, prepared in accordance with requirements of Section 1.12, of the excavated groundwater drainage trenches, the placed Unit 15 Groundwater Collection Pipe and Unit 16 Solid Drainage Pipe, and the constructed Unit 4 Subgrade Drainage Aggregate to the Superintendent for review and approval prior to placing overlying materials. Placement of overlying materials shall not commence until this Hold Point is released by the Superintendent.
HP8	Method Statement for Construction of pond liners	The Contractor shall submit a Method Statement for Construction of pond liners to the Superintendent for review and approval prior to the commencement of construction of pond liners on site. The Method Statement shall conform to the requirements detailed in Section 1.26 of the Specification (including the requirement for provision of geosynthetic panel layout drawings). Construction of pond liners shall not commence on site until this Hold Point is released by the Superintendent.
HP9	Survey of excavated anchor trenches	The Contractor shall submit a survey, prepared in accordance with requirements of Section 1.12, of the excavated anchor trenches to the Superintendent prior to placing overlying materials. Backfill of the anchor trenches shall not commence until this Hold Point is released by the Superintendent.
HP10	Unit 10 BGM, Unit 11 Geonet and Unit 12 HDPE Geomembrane construction information	The Contractor shall submit a survey, prepared in accordance with requirements of Section 1.12, and as-built panel layout records, of the constructed Unit 10 BGM, Unit 11 Geonet and Unit 12 HDPE Geomembrane on the pond floors and batters, along with quality assurance documentation for the materials and installation, to the Superintendent for review and approval prior to placing overlying materials. Placement of overlying materials shall not commence until this Hold Point is released by the Superintendent.
HP11	Method Statement for Construction of sumps and risers	The Contractor shall submit a Method Statement for Construction of sumps and risers to the Superintendent for review and approval at least 2 working days prior to the commencement of construction of sumps and risers on site. The Method Statement shall conform to the requirements detailed in Section 1.26 of the Specification. Construction of sumps and risers shall not commence on site until this Hold Point is released by the Superintendent.
HP12	Survey of placed Unit 17 Riser Pipe	The Contractor shall submit a survey, prepared in accordance with requirements of Section 1.12, of the constructed Unit 17 Riser Pipe to the Superintendent prior to placing overlying materials. Placement of overlying materials shall not commence until this Hold Point is released by the Superintendent.
HP13	Method Statement for Construction of Unit 18 – Leachate Inlet Pipe	The Contractor shall submit a Method Statement for Construction of leachate inlet pipe to the Superintendent for review and approval at least 2 working days prior to the commencement of construction of sumps and risers on site. The Method Statement shall conform to the requirements detailed in Section 1.26 of the Specification. Construction of sumps and risers shall not commence on site until this Hold Point is released by the Superintendent.
HP14	Survey of placed Unit 18 Leachate Inlet Pipe	The Contractor shall submit a survey, prepared in accordance with requirements of Section 1.12, of the constructed Unit 18 Leachate Inlet Pipe to the Superintendent prior to placing overlying materials.

Hold Point Reference	Item	Description
		Placement of overlying materials shall not commence until this Hold Point is released by the Superintendent.
HP15	Method Statement for Construction of crest access roads and safety barriers	The Contractor shall submit a Method Statement for Construction of crest access roads and safety barriers to the Superintendent for review and approval at least 2 working days prior to the commencement of construction of the crest access roads on site. The Method Statement shall conform to the requirements detailed in Section 1.26 of the Specification. Construction of crest access roads shall not commence on site until this Hold Point is released by the Superintendent.
HP16	Method Statement for Construction of spillways	The Contractor shall submit a Method Statement for Construction of spillways to the Superintendent for review and approval at least 2 working days prior to the commencement of construction of the spillways on site. The Method Statement shall conform to the requirements detailed in Section 1.26 of the Specification. Construction of the spillways shall not commence on site until this Hold Point is released by the Superintendent.
HP17	Survey of excavated base of spillways	The Contractor shall submit a survey, prepared in accordance with requirements of Section 1.12, of the excavated base of the spillways to the Superintendent for review and approval prior to placing overlying materials. Placement of overlying materials shall not commence until this Hold Point is released by the Superintendent.
HP18	Survey of constructed spillways	The Contractor shall submit a survey, prepared in accordance with requirements of Section 1.12, of the constructed spillways to the Superintendent prior to placing overlying materials. Placement of overlying materials shall not commence until this Hold Point is released by the Superintendent.
HP19	Survey of overflow weir box and outlet pipe	The Contractor shall submit a survey, prepared in accordance with requirements of Section 1.12, of the constructed overflow weir box to the Superintendent prior to placing overlying materials. Placement of overlying materials shall not commence until this Hold Point is released by the Superintendent.
HP20	Method Statement for Construction of external batter protection	The Contractor shall submit a Method Statement for Construction of external batter protection to the Superintendent for review and approval at least 2 working days prior to the commencement of construction of the external batter protection. The Method Statement shall conform to the requirements detailed in Section 1.26 of the Specification. Construction of the external batter protection shall not commence on site until this Hold Point is released by the Superintendent.
HP21	Survey of Unit 3 Topsoil	The Contractor shall submit a survey, prepared in accordance with requirements of Section 1.12, of the constructed Unit 3 Topsoil surface to the Superintendent for review and approval prior to commencing construction of overlying unit materials. Placement of overlying unit materials shall not commence until this Hold Point is released by the Superintendent.
HP22	Unit 14 Erosion Protection	The Superintendent shall inspect the vegetation coverage for conformance with the technical specification. The subjects works shall not be considered completed until approved by the Superintendent.

Hold Point Reference	Item	Description
HP23	Survey of excavated stormwater drains	The Contractor shall submit a survey, prepared in accordance with requirements of Section 1.12, of the excavated base of the stormwater drains to the Superintendent prior to placing overlying materials. Placement of overlying materials shall not commence until this Hold Point is released by the Superintendent.
HP24	Survey of constructed stormwater drains	The Contractor shall submit a survey, prepared in accordance with requirements of Section 1.12, of the constructed stormwater drains to the Superintendent prior to placing overlying materials. Placement of overlying materials shall not commence until this Hold Point is released by the Superintendent.

1.6 Inspection Points

Inspection Points for the Works are summarised in Table 6.

Table 6: Summary of Inspection Points

Inspection Point Reference	Item	Description
IP1	Subgrade Surfaces	The Superintendent shall inspect and approve all subgrade surfaces prior to the placement of overlying material layers.
IP2	Inspection of Unit 2 Select Fill placement and compaction	The GITA is to be present when Unit 2 Select Fill is being placed and compacted.
IP3	Inspection of pipe perforations	The Superintendent shall inspect and approve completed perforations of Unit 15 Groundwater Collection Pipe and Unit 17 Riser Pipe before installation.
IP4	Inspection of pipe installations	The Superintendent shall inspect and approve completed installation of Unit 15 Groundwater Collection Pipe, Unit 16 Solid Drainage Pipe and Unit 17 Riser Pipe before placement of overlying / backfill materials.
IP5	Unit 4 Subgrade Drainage Aggregate, Unit 9 Separation Geotextile and Unit 21 Geocomposite Drain	The Superintendent shall inspect and approve the construction of Unit 4 Subgrade Drainage Aggregate, Unit 13 Cushion Geotextile over the Unit 21 Geocomposite Drain prior to placing overlying materials.
IP6	Geosynthetic material inspections	The Superintendent shall inspect and approve geosynthetic materials delivered to the Site, including cross-referencing each roll against material testing certificates. The GITA may also sample and undertake independent testing of any materials delivered to the Site.
IP7	Inspection of Unit 10 BGM, Unit 11 Geonet and Unit 12 HDPE Geomembrane installation	The GITA is to be present when Unit 10 BGM, Unit 11 Geonet and Unit 12 HDPE Geomembrane is being installed.
IP8	Inspection of overflow weir box and outlet pipe	The Superintendent shall inspect and approve the construction of the concrete weir box and outlet pipe to placing overlying materials. Placement of overlying materials shall not commence until this Hold Point is released by the Superintendent.
IP9	Other geosynthetic material installation	The Superintendent shall inspect and approve completed installation of Unit 9 Separation Geotextile and Unit 13 Cushion Geotextile prior to placement of overlying material layers.
IP10	Unit 5 Sump Drainage Aggregate and Unit 13 Cushion Geotextile	The Superintendent shall inspect and approve the construction of Unit 5 Sump Drainage Aggregate and Unit 13 Cushion Geotextile as part of the Unit 17 Riser Pipe construction prior to placing overlying materials.
IP11	Reinforced Concrete Structures	The Superintendent shall inspect and approve all installed steel reinforcement prior to placement of concrete.
IP12	Leachate pond anchor trench	The Superintendent shall inspect and approve the anchor trench subgrade prior to placement of Unit 10 BGM, Unit 12 HDPE Geomembrane and Unit 6 Cement Stabilised Sand for trench backfill.

Inspection Point Reference	Item	Description
IP13	Spillway excavation	The Superintendent shall inspect the geometry of the spillways (as well as approved survey – refer to HP15) prior to installing materials in the spillways.
IP14	Stormwater drain excavation	The Superintendent shall inspect the geometry of the stormwater drains (as well as approved survey – refer to HP19) prior to installing materials in the spillways.

1.7 Information Supplied to the Contractor

The following information will be supplied to the Contractor:

- Issued for Construction Drawings in digital pdf. format and selected digital CADD files.
- Digital dxf file of 3D CADD surface for selected top of design surfaces.
- Available groundwater and geotechnical information reports relating to ground conditions in the vicinity of the Site.

1.8 Existing Services

The Client shall provide the Site clear of all services and infrastructure.

The Contractor shall take all precautions necessary to prevent damage to known fencing, drainage structures, telephone and power lines, stormwater infrastructure, landfill gas and leachate management infrastructure, water mains and services and/or other infrastructure during the performance of the Works.

At the direction of the Superintendent, any damage caused by the Contractor to known services and infrastructure shall be made good by the Contractor and at the expense of the Contractor.

The Contractor shall immediately notify the Superintendent, the Service Authorities or other persons concerned (as appropriate) of any damage caused to existing services.

Negligence by the Contractor in managing and supervising the protection of known services shall be sufficient cause for the Superintendent to direct the Contractor to remove relevant persons from the Site or from any activity connected with the Works.

1.9 Site Access

The Contractor shall coordinate with the Principal and Veolia to receive formal possession and handover of the Pond Work area, and for access to parts of the Site remaining under Veolia control. The Contractor shall not disrupt existing Site operations during construction of the Works. The Contractor shall coordinate with Veolia and the Principal about acceptable working hours at the site.

The Contractor must comply with the Client's requirements for site access, vehicle traffic, security, access to the water supply, temporary stormwater management and material stockpile locations. This includes, but is not limited to locking of gates, keeping unauthorised persons out of the Works site, shared access for the GITA and others that may be engaged by the Client to carry out works at the Site, use and maintenance of access roads and the traffic management plan that considers all vehicles accessing the site.

The Contractor shall prepare a management plan to manage and coordinate access and traffic for approval by the Superintendent.

The location and management of proposed material stockpiles shall be approved by the Superintendent.

1.10 Traffic over Constructed Works

Construction traffic over geosynthetic and drainage layer materials is not permitted, except where special arrangements are put in place and agreed with the Superintendent and the GITA. General traffic limitations are as follows:

i) BGM liner: Controlled vehicle access by a 4.5 tonne Manitou/telehandler (or equivalent approved by the Superintendent) over deployed BGM for installation of Geomembrane liner only will only be permitted based on a successful field trial that demonstrates that the integrity of the deployed BGM, Unit 2 Select Fill or underlying materials are not compromised under the proposed vehicle loading. The field trial must be observed by the Superintendent and results assessed in consultation with the Designer. The proposed methodology for access over the deployed BGM must be submitted to the Superintendent based on outcomes of the field trial; the method shall include measures to minimise vehicle access movements over the deployed BGM as part of construction of overlying materials.

   Foot traffic over deployed BGM shall comply with the requirements documented in the geosynthetics installation plan or other suitable types as approved by the Superintendent.

ii) Geomembrane liner: No vehicle access over deployed Geomembrane, only careful foot traffic that comply with the requirements documented in the geosynthetics installation approved by the Superintendent.

iii) Other geosynthetic layers: No vehicle access over deployed geosynthetic materials, only foot traffic.

iv) Groundwater drainage pipework: No vehicle access over pipe, only foot traffic, unless acceptable cover in place.

1.11 Layout of Work Zones

The layout of work zones as shown on drawings shall be taken as diagrammatic only and all measurements and other information required to carry out the work under the contract shall be obtained by the Contractor on site. Details of site survey are presented below. No claims arising from failure to obtain measurements and other information on site will be accepted.

1.12 Survey

The Contractor shall be responsible for setting out the Works and maintaining all benchmarks and set out points needed for the construction of the Works, as well as measurements for payment and “work as executed” drawings. Survey work shall be performed by an appropriately experienced and licensed surveyor.

The Contractor shall ensure that survey is undertaken on all surfaces required to allow volume or area calculations for payment in accordance with the contract. The Contractor shall ensure the nominated surveyor provides volumetric calculations and survey information to satisfy the quality assurance requirements, prepare “work as executed” drawings, and to justify all claims and measurements for payment.

The Contractor shall include methodologies for the surveys in relevant Method Statements to be provided to the Superintendent as detailed in Section 1.26. Methodologies shall be approved by the Superintendent prior to survey works commencing. Methodologies shall consider the scope and method of survey, including methodology for the location of data points and assessment of the thickness of subgrade and fill layers, granular layers and drainage layers.

Surveys shall be carried out at maximum 10 m intervals and shall pick up the crest and valley lines and all changes in grade. The Contractor shall prepare and issue drawings showing the as-built Works listed above. The results of the surveys shall be presented to the Superintendent within one week of completing construction of each of the components listed below.

The following surveys are deemed necessary for completion of the Works. Other surveys may be required for construction and measurement for payment.

- Survey of the surface water diversion drain and swale drain, including the invert and crests of the drain.
- Survey after excavation of the groundwater drainage trenches. Survey shall include the invert and crest of the trenches.
- Survey of the crown and alignment of Unit 15 Groundwater Collection Pipe and Unit 16 Solid Drainage Pipe.
- Survey after placement of Unit 4 Subgrade Drainage Aggregate. Survey shall include the extent and surface elevation of the groundwater drainage blanket.
- Survey prior to and after placement of each of Unit 1 Engineered Fill in the perimeter embankments and access ramp.
- Survey prior to and after construction of Unit 2 Select Fill on the floor and batter of the pond. The top of the Unit 2 Select Fill shall again be surveyed prior to installation of Unit 10 BGM if the Unit 2 Select Fill is to be reworked due to degradation (e.g. cracking and erosion).
- Survey of the extent of the Unit 10 BGM, Unit 11 Geonet and Unit 12 HDPE Geomembrane.
- Survey of the invert and alignment of the inside and outside edges at the base of all anchor trenches, and of the inside crest edges of all anchor trenches.
- Survey of the invert of the overflow weir box.
- Survey of the crown and alignment of the Unit 19 Overflow Pipe in the overflow weir pipe.
- Survey of the crown and alignment of the Unit 17 Riser Pipes in the sump and at the crest of the ponds.
- Survey of the placed Unit 5 Sump Drainage Aggregate over the Unit 17 Riser Pipes in the sump and on the internal batter along the alignment of the pipes.
- Survey of the invert and alignment of the leachate inlet pipes.
- Survey of the external spillway prior to and after placement of Unit 7 Riprap.

1.12.1 Tolerances and spatial compliance

The final surface finish of earthworks, geosynthetics and drainage pipes shall be within the following tolerances:

- Subgrade elevations of Unit 1 Engineered Fill on the pond floors and embankments shall have a maximum deviation of -50 mm to +50 mm, but minimum grades must be achieved.
- Thickness of Unit 4 Subgrade Drainage Aggregate shall have a tolerance of –0 mm and +50 mm.
- For construction of the Unit 2 Select Fill for the Pond Liner:
  - The minimum completed thickness shall be 200 mm, with a tolerance of –0 to +50 mm
  - The final surface shall be smooth and graded evenly and constructed to achieve the grades shown on the drawings, with a tolerance of -0% to +0.2%.
- The specified grade of the top of Unit 2 Select Fill and the invert of the drainage pipes is the minimum grade. The grade may not be flatter at any location within the Works. The Superintendent may instruct the

Contractor to improve the grades where they are outside the specified tolerances and also deemed as being not appropriate for the Works.

- Embankment crest elevation shall a maximum deviation of –0 mm to +50 mm.
- For construction of the Unit 8 Pavement Material:
  - The minimum completed thickness shall be 200 mm, with a tolerance of –0 to +50 mm
  - The final surface shall be smooth and graded evenly and constructed to achieve the grades shown on the drawings, with a tolerance of -0% to +0.2%.
- The external embankment batter slopes shall be uniform with no concave sections. The maximum misalignment shall be 75 mm over any 3 m length of slope.
- The spillway invert level shall have a maximum deviation from design elevation of -20 mm to +20 mm.
- Pipework shall be installed within -100 mm to +100 mm of the horizontal alignment shown on the drawings. The pipework shall grade within 1/20th of the specified grade.
- The overflow weir box invert shall have a maximum deviation from design elevation of -0 mm to +20 mm.
- The stormwater diversion drain shall be graded within 1/20th of the specified grade.

1.13 Construction Management Plan

The Contractor shall, within one week of acceptance of the Tender, prepare a Construction Management Plan (CMP) for the site and submit it to the Superintendent for approval at least 5 working days prior to the commencement of the physical works. The CMP shall include the following elements and incorporate the relevant clauses of the Specification:

- Safety/Risk Management.
- Environmental Management Plan.
- Provision for Traffic.
- Quality Plan.

1.14 Safety and Risk Management

1.14.1 General

The Contractor shall comply with the Work Health and Safety legislation and regulations of the Northern Territory.

The Contractor shall be solely responsible for ensuring that wherever practicable, its employees and those of its subcontractors or others at the site are not exposed to hazards.

The Contractor shall appoint a person competent to undertake the duties of Health and Safety Officer in relation to the execution of the Works.

The Contractor shall notify the Superintendent of every work-related illness, injury and serious bodily injury which occur in respect of the execution of the Works as soon as possible but not later than twelve (12) hours after each occurrence.

1.14.2 Safety Management Plan

The Contractor may at its sole discretion carry out the Works under its existing Safety Management Plan for the Landfill Site modified as required to address the Works or shall establish, implement and maintain a documented new "Safety Management Plan" containing provision for but not limited to the following elements:

a) induction for new employees.

b) listing of competencies required for specialist work.

c) accident/incident reporting.

d) accident/incident investigation.

e) hazard identification, risk assessment and risk control including routine inspection processes.

f) plant/equipment inspection processes.

g) pre-job planning, procedural issues and JSA's (Job Safety Analyses).

h) emergency response.

i) methods of communicating and consulting with employees and transmitting new work procedures to employees.

j) hazardous substances exposure management.

k) site security.

l) purchasing/hiring controls (to avoid unknowingly bringing hazards onto the Site).

m) quantitative performance measures.

n) Material Safety Data Sheets for hazardous chemicals used on site.

Each element of the "Safety Management Plan" shall specifically address:

- The person on the Site who shall take responsibility for the successful implementation of each element.
- The hierarchical structure by which the responsibility is performed.
- The specific manner by which the element is performed.

The Safety Management Plan shall be submitted to the Principal at least one week prior to the commencement of the Works.

1.14.3 Induction Training

Employees of the Contractor and its subcontractors shall not commence work on the Site until they have been inducted. Such induction shall include:

a) hazard identification, risk assessment and risk control measures.

b) reporting of accidents and incidents – which shall include the type of events to be reported, how an event is reported and to whom the event is reported.

c) emergency procedures – which shall cover the procedure for a medical emergency and for evacuation of the Site in the event of a life-threatening situation arising.

d) personal protective equipment ("PPE") – the standard requirements for the Site.

e) lifting and manual handling skills.

f) sun protection.

g) avoidance of noise induced hearing loss.

h) location of and access to First Aid on the Site.

i) legislative framework – an employee's rights and responsibilities under the Act and Regulations.

j) Site security.

k) Traffic management.

Upon commencement of work on the Site, the Contractor shall then further induct each employee with regard to all significant hazards associated with their particular activity and area of employment on the Site and where relevant shall include the hazards associated with use of powered plant, tools and equipment.

All mobile plant and equipment operators must provide evidence of their successful completion of operator training for the plant or equipment they will be using at the site.

1.14.4 Pre-job Planning

Where legislation and codes of practice identify particular hazardous activities including work in confined spaces; asbestos removal; demolition work; excavation work; working near power lines and live conductors; working at heights, the Contractor shall prepare a Safe Work Procedure (SWP) or equivalent documentation prior to commencing that activity or work on the Site.

Hazard identification and preparation of safe work procedures at the site must also consider:

- Work on slopes.
- Work with geosynthetic materials with low friction surfaces and interfaces.
- Hazards associated with work near the existing landfill, including waste materials, leachate, landfill gas, geotechnical stability and working in the vicinity of mobile plant.
- Installation and joining of geosynthetic materials.
- Wind uplift of geosynthetic materials during installation.
- Excavation.
- Work near water containment ponds that may contain water or leachate (i.e. one pond in use prior to completion of second pond).

The Contractor shall induct its employees with regard to SWP's and shall make available "Training Session Attendance" sheets signed by each employee verifying that such induction has occurred upon request by the Superintendent.

1.14.5 Site and Public Security

The Contractor shall monitor and control, wherever practicable, the access of all persons to the Site.

The Contractor shall ensure that no unauthorised persons be allowed to access the Site without the express permission of the Client.

Authorised persons shall only enter the Site if they have been site inducted and are wearing the appropriate PPE.

1.15 Environmental Management Plan

The Contractor may at its sole discretion carry out the Works under its existing Environmental Management Plan for the Landfill Site modified as required to address the Works or shall, within one week of acceptance of the Tender, prepare a new Environmental Management Plan (EMP) for approval by the Superintendent that shall include as a minimum the following elements:

- Minimisation of land disturbance including erosion and sediment control.
- Vegetation and existing waste or cover materials shall not be disturbed or removed unless prior approval is given by the Superintendent.
- Temporary management of stormwater.
- Dust control.
- Litter control.
- Management of waste materials.
- Noise and vibration control.

1.15.1 Noise and Vibration Control

The Contractor shall, at all times, take adequate measures to control noise and vibration on the site. Ground vibrations shall not damage existing and adjacent facilities.

1.15.2 Soil Erosion

The Contractor shall, at all times, take all proper precautions to prevent soil erosion from any land used or occupied by the Contractor in the execution of the work under the contract.

1.15.3 Dust, dirt, water and fumes

The contractor shall, at all times take all appropriate precautions to prevent any nuisance occurring through discharge of dust, dirt, water and fumes and the like to any person(s) or property.

1.16 Wet Weather Mitigation Plan

The contractor shall prepare a Wet Weather Mitigation Plan for the site, which shall be approved by the Superintendent prior to commencement of the Works.

The plan shall detail all reasonable measures to reduce the negative impacts caused by wet weather which may include, but not limited to, construction delays, negative environmental impacts, damage to the liner, or health and safety

1.17 Provision for Traffic

1.17.1 Traffic Control Devices & Management

The Contractor shall supply signs, cones, lights, communication devices and any other necessary equipment and erect and maintain the same in good condition in accordance with the requirements of the safe operation of the site.

The Contractor may at its sole discretion carry out the Works under its existing Traffic Management Plan for the Landfill Site modified as required to address the Works or shall, within one week of acceptance of Tender, prepare a new traffic management plan for approval by the Superintendent. It shall consider joint access to the site by other parties and traffic associated with vehicles associated with accessing the active landfill tipping face, material handling and storage and the construction works. It shall consider traffic pathways, management and on-site communication.

1.18 Quality Assurance and Quality Systems

The Contractor may at its sole discretion carry out the Works under its existing Quality Management Plan for the Landfill Site modified as required to address the Works or shall plan, establish and operate such new quality systems as are required to provide the Client with assurance that the quality for the works meets or exceeds the requirements of the contract documents. Quality systems proposed by the Contractor shall be used as an aid to achieve compliance with the contract documents, and to document such compliance.

The Contractor shall provide the Superintendent with access to the Contractor's and any subcontractor's quality systems for the purpose of monitoring and auditing the quality of the works as required.

The Contractor shall be entirely responsible for achieving the required quality, and for demonstrating that the required quality has been achieved.

Notwithstanding any statements to the contrary in the Contractor's quality documents, no part of a quality system shall be used to pre-empt, preclude or otherwise negate either technical or any other requirement of the Contract documents, unless written approval of the amendment is received in advance from the Superintendent.

1.18.1 Quality Objectives

It shall be the Contractor's responsibility to construct the works in accordance with the Specification and to implement quality control procedures in accordance with the requirements of the contract documents and in line with the quality of the project.

To this end the Contractor shall ensure that adequate resources are allocated to the function of quality assurance.

1.18.2 Quality Plan

The Quality Plan shall define the quality standards that are to be achieved and shall detail the system procedures (management processes, checks, tests, inspections and reports) required to demonstrate that the necessary standards have been achieved.

The Quality Plan shall provide for the identification and rectification of all non-conforming or substandard work, and shall cover all Contractor and subcontractor activities, both on and off site.

The contents of the Quality Plan shall include, but not be limited to the following:

- Project Description.
- Project Organisation and Responsibilities.
- Quality System.
- Method Statement.
- Quality Control Procedures (material supply, inspection, measurement, hold points, approvals, non-conformance procedures, planning and approval and communication of corrective action).

- Reporting and resolution of complaints and notifying the Client.
- Quality Records/Documentation.
- Documentation of complaints and reporting of these to the Client.
- Other items in the Specification relating to supply and installation of materials.

1.19 Considerations for Detailed Construction Program

The Contractor's construction program shall allow for the following:

- Assessment and approval of the CMP (including health and safety management, EMP, traffic management plan, quality plan, and construction stormwater management plan), method statements and submittals by the Superintendent as outlined in the Specification.
- Review by the Designer as required by the Specification.
- Review of method statements and submittals as outlined in the Specification.
- Testing of materials and subsequent review of results by the GITA and Designer as required by the Specification.
- Timing required for inspection, sampling, testing and assessment of results by the GITA (commissioned by the Client) as indicated in the Specification.
- Construction of the floating pond covers (Design by Others).

1.20 Construction Stormwater Management

Temporary stormwater management for the Works shall be the responsibility of the Contractor and the Contractor shall address temporary stormwater management in the Method Statements required under Section 1.26.

The Contractor shall carry out the works so that stormwater will not impact on the Works, nor existing activities at the landfill site.

Management and discharge of stormwater from the Works shall be in accordance with the methodology described in the Method Statements required under Section 1.26. This includes the volume, quality and location of the proposed discharge.

1.21 Supply of Water for Construction

Water to be used for moisture conditioning earthworks materials during construction and dust suppression shall be approved by the Superintendent.

Water for construction purposes and general use is available on site on a Client-supplied (free issue) basis. The location and methodology of access to this water shall be approved by the Superintendent. The Contractor must assess availability and flow rate in relation to its proposed rate and method for construction.

Damage to the water supply infrastructure by the Contractor shall be made good at the Contractor's expense.

1.22 Geotechnical Inspection and Testing of the Work

As outlined in this document, the Contractor is responsible for the quality plan and quality assurance of the work.

Independent quality control inspections for Unit 2 Select Fill, Unit 10 BGM, Unit 11 Geonet and Unit 12 HDPE Geomembrane shall be performed by a GITA that is commissioned and directed by the Principal. This may also include independent testing organised by the GITA on materials and geomembrane seams.

1.23 Temporary Works

The Contractor shall make full allowance for the provision of all temporary works required to construct the works. Temporary works shall include, but not be limited to:

- Maintenance of drainage channels, tracks and roads.
- Erection of barriers.
- Ramps.
- Erosion and sediment controls.
- Site preparation for storing, handling or processing materials to be used in the works.
- Temporary stockpiling of materials.
- Traffic provisions.
- Temporary fencing as necessary to delineate work area limits where there is an interface with existing activities at the landfill site and as needed for safety.
- Placement of temporary ballast over geosynthetic materials as required during construction.

1.24 Manufacture and Supply of Material

In addition to the requirements of any Quality System Specification, the Contractor shall provide the Superintendent upon request full particulars of the mode and place of manufacture and source of supply and the performance capacities and such other information as the Superintendent considers necessary in respect of any of the material, machinery or other equipment to be used in connection with the Contract. The Contractor shall, before it arranges manufacture off site of any works, materials or fabricated material to be used in connection with the Contract, give the Superintendent reasonable written notice of its intention to do so.

1.25 Non-Conformance

If the Contractor discovers material or work which is not in accordance with the Contract, the Contractor shall promptly initiate the non-conformance procedures detailed in the Quality Plan. If the Contractor proposes a disposition of any non-conforming materials or work which varies the requirements of the Contract, such a proposal shall be submitted in writing to the Superintendent whose decision on the proposal shall be obtained in writing before the non-conforming material or work is covered up or incorporated into the works, or is the subject of any other disposition.

1.26 Method Statements

1.26.1 Excavation, subgrade preparation and construction of the groundwater drainage system

Details of the Contractor's proposed method for excavation, subgrade preparation and construction of the groundwater drainage system shall be submitted to the Superintendent for comment and approval at least 2 working days before earthworks commence on site. The method statement shall consider the following:

- Management of safety, including safe excavation of groundwater drainage trenches which may be at depths of more than statutory requirements for below ground level works in some locations.

- Removal of vegetation, topsoil and laterite materials.
- Excavation of soil and weathered rock, management of excavated material and re-use of materials.
- Excavation, identification, separation, stockpiling and placement of site-won soil units.
- Material supply, quality assurance and storage of Unit 4 Subgrade Drainage Aggregate, Unit 15 Groundwater Collection Pipes, Unit 16 Solid Drainage Pipe and Unit 9 Separation Geotextile.
- Method of moisture conditioning, site access, material placement and compaction for earthworks materials.
- Layer thickness control and survey.
- Supply, fabrication and installation of the Unit 15 Groundwater Collection Pipes and Unit 16 Solid Drainage Pipe.
- Construction quality assurance.
- Trimming and final surface preparation.
- Construction of the groundwater drainage system.
- Panel layout, overlaps, deployment and temporary ballast of Unit 9 Separation Geotextile.
- Temporary stormwater management.

1.26.2 Construction of pond liners

Details of the Contractor's proposed method for construction of the pond liners shall be submitted to the Superintendent for comment and approval at least 5 days before Works commence on site. The method statement shall consider the following:

- Management of safety.
- Material supply, quality assurance and storage of Unit 2 Select Fill, Unit 10 BGM, Unit 11 Geonet, Unit 12 HDPE Geomembrane and Unit 18 Emergency Ladder.
- Method of moisture conditioning, material placement, compaction and layer thickness for construction of Unit 2 Select Fill on the pond floors and internal batters.
- Thickness control and survey.
- Construction quality assurance.
- Trimming and final surface preparation.
- Schedule to carry out the trimming, final surface preparation and survey of the Unit 2 Select Fill on the pond floors and internal batters, and subsequent placement of the overlying materials.
- Panel layout, overlaps, deployment and temporary ballast of Unit 10 BGM, Unit 11 Geonet and Unit 12 HDPE Geomembrane. This must include a layout plan showing layout and sequence of installation for the geosynthetics and locations of overlaps.
- CQA testing of the Unit 12 HDPE Geomembrane seams.
- Timing and methodology for the anchor trench excavation and backfill, including securing of Unit 18 Emergency Ladders in the anchor trenches.

- Temporary stormwater management.

1.26.3 Construction of sumps and risers

Details of the Contractor's proposed method for construction of the pond sumps and risers shall be submitted to the Superintendent for comment and approval at least 2 days before Works commence on site. The method statement shall consider the following:

- Management of safety.
- Material supply, quality assurance and storage of Unit 17 Riser Pipe, Unit 13 Cushion Geotextile, Unit 5 Sump Drainage Aggregate, and Unit 20 Concrete.
- Survey.
- Construction quality assurance.
- Trimming and final surface preparation.
- Fabrication of the Unit 17 Riser Pipe.
- Positioning and securing the Unit 17 Riser Pipe with Unit 20 Concrete base and wingwalls.
- Placement of Unit 13 Cushion Geotextile under the Unit 5 Sump Drainage Aggregate.
- Placement of Unit 17 Riser Pipe and Unit 5 Sump Drainage Aggregate.
- Placement of the Unit 13 Cushion Geotextile overlying the gravel where shown.
- Protection of the integrity of completed portions of the Works, including the Unit 12 HDPE Geomembrane.
- Temporary stormwater management.

1.26.4 Construction of crest access roads

Details of the Contractor's proposed method for construction of access roads on the crest of the ponds shall be submitted to the Superintendent for comment and approval at least 2 days before Works commence on site. The method statement shall consider the following:

- Management of safety.
- Access.
- Material supply, quality assurance and storage of Unit 8 Pavement Material and Unit 20 Concrete.
- Survey.
- Construction quality assurance.
- Placement and compaction of Unit 8 Pavement Material.
- Thickness control of the Unit 8 Pavement Material.
- Protection of the integrity of completed portions of the Works, including management of the risk of Unit 8 Pavement Material rolling down the internal batters over the Unit 12 HDPE Geomembrane.
- Temporary stormwater management.

1.26.5 Construction of spillways

Details of the Contractor's proposed method for construction of spillways shall be submitted to the Superintendent for comment and approval at least 2 days before Works commence on site. The method statement shall consider the following:

- Management of safety.
- Material supply, quality assurance and storage of Unit 7 Riprap.
- Placement and securing of Unit 9 Separation Geotextile.
- Placement and thickness control of Unit 7 Riprap.
- Construction quality assurance.
- Survey.
- Protection of the integrity of completed portions of the Works.
- Temporary stormwater management.

1.26.6 Construction of external batter protection

Details of the Contractor's proposed method for construction of the external batter protection shall be submitted to the Superintendent for comment and approval at least 2 days before Works commence on site. The method statement shall consider the following:

- Management of safety.
- Material supply, quality assurance and storage of Unit 3 Topsoil and Unit 14 Erosion Protection.
- Method of placement and thickness control for construction of Unit 3 Topsoil.
- Method of placement of Unit 14 Erosion Protection material.
- Method of placement of Unit 9 Separation Geotextile and Unit 7 Riprap at the discharge of the crest drain.
- Construction quality assurance.
- Survey.
- Protection of the integrity of completed portions of the Works.
- Temporary stormwater management.

2.0 MATERIAL PROPERTIES, QUALITY ASSURANCE AND QUALITY CONTROL

2.1 Material Specifications and Supply

The materials supplied for the Contract shall meet the requirements of this Technical Specification. Compliance shall be demonstrated to the satisfaction of the Superintendent. The Contractor shall be responsible for the supply, storage and for protecting the materials until the Works have been completed as defined in the Contract.

If the materials are damaged while under the Contractor's care, the Contractor shall replace the materials to the same specification. If materials are to be excavated from a borrow area or stockpiles, the Contractor shall be responsible for hauling materials to the Works area.

Imported soil and granular materials shall be from virgin sources and shall be approved by the Superintendent prior to delivery to the Site.

2.2 Unit 1 Engineered Fill

2.2.1 Material Properties

Unit 1 Engineered Fill shall be sourced from on-site excavations within the construction area and/or imported to site as approved by the Superintendent prior to placement.

Unit 1 Engineered Fill material shall comprise soil conforming to the material properties specified in Table 7 or as approved by the Superintendent in accordance with a method specification following a field trial.
Materials used for final surface layers shall consider the practical considerations associated with trimming, final surface preparation, access and compatibility with overlying materials.

Table 7: Unit 1 Engineered Fill Material Properties

Property	Acceptance Criteria		Test Method	Minimum Test Frequency
	Minimum	Maximum		
Particle Size Distribution				
Maximum Particle Size Content Passing 37.5 mm Sieve Content Passing 2.36 mm Sieve Content Passing 0.075 mm Sieve	- 70% 50% 25%	130 mm - - -	AS 1289.3.6.1	1 test per 2 000 m^3 and a minimum of 2 samples per source evenly distributed throughout the material source
Other	■ Well graded material ■ Shall not be silt ■ Can be moisture conditioned ■ Can be compacted in layers to form a uniform, dense, stable fill ■ Low Susceptibility to excessive softening, erosion or instability when exposed to water ■ Free from debris, refuse, vegetation, roots, organic material and other deleterious material.			

2.2.2 Pre-construction Compliance Testing

A method specification will be implemented for the construction of the Unit 1 Engineered Fill. The method specification trials will be undertaken in the presence of the Superintendent.

As part of the method specification trial verification process the Contractor shall conduct compliance tests on samples of the placed and compacted Unit 1 Engineered Fill material as detailed in Table 7 respectively for material properties and Table 8 for compaction and moisture content. All compliance testing results shall be submitted to the Superintendent for review.

Based upon the outcomes of the compliance test results from the method specification trial, the Superintendent shall consider changes to the specified material properties of the Unit 1 Engineered Fill.

The method of sampling, test specimen preparation and results of the compliance testing shall be submitted to the Superintendent as part of the method statement for Excavation, subgrade preparation and construction of the groundwater drainage system (refer to Section 1.26) for approval at least 2 days prior to construction. The frequency of testing may be varied by the Superintendent based on the material source and test results (additional testing at Principal's cost).

2.2.3 As-built Compliance Testing

The Contractor shall undertake testing of the as-built Unit 1 Engineered Fill to demonstrate compliance with the requirements of the Specification. Compliance testing shall be carried out in a NATA Laboratory. All compliance testing results shall be submitted to the Superintendent.

Testing of Unit 1 Engineered Fill during placement and compaction shall be undertaken by the GTA commissioned by the Contractor in accordance with the provisions of AS3798 – 2007 "Guidelines on Earthworks for Commercial and Residential Developments" at Level 2 responsibility.

Compliance testing by the Contractor shall comprise field density, compaction and moisture content. The frequency of field density testing during placement of the materials shall as a minimum conform to the requirements as given in Table 8, distributed reasonably evenly throughout the full depth and area.

Table 8: Unit 1 Engineered Fill as-built compliance testing acceptance criteria

Property	Acceptance Criteria		Test Method	Minimum Test Frequency
	Minimum	Maximum		
Dry density ratio or Hilf density ratio (relative to Standard Compaction)	95%	-	AS1289 5.8.1 AS1289 2.1.1 AS1289 5.7.1	1 test per 500 m^3
Standard Optimum Moisture Content (SOMC) or Hilf moisture variation	-3%	+3%		1 test per 500 m^3

The Superintendent shall visually inspect the materials to assess for consistency with the pre-construction compliance and as-built compliance results.

The Superintendent, in consultation with the GITA, may vary the test frequency depending on the observed general performance of the Unit 1 Engineered Fill placement (additional testing at Client's cost).

In accordance with *AS 3798 Guidelines on Earthworks for Residential and Commercial Developments*, a method specification may also be adopted for quality assurance of the fill, for the case that granular materials are being used for filling and in-situ determination of dry density or laboratory determination of maximum dry density, as specified in AS1289, may not be applicable. If a method specification is to be adopted, the

Contractor shall provide details of the specification and associated field trial to the Superintendent for approval prior to full scale earthworks.

2.3 Unit 2 Select Fill

2.3.1 Material Properties

The source and type of Unit 2 Select Fill shall be sourced from on-site excavations within the construction area and/or imported to site as approved by the Superintendent. Material shall comprise soil conforming to the material properties specified in Table 9.

Table 9: Unit 2 Select Fill Material Properties

Property	Acceptance Criteria		Test Method	Minimum Test Frequency
	Minimum	Maximum		
Particle Size Distribution				
Maximum Particle Size Content Passing 2.36 mm Sieve Content Passing 0.075 mm Sieve	- 70% 30%	50 mm - -	AS 1289.3.6.1	1 test per 500 m^3 and a minimum of 2 samples per source evenly distributed throughout the material source
Atterberg Limits				
Plasticity Index Liquid Limit	10 20	- 45		1 test per 500 m^3 and a minimum of 2 samples per source evenly distributed throughout the material source
Other	■ Shall not be silt, and plots above the Casagrande A-line ■ Predominantly fine grained soil ■ Non-calcareous ■ Free of waste and organic matter			

2.3.2 Pre-construction Compliance Testing

Prior to construction, the Unit 2 Select Fill material shall be inspected and tested to confirm whether it meets the specified property values listed in the Specification. All compliance testing results shall be submitted to the Superintendent. Following receipt of compliance test results, the Superintendent and GITA shall undertake the inspection.

The Superintendent shall assess which stockpiled materials comply with the material properties required for Unit 2 Select Fill. Where there is a shortfall in the required quantities of Unit 2 Select Fill sourced from on-site excavations within the construction area, the Superintendent shall instruct the contactor to either:

- Option 1: Source material from an alternative location within the Shoal Bay Landfill Site; and/or
- Option 2: Import Unit 2 Select Fill material that meets the material properties specified in Table 9 from off-site.

Where the Contractor is instructed to undertake Option 1 or Option 2 the Contractor shall be reimbursed in accordance with the agreed schedule of rates.

The Contractor shall conduct the tests on samples of the proposed Unit 2 Select Fill material detailed in Table 9.

The method of sampling, test specimen preparation and results of the compliance testing shall be submitted to the Superintendent as part of the method statement for Excavation, subgrade preparation and construction of the groundwater drainage system (refer to Section 1.26) for approval at least one week prior to construction. The frequency of testing may be varied by the Superintendent based on the material source and test results.

2.3.3 As-built Compliance Testing

The Contractor shall undertake testing of the as-built Unit 2 Select Fill to demonstrate compliance with the requirements of the Specification. Compliance testing shall be carried out in a NATA Laboratory. All compliance testing results shall be submitted to the Superintendent.

Works shall be programmed such that an area that has been tested shall not be covered until satisfactory compliant test results are obtained. The Contractor's program shall allow time for testing to be carried out and reported to the Superintendent, allowing a reasonable timeframe for the Superintendent's review of the results.

Compliance testing by the GTA shall comprise field density, compaction and moisture content. The frequency of field density testing during placement of the materials shall as a minimum conform to the requirements as given in Table 10, distributed reasonably evenly throughout the full depth and area.

Table 10: Unit 2 Select Fill as-built compliance testing acceptance criteria, method and frequency

Property	Acceptance Criteria		Test Method	Minimum Test Frequency
	Minimum	Maximum		
Dry density ratio or Hilf density ratio (relative to Standard Compaction)	95%	-	AS1289 5.8.1 AS1289 2.1.1 AS1289 5.7.1	1 test per 500 m^3
Standard Optimum Moisture Content (SOMC) or Hilf moisture variation	-2%	+3%		1 test per 500 m^3

The minimum frequency of testing, test methods and acceptance criteria of the as-built material by the Contractor is indicated in Table 10. The Superintendent, in consultation with the GITA, may vary the test frequency depending on the observed general performance of the Unit 2 Select Fill placement (additional testing at Client's Cost).

The Superintendent shall visually inspect the materials to assess for consistency with the pre-construction compliance and as-built compliance results.

2.4 Unit 3 Topsoil

Unit 3 Topsoil shall be sourced on-site and approved by the Superintendent. The key design objective of the Unit 3 Topsoil is to support the establishment of grass cover. The intent is to re-use topsoil material stripped as part of subgrade preparation works.

2.5 Unit 4 Subgrade Drainage Aggregate

2.5.1 Material Properties

The source and type of Unit 4 Subgrade Drainage Aggregate shall be approved by the Superintendent. Material shall comprise gravel conforming to the material properties specified in Table 11.

Table 11: Unit 4 Subgrade Drainage Aggregate Material Properties

Property	Acceptance Criteria		Test Method	Minimum Test Frequency
	Minimum	Maximum		
Particle Size Distribution				
Content Passing 37.5mm Sieve Content Passing 13.2 mm Sieve Content Passing 9.5 mm Sieve Content Passing 2.36 mm Sieve	100% - - -	- 15% 10% 3%	AS 1289.3.6.1	2 samples per material source
Permeability (m/s)	-	2.7×10^{-2}	AS1289.6.7.1	1 sample per material source
Other	■ Comprises clean, hard, durable stone ■ Free of organic matter, lumps of clay or other deleterious material.			

2.5.2 Compliance Testing

Prior to delivery to site and placement in the Works, the Superintendent shall be notified in writing of the Unit 4 Subgrade Drainage Aggregate source. The Contractor shall supply information to the Superintendent regarding the source, e.g. particle size distribution and location and parent geology of the source material. The Contractor may be requested to arrange a site visit to the source quarry, to be attended by the Superintendent and the GITA, who would undertake a visual inspection of the material proposed to be used in the Works.

The Contractor shall undertake testing of the Unit 4 Subgrade Drainage Aggregate to demonstrate compliance with the requirements of the Specification. Compliance testing shall be carried out in a NATA Laboratory. All compliance testing results shall be submitted to the Superintendent.

Samples shall be collected by the GTA for testing in accordance with AS 1141.3.1 –1996 *"Methods for Sampling and Testing Aggregates Method 3.1: Sampling Aggregates."* The sample at each location will be collected using a metal 'cone' of approximately 330 mm in diameter designed to allow a sample to be collected from a depth interval of 200 mm to 300 mm of the placed materials. The sample locations shall be agreed with the Superintendent prior to sample recovery. Compliance test results shall be submitted to the Superintendent for approval prior to construction.

The minimum frequency of testing, test methods and acceptance criteria of the as-built material by the Contractor is indicated in Table 12. The Superintendent, in consultation with the GITA, may vary the test frequency depending on the observed general performance of the Unit 4 Drainage Aggregate placement (additional testing a Principal's cost).

Table 12: Frequency of Compliance Testing - Unit 4 Drainage Aggregate

Property	Test Method	Minimum Test Frequency
Particle Size Distribution	AS 1289 3.6.1	1 per 500 m^3 per material source evenly distributed throughout the Works, or a minimum of one sample

Property	Test Method	Minimum Test Frequency
Permeability	AS1289.6.71	Review QC test results[1]

[1] Designer will review quality control test result/s and assess whether independent testing is required based on the results presented.

The Superintendent shall visually inspect the materials to assess for consistency with the pre-construction compliance and as-built compliance results.

2.6 Unit 5 Sump Drainage Aggregate

The source and type of Unit 5 Sump Drainage Aggregate shall be approved by the Superintendent. Unit 5 Sump Drainage Aggregate shall comprise clean, hard, durable stone; free of organic matter, lumps of clay or other deleterious material. The aggregate particles must be rounded, subrounded or subangular in shape. The aggregate material must not contain limestone or other calcareous material that would be subject to chemical attack by the leachate.

Unit 5 Sump Drainage Aggregate shall conform to the properties specified in Table 13.

Table 13: Unit 5 Sump Drainage Aggregate Material Properties

Property	Minimum	Maximum	Test Method
Particle Size Distribution			
Maximum particle size	-	50 mm	AS 1289.3.6.1
D50 particle size	23 mm	-	
Content Passing 13.2 mm Sieve Content Passing 9.5 mm Sieve Content Passing 2.36 mm Sieve	- - -	15% 10% 3%	
Other	■ Comprises clean, hard, durable stone. ■ Free of organic matter, lumps of clay or other deleterious material. ■ Non-calcareous.		

If the aggregate shape is different to the above requirements a review of material properties must be conducted by the GITA. Alternative aggregates may be considered subject to the approval of the Designer and the Superintendent.

2.6.1 Pre-construction Compliance Testing

Prior to delivery to site and placement in the Works, the Superintendent shall be notified in writing of the Unit 5 Sump Drainage Aggregate source. The Contractor shall supply information to the Superintendent regarding the source, e.g. particle size distribution and location and parent geology of the source material. The Contractor may be requested to arrange a site visit to the source quarry, to be attended by the Superintendent, who would undertake a visual inspection of the material proposed to be used in the Works.

The Contractor shall conduct the following tests on samples of the proposed Unit 5 Sump Drainage Aggregate:

- **Particle Size Distribution** on a minimum of one sample

2.7 Unit 6 Cement Stabilised Sand

5% Cement Stabilised Sand that has been pre-mixed at a concrete batch plant and approved by the Superintendent.

2.8 Unit 7 Riprap

Unit 7 Riprap shall comprise hard durable rock fragments from commercial quarries. The material used shall comprise slightly or less weathered rock, be of high to very high strength in accordance with AS 4133 and have a minimum specific gravity of 2.6 or higher in accordance with AS1141.6. The source and type of Unit 7 Riprap shall be approved by the Superintendent. Unit 7 Riprap shall comprise nominal 100 mm particles (D50 of 100 mm).

Unit 7 Riprap shall conform to the properties specified in Table 14 and the Contractor shall provide test results on one sample.

Table 14: Unit 7 Riprap Material Properties

Property	Test Method	Value
Maximum particle size	ASTM D5519	170 mm
Median particle size (D50) (minimum)	ASTM D5519	100 mm
Ten percent particle size (minimum)	ASTM D5519	50 mm

2.9 Unit 8 Pavement Material

Unit 8 Pavement Material shall comprise Type II Gravel in accordance with Northern Territory Government's Department of Infrastructure Technical Specification for Pavement Materials. The material shall be compacted to a minimum dry density ratio of 96% relative to Modified Compaction and within 2% of optimum moisture content.

The source, type and properties of Unit 8 Pavement Material shall be approved by the Superintendent.

2.9.1 Compliance Testing

The Contractor shall undertake testing of the as-built Unit 8 Pavement Material to demonstrate compliance with the requirements of the Specification. Compliance testing shall be carried out in a NATA Laboratory. All compliance testing results shall be submitted to the Superintendent.

Compliance testing by the GTA shall comprise field density, compaction and moisture content. The frequency of field density testing during placement of the materials shall be a minimum of three tests evenly distributed around the crest of the pond.

The Superintendent shall visually inspect the materials to assess for consistency with the pre-construction compliance and as-built compliance results.

2.10 Unit 9 Separation Geotextile

A separation geotextile shall be placed over the surface of the Unit 4 Subgrade Drainage Aggregate to provide a separation layer between the aggregate and Unit 2 Select Fill. Unit 9 Separation Geotextile is also installed as part of the spillway and stormwater diversion drain erosion protection lining.

Unit 9 Separation Geotextile shall comprise polymeric yarns or fibres, seamed or drawn strands oriented into a stable network which retains its structure during handling, placement, and long-term service. Unit 9 Separation Geotextile shall be non-woven, needle punched, resin or heat bonded, manufactured from either polyester, polyethylene or polypropylene.

Tests shall be conducted by the Manufacturer on samples from various rolls within each of the supplied manufacturer's batches that represent the rolls delivered to Site at the frequencies listed on Table 15.

Upon review of the information the Superintendent shall decide whether further independent tests on samples of the supplied Unit 9 Separation Geotextile shall be required. If any test result on the MQC data sheets does not comply with the requirements of Table 15 of this Technical Specification, the Superintendent, in consultation with the GITA, may direct that additional tests are to be undertaken on that particular roll.

A sample will be taken from the non-conforming roll by the GITA and independently re-tested for the non-complying property. If the results of the retest show a further non-compliance, the roll shall be replaced. The replacement roll shall be subject to the same testing procedures as outlined in this Technical Specification.

Unit 9 Separation Geotextile shall satisfy the property values specified in Table 15.

Table 15: Unit 9 Separation Geotextile Properties

Property	Units	Separation Geotextile Value MARV*	Test	Minimum Frequency of Testing by Supplier
Grab Strength	N	> 1 480	AS 2001.2.3	1 sample per 5 000 m^2
Trapezoidal Tear	N	> 510	AS 3706.3	
CBR Burst Strength	N	> 3 950	AS 3706.4	
Permittivity	S^{-1}	≥ 0.9	AS3706.9	

*MARV = mean average roll value which represents a confidence level that at least 97.5% of the material meets or exceeds the required value.

2.11 Unit 10 Bituminous Geomembrane Liner

2.11.1 Material properties

Unit 10 – Bituminous Geomembrane (BGM) liner shall be an elastomeric BGM. The material shall be a reinforced multi-layer system comprising a layer of non-woven geotextile with an elastomeric bituminous binder, such as Coletanch or Siplast proprietary products. The BGM shall satisfy the material properties listed in Table 16.

Table 16: BGM Liner Material Property Requirements

Property	Units	Minimum Value	Test Method
Thickness	mm	≥ 3.6	ASTM D 5199
Surface mass	kg/m^2	≥ 4.3	ASTM D 3776
Resistance to tearing (1)	N	≥ 525	ASTM D 4073

Property	Units	Minimum Value	Test Method
Tensile strength (1)	kN/m	≥ 18	ASTM D 7275
Elongation (1)	%	≥ 45	ASTM D 7275
Static puncture	N	≥ 470	ASTM D 7833

1: Both machine direction and cross machine direction

The Contractor shall submit to the Superintendent manufacturer quality control (MQC) test results conducted on samples proposed for the Works. MQC data shall demonstrate the proposed material will meet the requirements of Table 16 with regards to material property values and testing frequencies. The Designer will review manufacturers information and assess whether independent testing is required based on the MQC results presented.

The GITA may recover samples from the geomembrane rolls delivered to site and arrange independent testing of the samples to confirm the material meets the requirements of the Specification.

2.12 Unit 11 Geonet

Unit 11 Geonet shall comprise a high-density polyethylene (HDPE) bi-planar or tri-planar geonet. A layer of geotextile on the bottom of the geonet may be required if installation is to occur during the day time, due to the potential softening effects of the Unit 10 - BGM from high ambient temperature conditions. The geotextile shall be non-woven, needle punched and manufactured from either polyester, polyethylene or polypropylene with a fabric weight more than 100 g/m^2.

Unit 11 Geonet must have the minimum properties specified in Table 8.

Table 17: Required properties of Unit 11 Geonet

Property	Units	Value	Test Method
Thickness at 50 kPa	mm	≥ 7.5	AS 3706.1
Density	g/cm³	≥0.94	ASTM D1505
Compressive Strength	kPa	≥500	ASTM D1621
Flow rate per unit width	L/s/m	≥0.1 L/s/m (Note 1)	ASTM D4716

1. Flow rate measured with 50 kPa confinement pressure, hydraulic gradient of 0.01, with a firm rubber bottom plate and a HDPE top plate.

2.12.1 Testing

The Contractor shall supply the GITA with manufacturer quality control (MQC) data certificates showing the testing of each property at frequencies stated in Table 17. The quality Assurance documentation must be referenced to the roll numbers to be delivered to the Works.

The Superintendent, based on advice from the GITA, shall request the Contractor to recover samples from the geosynthetic rolls delivered to site and arrange independent testing at the frequencies listed in Table 18 of the samples to confirm the material meets the specified minimum material property values. The samples to be tested shall be recovered under the supervision of the GITA and shall be from different rolls evenly distributed

through the batch delivered to site. The Superintendent is responsible for any independent testing. The results of the independent testing shall take precedence over the MQC test results.

Table 18: Required Testing of Unit 11 Geonet

Property	Test Method	Minimum Independent Testing Frequency (GITA)
HDPE Core		
Thickness at 50 kPa	AS 3706.1	10
Density	ASTM D1505	2
Flow rate per unit width	ASTM D4716	2

2.13 Unit 12 HDPE Geomembrane

Unit 12 HDPE Geomembrane shall comprise nominal 2 mm thick double-sided smooth HDPE Geomembrane. The Unit 12 HDPE Geomembrane shall be manufactured from a virgin premium-quality polythene resin and shall be designed and manufactured specifically for use in landfill leachate storage. All Unit 12 HDPE Geomembrane for the Works shall be manufactured from the same resin from the same source with the same stabiliser additives and antioxidants. The extrudate used for welding shall be manufactured from resin of the same type and source as the Unit 12 HDPE Geomembrane.

The Unit 12 HDPE Geomembrane shall not contain more than 2% clean recycled polymer by weight of the HDPE resin. In addition, the Unit 12 HDPE Geomembrane shall contain a maximum of 1% by weight of additives, fillers or extenders (not including carbon black content).

Prior to supply of geomembrane to site, the Contractor shall submit to the Superintendent a statement from the geomembrane manufacturer certifying the quality of resin used for the Works. This statement shall include, at a minimum, the name of the resin and the supplier and the maximum amount of regrind or trim material used in the manufacture of the geomembrane rolls sent to site, together with the supporting OIT test information.

The geomembrane material shall be free from holes, blisters, blemishes, striations, bubbles, roughness, undispersed raw materials, and contamination by foreign matter, to the satisfaction of the Superintendent. The edges of the liner shall be straight and free from nicks or cuts. Geomembrane rolls of poor manufactured quality, or those damaged in transport and/or handling, shall be rejected by the Superintendent and replaced. Unit 12 HDPE Geomembrane shall satisfy the specification listed in Table 19.

The Contractor shall submit to the Superintendent manufacturer quality control (MQC) test results conducted on samples proposed for the Works. MQC data shall demonstrate the proposed material will meet the requirements of Table 18 with regards to material property values and testing frequencies. The MQC data test frequencies shall meet the minimum frequencies specified in Geosynthetic Research Institute GRI – GM13 Standard Specification for ““Test Methods, Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes”.

The GITA may recover samples from the geomembrane rolls delivered to site and arrange independent testing of the samples to confirm the material meets the requirements of the Specification.

Table 19: Required properties and Testing of Unit 12 HDPE Geomembrane

Property	Units	Test Method	Value (MARV1)	Minimum Independent Testing Frequency (CQA)
Thickness (average)	mm	ASTM D 5199	≥2.0	7 tests
Minimum Thickness	mm	ASTM D 5199	>1.8	7 tests
Density (min)	g/cm3	ASTM D 1505 or ASTM D792	≥0.94	4 tests
Density (max)[2]	g/cm3	ASTM D 1505 or ASTM D792	≤0.951	4 tests
Tensile Properties (each direction)				
Strength at break	N/mm	ASTM D 6693	>53	3 tests
Elongation at break	%	ASTM D 6693	>700	3 tests
Strength at yield	N/mm	ASTM D 6693	>29	3 tests
Elongation at yield	%	ASTM D 6693	>12	3 tests
Tear Resistance	N	ASTM D 1004	>250	3 tests
Puncture Resistance	N	ASTM D 4833	>640	3 tests
Carbon Black Content	%	ASTM D 1603	2 to 3	4 tests
Carbon Black Dispersion	Rating	ASTM D 5596	100 % in Cat 1 or 2	4 tests
Oxidative Induction Time[3] Standard OIT (AND) High pressure OIT	 Minutes Minutes	 ASTM D 3895 ASTM D 5885	 >100 ≥400	Review manufacturers information[4]
Oven aging @ 85º C Standard OIT OR High pressure OIT	% retained after 90 days	ASTM D5721 ASTM D5885	 ≥55 ≥80	Review manufacturers information[4]
Environmental Tensile Load Crack Resistance	hr	ASTM D 5397	>700	Review manufacturers information[4]
UV Resistance High pressure OIT remaining after 1600 hours	%	ASTM D 5885	>50	Review manufacturers information[4]

[1] MARV = Minimum or Maximum Average Roll Value representing a confidence level of 97.5% of test results meet the required value.
[2] May be reviewed based on Environmental Tensile Load Crack Resistance results.
[3] OIT testing shall be performed on both the core and surface of the geomembrane.
[4] Designer will review manufacturers information and assess whether independent testing is required based on the MQC results presented.

2.14 Unit 13 Cushion Geotextile

Unit 13 Cushion Geotextile shall be a UV-resistant non-woven geotextile comprising new (i.e. no recycled materials) polymeric yarns or fibres, seamed or drawn strands oriented into a stable network which retains its

structure during handling and placement. Unit 13 Cushion Geotextile must be staple fibre, needle punched polyester or polypropylene and must meet the requirements of Table 20.

Table 20: Unit 13 Cushion Geotextile Material Properties

Property	Units	Value (MARV*)	Test
Thickness	mm	> 3.8	AS 3706.1
Mass per unit area	g/m^2	> 510	AS 3706.1
Trapezoidal Tear (both directions)	N	> 800	AS 3706.3
CBR Burst	N	> 6300	AS 3706.4
Puncture resistance	mm	> 4000	AS 3706.5
Grab Strength	N	> 1900	AS 2001.1.2.3
Grab Elongation	%	> 50	

*MARV = Minimum or Maximum Average Roll Value representing a confidence level of 97.5% of test results meet the required value.

Unit 13 Cushion Geotextile must be capable of withstanding direct exposure to sunlight for two months with no visible deterioration. Unit 13 Cushion Geotextile must retain at least 70% of the original strength when exposed to the test requirements of ASTM D 7238, or Australian Standard AS 3706.11.

Unit 13 Cushion Geotextile shall be free of needles or other foreign matter. The Contractor shall supply documentation from the manufacturer of the Unit 13 Cushion Geotextile to demonstrate what process is adopted in the manufacture of the geotextile to ensure that any broken needles or other sharp objects from the manufacturing process are identified and removed from the geotextile prior to dispatch of the materials to site. The Superintendent shall review the provided documentation to assess whether field sensing should be carried out to verify the absence of sharp items in the geotextile that may pose a puncture risk to the geomembrane liner.

Alternative types of geotextile may be considered subject to consultation with the designer.

2.14.1 Testing

The Contractor shall present MQC test certificates performed by the manufacturer on the actual materials that are to be delivered to site.

Upon review of the information the Superintendent shall decide whether further independent tests on samples of the supplied Unit 3 Cushion Geotextile shall be required. If any test result on the MQC data sheets does not comply with the requirements of Table 20 of this Technical Specification, the Superintendent, in consultation with the GITA, may direct that additional tests are to be undertaken on that particular roll.

A sample will be taken from the non-conforming roll by the GITA and independently re-tested for the non-complying property. If the results of the retest show a further non-compliance, the roll shall be replaced. The replacement roll shall be subject to the same testing procedures as outlined in this Technical Specification.

2.15 Unit 14 Erosion Protection

Unit 14 Erosion Protection shall comprise hydromulch by spray-on seeding with binder material using a method approved by the Superintendent and shall achieve at least 80% surface coverage within 4 weeks of application. The Contractor shall maintain the hydromulch for an establishment period of 12 weeks, including watering as required.

Seed types and application rates as follows:

- Paspalum and couch - 200kg/ha
- Millet cover crop - 100kg/ha

2.16 Unit 15 Groundwater Collection Pipe

2.16.1 Material Properties

Unit 15 Groundwater Collection Pipe shall comprise nominal diameter 90 mm perforated HDPE SDR13.6 PE100 PN12.5 pipes to conform with AS/NZS 4130:2009 'polyethylene (PE) pipes for pressure applications'. The pipe must be drilled in accordance with the details shown on Drawing D010 in the pipe manufacturer's factory or on-site using a template and all waste material must be removed prior to installation.

The prepared pipes shall be welded into a pipe string on-site using butt fusion or electrofusion welded joints and connections. Butt fusion welding shall be undertaken in accordance with ASTM F2620 – *Standard Practice for Heat Fusion Jointing of Polyethylene Pipe and Fittings* or equivalent standard. Electrofusion welding shall be undertaken in accordance with ASTM F1290:98a (2011) – *Standard Practice for Electrofusion Joining Polyolefin Pipe and Fittings* or equivalent standard. All connections, bends and specials shall be solid wall units with the same pressure class as the pipe.

2.16.2 Quality Assurance

The Contractor shall obtain and present Manufacturer's documentation related to the Unit 15 Groundwater Collection Pipe to the Superintendent that demonstrates that the materials meet the property requirements of the Specification.

The Contractor shall be responsible for the storage, joining and installation of Unit 15 Groundwater Collection Pipe delivered to Site.

All pipes and fittings delivered to site shall be marked or tagged with the following information:

- Manufacturers Name.
- Product identification including pressure class and SDR rating.
- Lot or Batch number.
- Standard Certification.

2.17 Unit 16 Solid Drainage Pipe

2.17.1 Material Properties

Unit 16 Solid Drainage Pipe shall comprise nominal diameter 110 mm solid wall HDPE SDR13.6 PE100 pipes to conform with AS/NZS 4130:2009 'polyethylene (PE) pipes for pressure applications'.

The pipes shall be welded into a pipe string on-site using butt fusion or electrofusion welded joints and connections. Butt fusion welding shall be undertaken in accordance with ASTM F2620 – *Standard Practice for Heat Fusion Jointing of Polyethylene Pipe and Fittings* or equivalent standard. Electrofusion welding shall be undertaken in accordance with ASTM F1290:98a (2011) – *Standard Practice for Electrofusion Joining Polyolefin Pipe and Fittings* or equivalent standard. All connections, bends and specials shall be solid wall units with the same pressure class as the pipe.

2.17.2 Quality Assurance

The Contractor shall obtain and present Manufacturer's documentation related to the Unit 16 Solid Drainage Pipe to the Superintendent that demonstrates that the materials meet the property requirements of the Specification.

The Contractor shall be responsible for the storage, joining and installation of Unit 16 Solid Drainage Pipe delivered to Site.

All pipes and fittings delivered to site shall be marked or tagged with the following information:

- Manufacturers Name.
- Product identification including pressure class and SDR rating.
- Lot or Batch number.
- Standard Certification.

2.18 Unit 17 Riser Pipe

2.18.1 Material Properties

Unit 17 Riser Pipe shall comprise nominal diameter 450 mm solid wall HDPE SDR 17 PE 100 pipes with smooth inner walls and HDPE end caps. The pipes shall conform with AS/NZS 4130:2009 'polyethylene (PE) pipes for pressure applications'. The lower part of the pipe must be drilled in accordance with the details shown on Drawing D012 in the pipe manufacturer's factory or on-site using a template and all waste material must be removed prior to installation.

The prepared pipes shall be welded into a pipe string on-site using butt fusion or electrofusion welded joints and connections. Butt fusion welding shall be undertaken in accordance with ASTM F2620 – *Standard Practice for Heat Fusion Jointing of Polyethylene Pipe and Fittings* or equivalent standard. Electrofusion welding shall be undertaken in accordance with ASTM F1290:98a (2011) – *Standard Practice for Electrofusion Joining Polyolefin Pipe and Fittings* or equivalent standard. All connections, bends and specials shall be solid wall units with the same pressure class as the pipe.

2.18.2 Quality Assurance

The Contractor shall obtain and present Manufacturer's documentation related to the Unit 17 Riser Pipe to the Superintendent that demonstrates that the materials meet the property requirements of the Specification.

The Contractor shall be responsible for the storage, joining and installation of Unit 5 Riser Pipe delivered to Site.

All pipes and fittings delivered to site shall be marked or tagged with the following information:

- Manufacturers Name.
- Product identification including pressure class and SDR rating.
- Lot or Batch number.
- Standard Certification.

2.19 Unit 18 Leachate Inlet Pipe

Unit 18 Leachate Inlet Pipe shall comprise nominal diameter 160 mm solid wall HDPE SDR17 PE100 pipes to conform with AS/NZS 4130:2009 'polyethylene (PE) pipes for pressure applications.

The pipes shall be welded into a pipe string on-site using butt fusion or electrofusion welded joints and connections. Butt fusion welding shall be undertaken in accordance with ASTM F2620 – *Standard Practice for Heat Fusion Jointing of Polyethylene Pipe and Fittings* or equivalent standard. Electrofusion welding shall be undertaken in accordance with ASTM F1290:98a (2011) – *Standard Practice for Electrofusion Joining Polyolefin Pipe and Fittings* or equivalent standard. All connections, bends and specials shall be solid wall units with the same pressure class as the pipe.

2.19.1 Quality Assurance

The Contractor shall obtain and present Manufacturer's documentation related to the Unit 18 Leachate Inlet Pipe to the Superintendent that demonstrates that the materials meet the property requirements of the Specification.

The Contractor shall be responsible for the storage, joining and installation of Unit 16 Solid Drainage Pipe delivered to Site.

All pipes and fittings delivered to site shall be marked or tagged with the following information:

- Manufacturers Name.
- Product identification including pressure class and SDR rating.
- Lot or Batch number.
- Standard Certification.

2.20 Unit 19 Overflow Pipe

Unit 19 Overflow Pipe shall comprise nominal diameter 200 mm solid wall HDPE SDR17 PE100 pipes to conform with AS/NZS 4130:2009 'polyethylene (PE) pipes for pressure applications'.

The pipes shall be welded into a pipe string on-site using butt fusion or electrofusion welded joints and connections. Butt fusion welding shall be undertaken in accordance with ASTM F2620 – *Standard Practice for Heat Fusion Jointing of Polyethylene Pipe and Fittings* or equivalent standard. Electrofusion welding shall be undertaken in accordance with ASTM F1290:98a (2011) – *Standard Practice for Electrofusion Joining Polyolefin Pipe and Fittings* or equivalent standard. All connections, bends and specials shall be solid wall units with the same pressure class as the pipe.

2.20.1 Quality Assurance

The Contractor shall obtain and present Manufacturer's documentation related to the Unit 19 Overflow Pipe to the Superintendent that demonstrates that the materials meet the property requirements of the Specification.

The Contractor shall be responsible for the storage, joining and installation of Unit 16 Solid Drainage Pipe delivered to Site.

All pipes and fittings delivered to site shall be marked or tagged with the following information:

- Manufacturers Name.
- Product identification including pressure class and SDR rating.
- Lot or Batch number.
- Standard Certification.

2.21 Unit 20 Concrete

Unit 20 Concrete shall comprise commercially manufactured and supplied wet mix concrete with a minimum compressive strength of 32 MPa at 28 days or an equivalent material approved by the Superintendent. Specifications for Unit 10 Concrete are provided in the Drawings.

All concrete and formwork shall be in accordance with AS 3600 and AS 3610.

2.22 Unit 21 – Geocomposite Drain

Unit 21 Geocomposite Drain shall comprise a high-density polyethylene (HDPE) bi-planar or tri-planar geonet with a layer of filter geotextile thermally bonded to both sides of the geonet.

Unit 21 Geocomposite Drain must have the minimum properties specified in Table 21.

Table 21: Required properties of Unit 21 Geocomposite Drain

Property	Units	Value	Test Method
HDPE Core			
Thickness at 50 kPa	mm	≥ 5	AS 3706.1
Density	g/cm³	≥0.94	ASTM D1505
Compressive Strength	kPa	≥500	ASTM D1621
Geotextile			
Fabric Weight	g/m²	≥200	ASTMD5261
CBR Burst Strength	N	≥1900	AS 3706.4 or ASTM D6241
Grab Tensile strength	N	≥700	AS 3706.2 or ASTM 4632
Geocomposite			
Flow rate per unit width	L/s/m	≥0.15 (Note 1)	ASTM D4716

1. Flow rate measured with 50 kPa confinement pressure and hydraulic gradient of 0.33. Based on testing with geotextile on both sides and soft plates top and bottom.

2.22.1 Testing

The Contractor shall supply the GITA with manufacturer quality control (MQC) data certificates showing the testing of each property at frequencies stated in Table 21. The quality Assurance documentation must be referenced to the roll numbers to be delivered to the Works.

The Superintendent, based on advice from the GITA, shall request the Contractor to recover samples from the geosynthetic rolls delivered to site and arrange independent testing at the frequencies listed in Table 22 of the samples to confirm the material meets the specified minimum material property values. The samples to be tested shall be recovered under the supervision of the GITA and shall be from different rolls evenly distributed through the batch delivered to site. The Superintendent is responsible for any independent testing. The results of the independent testing shall take precedence over the MQC test results.

Table 22: Required Testing of Unit 21 Geocomposite Drain

Property	Test Method	Minimum Independent Testing Frequency (GITA)
HDPE Core		
Thickness at 50 kPa	AS 3706.1	3
Density	ASTM D1505	2
Geocomposite		
Flow rate per unit width	ASTM D4716	2

3.0 EXCAVATION, SUBGRADE PREPARATION AND PLACEMENT OF ENGINEERED FILL

3.1 General

Details of the Contractor's proposed set-out and method for construction shall be submitted to the Superintendent, as part of the method statement for Excavation, subgrade preparation and construction of the groundwater drainage system (refer to Section 1.26), for comment and approval at least two days before Works commence on site.

3.2 Subgrade preparation

Subgrade preparation shall be approved by the Superintendent and include the following:

- Removal of vegetation, mulch, and unsuitable subgrade materials as approved by the Superintendent.
- Excavation of soil and weathered rock to the design subgrade surface or as approved by the Superintendent.
- Inspection and proof rolling prior to placement of overlying materials.
- Excavation of silt and gravelly silt in the cut slopes and footprint of the pond embankments to the extent indicated in the Drawings and in accordance with the design intent detailed in the Design Report.

The shaping and preparation of the existing surface as part of the subgrade works shall be the responsibility of the Contractor. The Superintendent shall approve the subgrade preparation works.

The Contractor shall proof roll the prepared subgrade surface using the roller proposed for construction of overlying layers, or equivalent approved by the Designer. Proof rolling shall be carried out in the presence of the GITA, who shall identify any areas during the proof rolling that require improvement, using a methodology approved by the Superintendent. Additional excavations and fill placement shall be undertaken in accordance with the agreed schedule of rates.

The subgrade shall be maintained free of ponded water during the Works.

3.3 Placement of Unit 1 Engineered Fill and Unit 2 Select Fill

Placement of Unit 1 Engineered Fill and Unit 2 Select Fill includes the following:

- Placement of Unit 1 Engineered Fill to replace excavated material from site investigation test pits within the design footprint. Such excavations and fill placement shall be undertaken in accordance with the agreed schedule of rates.
- Placement of Unit 1 Engineered Fill using an approved method statement to achieve the design grades and surface for placement of the groundwater drainage system and pond liner.
- Construction of the perimeter embankments and access ramps with Unit 1 Engineered Fill. Note that construction of the groundwater drainage system (refer to Section 4.0) prior to completion of the perimeter embankments and access ramps may be preferable to avoid the need for deep excavation for the groundwater drainage pipes and trenches under the embankments.
- Construction of Unit 2 Select Fill layer as indicated in the Drawings.

The set out of the perimeter embankments, shall be approved by the Superintendent and shall consider the design drawings, ground conditions, site survey, proposed methodology, health and safety, access and temporary stormwater management.

The surface for fill placement shall be prepared by the Contractor in accordance with Section 3.2. The surface shall be shaped so that fill can be practically placed and that there are no areas of “undercuts” or undulating surface where uniform densification of the fill is not practical using the proposed methodology. The surface for fill placement shall be inspected and approved by the Superintendent prior to placement of Unit 1 Engineered Fill and Unit 2 Select Fill. Filling shall commence only after the surface upon which fill material is to be placed has been approved by the Superintendent.

The surface of constructed Unit 1 Engineered Fill shall be lightly scarified and inspected by the Superintendent prior to placement of Unit 2 Select Fill. Placement of Unit 2 Select Fill over the completed Unit 1 Engineered Fill surface shall commence only after the surface has been approved by the Superintendent.

The Contractor shall haul the Unit 1 Engineered Fill and Unit 2 Select Fill to the Works area from stockpiles located within the Site or from excavated and prepared materials.

Unit 1 Engineered Fill and Unit 2 Select Fill shall be constructed in layers of not more than 200 mm compacted thickness. The layer thickness may be able to be reviewed subject to field trials. The material shall be mixed and moisture conditioned prior to compaction. The mixing and moisture conditioning must be carried out to achieve a uniform composition and moisture condition throughout each layer of placed material. The Unit 1 Engineered Fill and Unit 2 Select Fill shall be placed in a manner that the distribution and gradation of the materials from that one layer is uniform. Each layer shall be free from lenses or pockets that differ substantially in composition, texture, moisture content or density from the surrounding material.

The fill shall be compacted and tested to achieve the requirements in Table 8 and Table 10. The surface of compacted material shall be rolled and shaped to prevent ponding of water and erosion of placed materials.

The integrity of the completed portions of the fill shall be maintained by the Contractor. This includes limiting traffic movements on completed works and prevention of disturbance, excessive wetting and erosion control. Should the fill be disturbed, excessively wetted or eroded, as determined by the Superintendent, then the Contractor shall rework the fill to the satisfaction of the Superintendent.

Should inspection or testing of the fill indicate that it is not in accordance with the Specification, then the Superintendent will direct the Contractor to rework the area. If the requirements again cannot be achieved after reworking, the failed layer shall be removed for moisture conditioning at an approved designated area.

If the Contractor detects Unit 1 Engineered Fill or Unit 2 Select Fill material changes or variations they shall inform the GTA to assess the suitability of the material for its purpose by undertaking the appropriate laboratory testing and assessing its suitability in accordance with the Specification.

4.0 CONSTRUCTION OF THE GROUNDWATER DRAINAGE SYSTEM

4.1 General

Details of the Contractor's proposed setout and method for construction shall be submitted to the Superintendent for comment and approval, as part of the method statement for Excavation, subgrade preparation and construction of the groundwater drainage system (refer to Section 1.26), at least two days before Works commence on site.

The Contractor shall excavate the groundwater drainage trenches in accordance with the details on the Drawings. Unit 15 Groundwater Collection Pipe and Unit 16 Solid Drainage Pipe shall be placed in the groundwater drainage trenches and backfilled with Unit 4 Subgrade Drainage Aggregate.

The groundwater drainage blanket shall be installed by the Contractor with a minimum thickness of 100 mm on the floor, including over groundwater drainage trenches, in accordance with the details on the Drawings.

The Unit 21 Geocomposite Drain shall be installed by the Contractor on the internal excavation batters and tied in to the groundwater drainage trenches.

4.2 Fabrication and Installation of Unit 15 Groundwater Collection Pipe and Unit 16 Solid Drainage Pipe

The Pipe Installer shall perforate the Unit 15 Groundwater Collection Pipe as per the Drawings prior to welding the sections of pipe. All the excess material from drilling the pipes shall be removed prior to welding the pipes together. Care shall be taken when welding together sections to orientate the sections to maintain the orientation of the holes in the pipeline.

Unit 15 Groundwater Collection Pipe and Unit 16 Solid Drainage Pipe shall be welded by the Pipe Installer using full face fusion joins. The pipes shall be welded next to the trenches ready to be rolled or to pull the welded pipe into place by hand and winch. The pipes shall not be welded in-situ.

All pipe joins and junctions shall be formed using the same type and strength of pipe as the Unit 15 Groundwater Collection Pipe and Unit 16 Solid Drainage Pipe, and shall be solid wall units. The upper ends of the pipes, once installed in the cell, shall be closed using bolted flanged galvanised plates. All excess material from welding the pipes shall be removed prior to moving the pipes to the ponds.

The Unit 15 Groundwater Collection Pipe shall be installed at the base of the groundwater drainage trenches on a 50 mm thick bedding of Unit 4 Subgrade Drainage Aggregate, as shown on the Drawings. The orientation of the holes in the pipes shall be maintained during installation as far as practical at 45 degrees to the vertical.

The Unit 16 Solid Drainage Pipe shall be installed at the base of the groundwater drainage trenches.

The outlet of Unit 16 Solid Drainage Pipe shall be fitted with a stainless steel backflow prevention flap, approved by the Superintendent.

4.3 Unit 4 Subgrade Drainage Aggregate

The Contractor shall be responsible for the selection, loading and transport of the Unit 4 Subgrade Drainage Aggregate from the source location, and placement of the aggregate in the groundwater drainage system.

The Contractor shall consider the following for supply and placement of the aggregate:

- Potential for breakdown of the aggregate during handling and placement and the generation of fine grained particles that may not comply with the specified requirements.

- Non-uniform particle size distribution during production, stockpiling, handling and placement. This includes accumulation of fine grained particles in localised locations that do not comply with the specified requirements.
- Potential inclusion of non-conforming materials during the loading of the aggregate at the source or stockpile.
- Carrying out corrective action for non-conformances in particle size distribution in the placed material.

Unit 4 Subgrade Drainage Aggregate shall be placed in the groundwater drainage trenches and groundwater drainage blanket to form continuous backfill in the trenches and a continuous blanket on the floors of the ponds, as shown on the Drawings. The shaping of the aggregate to the required thickness shall be controlled using a laser guide or similar system.

The Contractor shall take care to ensure that the Unit 4 Subgrade Drainage Aggregate is worked around the Unit 15 Groundwater Collection Pipe to provide uniform support around the pipes. This will require some placement of aggregate by hand.

The Unit 4 Drainage Aggregate shall be placed in a manner so as to ensure uniform particle size distribution.

The Superintendent shall be present on site to view aggregate placement.

4.4 Unit 9 Separation Geotextile

The Contractor shall install Unit 9 Separation Geotextile to encapsulate the Unit 4 Subgrade Drainage Aggregate in accordance with the Drawings, including wrapping the Unit 9 Separation Geotextile around the sides of the Unit 4 Drainage Aggregate blanket.

4.4.1 General

The Contractor shall handle all geotextiles in such a manner as to ensure they are not damaged in any way, and shall comply with the following:

1) On slopes, the Unit 9 Separation Geotextile shall be secured and then rolled down the slope in such a manner as to continually keep the geosynthetic tension to preclude folds and wrinkles.
2) Where there is underlying geosynthetics, the geotextile shall be installed by hand and not using machinery.
3) All geotextiles shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during placement and shall remain until covered with overlying materials. Deployment of the sandbags must not damage the geosynthetics.
4) The geotextile shall be cut using a sharp knife with a sheath and automatically retractable hooked blade or similar equipment/cutting method approved by the Superintendent.
5) The geotextile shall be examined over the entire surface, after installation, to ensure that no potentially harmful foreign objects are present. Any foreign objects encountered shall be removed or the geotextile shall be replaced.
6) If white geotextile is used, precautions shall be taken to avoid “snow-blindness” of personnel.
7) After installation, all geotextile shall be covered within 2 months to prevent exposure to ultraviolet (UV) radiation (sunlight).

4.4.2 Seams and Overlaps

Unit 9 Separation Geotextile shall be joined according to the following requirements:

1) Areas to be overlapped shall be clean and free of foreign matter.

2) Geotextile joints shall be overlapped by 250 mm.

Unit 9 Separation Geotextile shall be joined thermal heat bonding or an alternative methodology approved by the Superintendent. The proposed bonding method shall be in accordance with the manufacturer's recommendations and submitted to the Superintendent for approval 5 days in advance of the proposed works.

4.4.3 Repairs

Any holes or tears in the Unit 9 Separation Geotextile shall be repaired as follows:

1) Soil or other material that may have penetrated the torn geotextile shall first be removed.

2) A patch made from the same Unit 9 Separation Geotextile, shall be seamed into place with a minimum of 0.3 m overlap in all directions (with each seam no closer than 25 mm from any edge). Should any tear exceed 10% of the width of the roll, that roll shall be removed from the works and replaced.

4.5 Unit 21 Geocomposite Drain

The Unit 21 Geocomposite Drain is to be installed on the internal excavated subgrade batters. The surfaces of the batter shall be uniform and smooth and approved by the Superintendent prior to deployment.

4.5.1 Installation by Subcontractor

The Geocomposite Drain must be placed using a spreader bar to ensure minimum deformation during handling. The Geosynthetics Installation Contractor may opt to deploy by out-rolling it manually over the batter surface if it can be demonstrated to the GITA that it can be carried out safely and with appropriate measures to ensure low risk of damage to the geosynthetic material.

The GITA shall inspect the Geocomposite Drain as it is rolled out on the surface. This constitutes an inspection point and the GITA is required to be notified 48 hours in advance of commencing or recommencing the activity.

Placement of the Geocomposite Drain shall meet the following installation requirements:

- The rolls are to be placed in such a manner as to minimise seaming and ensure no cross-slope seams are created.
- Geocomposite Drain must be installed such that the ribs of each panel are orientated in the same direction as the flow direction. Panels must be deployed parallel with the slope direction.
- Temporary ballasting must be used to prevent wind uplift.
- On slopes, the ends of the geonet panels shall be shingled down (roof tile effect) in the direction of the slope.
- The overlap between adjacent panels of Unit 21 Geocomposite Drain shall be joined at approximately 2 m intervals with nylon cable ties. The geotextile of the Unit 6 Geocomposite Drain shall be heat bonded or glued along the full length of the overlap. This is intended to reduce the risk of the overlap opening during placement of the overlying Unit 2 Select Fill layer.
- The Geocomposite Drain panels must tie-in to the base of the groundwater drainage trenches.
- For transverse joints, the geonet component of the Geocomposite Drain must be overlapped by 200 mm and joined at approximately 1 m centres with nylon cable ties. The geotextile overlaps shall be heat bonded for the full length of the overlap.
- The top edge of the Geocomposite Drain shall be overlapped with geotextile and heat bonded for the full length of edge to prevent fines migration into the HDPE geonet core.

- Along the bottom edge of the Geocomposite Drain in the trench, the geotextile component shall remain open and not bonded closed.

The following installation steps are recommended for the installation of the Geocomposite Drain:

- Remove any loose material on the surface.
- The Geocomposite Drain shall be installed flush with the underlying subgrade surface.

4.5.2 Transportation, Labelling, Handling and Storage

The Unit 21 Geocomposite Drain delivered to site shall be unloaded with equipment that shall not damage the material. A spreader bar or other approved equipment by the Superintendent shall be used to handle the rolls of Geocomposite Drain.

The Geocomposite Drain shall be protected from ultraviolet light exposure, precipitation or other inundation, spills of hydrocarbons, mud, dirt, dust, puncture, cutting or other damaging deleterious conditions during delivery, storage and handling.

All rolls shall be stored off the ground on a hard, dry, free-draining surface, with suitable bearers at closely spaced centres, suitably protected from runoff, hydrocarbon spills, and other damage.

The Geosynthetics Installation Contractor shall be responsible for the storage of the materials for the Works.

4.5.3 Repairs

Rolls or panels of Unit 21 Geocomposite Drain that have been damaged or have identified defects shall be brought to the attention of the GITA, who shall judge if the panel or roll is to be removed from site or may be repaired.

Should the GITA assess the geonet to be crushed or damaged, the following procedure shall be undertaken:

- The extent of the damaged geonet core shall be identified and marked out.
- The full panel width of the Geonet extent shall be cut and the damaged panel removed.
- A new panel of Geocomposite Drain shall be installed in accordance with Section 4.5.1 of this Specification.

4.6 Unit 6 Cement Stabilised Sand

The Contractor shall be responsible for selection, loading and transport of the Unit 6 Cement Stabilised Sand from the source location, and placement of the material in the main outlet pipe trench as part of the in the subgrade groundwater drainage system.

Unit 6 Cement Stabilised Sand shall be placed in the main outlet pipe trench to form a continuous backfill in the trenches with bedding depth and minimum depth above the Unit 16 Solid Drainage Pipe as indicated on the Drawings.

The Contractor shall take care to ensure that the Unit 6 Cement Stabilised Sand is worked around the Unit 16 Solid Drainage Pipe to provide uniform support around the pipes.

The Superintendent shall be present on site to view placement of Unit 6 Cement Stabilised Sand.

4.7 Unit 1 Engineered Fill

Unit 1 Engineered Fill shall be placed as backfill in the main outlet pipe trenches and shall be moisture conditioned and compacted in layers in accordance with Unit 1 Engineered Fill requirements.

5.0 CONSTRUCTION OF THE LINER

5.1 Construction of Unit 2 Select Fill for the Pond Liner

The Contractor shall carry out the construction of the Works in accordance with the drawings and shall adhere to the slopes, levels, depths and heights shown thereon.

Details of the Contractor's proposed method for construction shall be submitted to the Superintendent for comment and approval as part of the method statement for Construction of pond liners (refer to Section 1.26) at least 2 days before Works commence on site.

Where the Unit 2 Select Fill is located over the Unit 9 Separation Geotextile and Unit 21 Geocomposite Drain, the methodology shall consider protection of the integrity of the underlying geosynthetic materials.

On the sidewalls where Unit 2 Select Fill is to be constructed directly on Unit 1 Engineered Fill, the surface of the Unit 1 Engineered Fill shall be lightly scarified and moisture conditioned if necessary to bond the units and to prevent laminations at the interface between Unit 1 Engineered Fill and Unit 2 Select Fill. If laminations occur, the area shall be reworked at the Contractor's expense to remove any laminations or defects.

5.1.1 Unit 2 Select Fill Placement

The Contractor shall perform survey and field measurements as part of its Quality Assurance plan to demonstrate that the Unit 2 Select Fill layer thickness and the completed thickness comply with the requirements of the Specification.

The Unit 2 Select Fill material shall be mixed and moisture conditioned prior to compaction. The mixing and moisture conditioning must be carried out to achieve a uniform composition and moisture condition throughout each layer of placed material. Where the clay is more than 3% dry of SOMC, moisture conditioning of the clay shall be planned to allow at least 12 hours of moisture curing between moisture conditioning/mixing and transportation to the ponds.

Acceptance criteria for moisture conditioning and compaction are outlined in Section 2.3.

Testing shall be carried out to demonstrate the compliance of the compacted Unit 2 Select Fill with the moisture content and density ratio requirements of the Specification as soon as practicable after compaction. It is the responsibility of the Contractor to coordinate with the GTA to ensure that this requirement for the scope and time of testing is met at all times during the construction of the liner.

Placed Unit 2 Select Fill shall be free from lenses or pockets that differ substantially in composition, texture, moisture content or density from the surrounding material. If the Contractor detects material changes or variations, it shall notify the Superintendent who shall assess the material for suitability.

It shall be smooth with no abrupt level changes or voids and be free of standing water. Sharp edges or objects protruding more than 5 mm shall be removed to the satisfaction of the GITA and Superintendent.

The integrity of the completed Unit 2 Select Fill shall be maintained by the Contractor. This includes limiting traffic movements on completed works and prevention of disturbance, excessive wetting, erosion and desiccation cracking. Each layer of the compacted material shall be maintained within the specified moisture tolerances specified between the completion of rolling the layer and the placement of the overlying layer. Should the material be disturbed, excessively wetted, eroded, desiccated or cracked, as determined by the Superintendent or the GITA, then the Contractor shall rework the material to the satisfaction of the Superintendent and the GITA.

Trafficked sections of constructed Unit 2 Select Fill are to be ripped, moisture conditioned and recompacted to the specified requirements if, in the opinion of Superintendent or the GITA, these areas have deteriorated.

Should inspection or testing of the constructed Unit 2 Select Fill indicate that the moisture content or compaction of material is not in accordance with the Specification, then the Superintendent will direct the Contractor to rework the area at the Contractor's own expense. If the material still does not conform with the requirements of the Technical Specification after reworking, the Contractor, at its own expense, shall remove the material or remove it to an approved designated area to potentially be mixed and moisture re-conditioned.

5.1.2 Compacted Unit 2 Select Fill Surface Preparation and Maintenance

Surface preparation shall be approved by the Superintendent prior to deployment of the overlying materials.

The integrity of the compacted Unit 2 Select Fill shall be maintained until deployment of the overlying materials. The surface of the compacted Unit 2 Select Fill shall provide a firm, unyielding foundation with no sudden, sharp or abrupt changes or break in grade, to the satisfaction of the Superintendent. It shall be smooth with no abrupt level changes or voids and be free of standing water. Sharp edges or objects protruding more than 5 mm shall be removed to the satisfaction of the GITA and Superintendent. No standing water shall be allowed to accumulate on the compacted Unit 2 Select Fill prior to installation of overlying materials. No geosynthetics shall be placed onto an area that has become softened by water. Portions of compacted Unit 2 Select Fill that are deemed by the Superintendent to have deteriorated to an extent that has compromised the quality of the compacted Unit 2 Select Fill, shall be reworked, and subjected to the necessary geotechnical testing in order to demonstrate compliance with the Specification.

The Contractor shall consider these requirements in the selection of Unit 2 Select Fill materials to construct the pond liner and in the methodology and schedule to carry out the trimming, final surface preparation and survey of the compacted Unit 2 Select Fill, and subsequent placement of the overlying materials.

5.1.2.1 Erosion Management of Compacted Unit 2 Select Fill

The Contractor shall take note that once lining starts, runoff from the liner area can be rapid and generally comprises all the rainfall volume. Experience has shown the compacted fill materials (e.g. Unit 2 Select Fill) can be damaged by runoff from placed geosynthetics.

The Contractor shall implement measures to protect the compacted Unit 2 Select Fill from erosion or other damage. The proposed methodology shall be included with the method statement for Construction of pond liners (refer to Section 1.26) approved by the Superintendent prior to commencement of liner installation.

The Contractor shall consider placement of sheets of geomembrane ballasted by sand bags as an erosion management layer. The upstream edge of the erosion management layer shall be tucked under the completed geomembrane liner of the cell to direct runoff onto the erosion management layer. Any overlaps in the erosion management layer shall be at least 1m and be formed using a roof tile effect and shall be ballasted with sand bags. The downstream end shall be shaped to direct runoff away from the works as approved by the Superintendent.

5.2 Unit 10 BGM

5.2.1 Installation

5.2.1.1 Field Panel Placement

The Contractor shall present the Superintendent with its proposed Unit 10 BGM Panel Layout Drawings as part of the method statement for the construction of pond liners (refer to Section 1.26) at least 5 days before installation starts, for review by the Superintendent. The drawings shall indicate the panel configuration, seam layout, the location and layout of complicated seams, the location of Unit 10 BGM and the staging/direction of deployment. The layout drawings shall be suitable for use as construction drawings, shall be to scale and include dimensions and details.

BGM field panels shall be installed on the prepared subgrade, at the locations and positions indicated on the approved panel layout plan.

Panel placement shall consider forecast weather conditions such as high atmospheric temperatures, heavy rain or high winds to minimise any possible damage from these conditions, and to achieve the requirements of effective seams.

The Contractor shall examine the entire surface of the BGM liner throughout installation to ensure no potentially harmful foreign objects or manufacturing defects are present. Any foreign objects or defects encountered shall be removed or the material shall be replaced, as directed by the GITA.

The Contractor shall ensure the following during installation of the BGM:

- No more liner materials are deployed than can be reasonably joined in one day or shift.
- Rolls are unrolled in conformity with the instructions and the direction specified in this document, or as approved by the GITA.
- No equipment used to deploy the rolls will damage the liner materials by handling, trafficking or other means.
- No materials are dragged or pushed along the surface of the liner materials. Liner materials damaged shall be considered installation damage and the GITA shall advise the Superintendent whether the damaged area should be patched, capped or replaced.
- The top surface of the BGM is provided with a thin peel-off polyethylene film that shall be removed immediately after deployment and before execution of the seaming. The film shall be disposed in accordance with the site requirements for waste management.
- Personnel working on the BGM do not smoke, wear studded footwear, or engage in other activities that could damage the liner materials. The Contractor shall protect the liner materials from damage by equipment or personnel traffic associated with construction at all times.
- Methods used to unroll panels do not cause scratches or crimps in the liner materials and do not damage the underlying liner component or subgrade. Liner rolls shall be unrolled in a controlled manner and not be released to unroll freely down slopes.
- Liner materials are to be cut using an approved cutting method and approved cutting equipment only. The cutting method shall comply with Principal standards and be approved by the Superintendent. Cutting tools shall not be placed on the liner surface and shall be stored in secure containers to prevent personal injury and accidental damage to the liner.
- Methods used to place panels preclude folds, wrinkles and bridging (trampolining). On slopes, the material shall be continually managed and maintained in sufficient tension to preclude folds and wrinkles by securing and then rolling the roll down slope.
- Liner joints shall be orientated so that overlaps are in the down slope direction (roof tile effect).
- The liner materials are weighted to prevent wind uplift using ballast, sandbags or other approved equivalent loading system of a suitable mass. As a minimum, ballast shall be placed along the free edges and in the middle of the edge panels to avoid wind-uplift in between working shifts.
- Trafficking over the BGM is restricted to foot traffic, unless approved by the GITA.
- Recording as-built panel layouts and construction quality control records.

5.2.1.2 Damage and Defects

5.2.1.2.1 General

Two types of defects may occur; manufacturing defects that exist in the BGM liner as delivered to the site that may only become apparent upon deployment, and defects related to the installation of the BGM. Repair of manufacturing and installation defects shall be the responsibility of the Contractor and its Geosynthetics Installer.

The responsibility for the identification of defects remains with the Geosynthetics Installer, but the type of defect is to be assessed by the GITA. The Geosynthetics Installer shall be responsible for recording all defects, labels, locations and preparing field quality control records of their repair.

5.2.1.2.2 Manufacturing Defects

The following manufacturing defects for BGM shall apply:

Both faces of the BGM shall be uniform in finish. The bitumen shall be uniform over the entire area and up to the edges of the sheet.

If the texturing on the surfaces varies to the extent that the surface roughness of the surfaces is significantly different, the BGM shall be rejected. A difference in surface roughness over 4 m^2 is considered significant. The difference shall be decided by the GITA using a visual assessment and shall be final. There shall be no significant depressions, striations or voids in the bitumen or unsaturated spots in the BGM. The BGM shall be free of visible defects such as holes, ragged or untrue edges, breaks, cracks, protuberances and indentations.

5.2.1.3 Repair of Defects

All defects shall be patched or capped and subject to quality control testing, reporting and documentation by the Geosynthetics Installer. The Geosynthetics Installer shall mark observed defects on the installed sheet. The Geosynthetics Installer shall record the defects on a layout drawing. The GITA shall assess all such repairs, reporting and documentation and advise the Superintendent of any non-conformances.

Repair of defects is part of the Geosynthetics Installers responsibility.

5.2.1.4 Patching

Patches shall be used to repair defects such as tears and holes which penetrate the entire BGM thickness. Small surface blemishes and localised flaws which do not penetrate the entire thickness of the BGM shall be repaired as instructed by and to the satisfaction of the GITA.

Patches shall extend a minimum of 600 mm beyond the limits of the defect. Patches shall follow the contour of the defect area and remain free of crimping or pinching. The BGM material used for patching shall, at a minimum, meet the requirements of this specification. Patches and defect areas shall be free of dirt, moisture, debris and markings. The patch shall have rounded edges and be installed flat along all edges with no wrinkles or folds and the terphane seal removed from the underside overlap prior to joining.

The entire patch shall be tested by ultra-sonic or vacuum method.

5.2.1.5 Capping

A cap is a patch of extended length and may be used to repair failed joins. Caps shall extend a minimum of 600 mm beyond the limits of the defective join. Caps over failed joins shall be carried out only with the approval of the GITA if no other method of repair is feasible

5.2.1.6 BGM Field Welding

5.2.1.6.1 Joining Equipment and Method

All equipment and joining methods shall be approved by the Manufacturer and Superintendent prior to use.

The Contractor shall conduct a field trial to prove the proposed methodology for installation, inspection and testing.

Alternative processes may be proposed and submitted to the Superintendent 14 days prior to the commencement of BGM deployment. No alternative joining methods or equipment may be used without approval from the Superintendent.

i) Welding shall extend to the outside edge of panels to be placed in the anchor trench;

ii) Fish-mouths or wrinkles at the seam overlaps shall be cut out and patched or capped.

iii) If required, a firm substrate shall be provided by using a flat board or similar hard surface directly under the seam overlap to achieve necessary support.

The panels of BGM shall be overlapped by a minimum of 200 mm. The plastic film shall be removed from the underside of the overlapping panel edge prior to joining.

5.2.1.6.2 Weld Preparation

Prior to welding, the weld area shall be cleaned and free of moisture, dust, dirt, debris, markings and foreign material.

5.2.1.6.3 Field Weld Record

The Contractor shall record the following information in permanent ink or as specified by the GITA on the BGM surface adjacent to the weld:

- Unique seam number
- Welding technician’s initials
- Date and time.

This information shall be legible for the duration of the Works.

The seam information shall be cross-referenced to the field notes and records of the Contractor and shall be marked on the As-built Drawings

5.2.1.6.4 Conditions for Welding

BGM jointing and welding shall not be started if the BGM material temperature is above 70°C, unless otherwise authorised by the GITA. The Geosynthetics Installer shall supply and maintain temperature recording equipment to measure the material temperature. BGM jointing shall not be undertaken under the following conditions:

- During rain,
- In an area of ponded water, or
- During periods of high wind or excessive dust.

5.2.1.6.5 Seams and Overlaps

In general, seams shall be oriented parallel to the line of maximum slope (i.e. oriented up and down, not across, the slope). In corners and odd-shaped geometric locations, the number of seams shall be minimised. No seams shall be located in areas of potential stress concentrations, as directed by the GITA.

All joints between panel ends are required to staggered by at least 0.5 m to form T-joints. All T-joints, defects, etc., shall be patched and be subject to quality testing.

5.2.2 Testing

5.2.2.1 Trial Welds

Each welding technician shall qualify to operate on a daily basis, by performing a trial weld prior to welding activities or at times designated by the GITA. A trial weld may be requested by the GITA at midday if required. Welding technicians that have not produced a passing trial weld shall not be permitted to perform production welding.

Trial welds shall be made on fragment pieces of BGM liner to verify that welding conditions are adequate. The trial weld sample shall be at least 0.7 m wide and 0.9 m long, with the weld centred length-wise along the long side. All trial welds shall be performed under the same weather and subgrade conditions as production welding.

Five specimens each shall be cut from the trial weld sample, by the Geosynthetics Installer, equally spaced over the length of the sample and tested in shear. Each weld sample must satisfy the shear criteria. All testing and evaluation shall be carried out in accordance with ASTM D 7056, with the exception of 24 hour wait. The results shall be recorded and copies of these submitted to the Superintendent as site records.

The Contractor shall allow sufficient period in their installation program for the trial weld to cool to less than 25 ºC following preparation prior to testing.

5.2.2.1.1 Trial Weld Evaluation Criteria

The Geosynthetics Installer shall supply appropriate equipment for field testing and accompanying jaw sizes. Equipment and jaws for conventional Geomembrane seam testing shall not be acceptable.

The target shear test value shall be a minimum of 20 kN/m when tested in accordance with ASTM D 7056. The specimen shall fail in the BGM sheet and not in the weld area.

If any one of the five (5) specimens (coupons) fails in shear, the entire trial weld is considered to have failed. In the event that a trial weld fails, the entire trial weld procedure shall be repeated after the appropriate adjustments to the welding device and/or operator have been made. If a second trial weld fails the welding device and/or the welding technician shall be rejected and shall not be used for welding until such time as the deficiencies are resolved, verification of the resolution is provided, and a successful trial weld performed

5.2.2.2 Non-Destructive Weld Continuity Testing

5.2.2.2.1 General

The Contractor shall non-destructively test all joins over their full length by visual testing and vacuum box testing (ASTM D5641. 2011), as approved by the Superintendent. The purpose of the non-destructive test is to check the continuity of joins. It provides limited information on join strength. Continuity testing shall be done daily as the joining work progresses. Any joins that fail non-destructive testing shall be repaired in accordance with this Technical Specification.

All test equipment shall be in calibration and conform to manufacturer's specifications. The Contractor shall submit current calibration certificates (not older than 12 months) to the GITA/Superintendent prior to commencing BGM installation works on site.

5.2.2.2.2 Non-destructive test of the joined seam

Visual test

- All joins will be visually inspected (the overlap is pulled at with a small trowel and the amount of bitumen edge is verified), once the join has cooled.
- Upon satisfactory inspection of the join the joiner finishes the seam join (reheats the extruded bitumen bead and smooths it with a small trowel).
- The equipment shall comprise the following:
  - A round tipped trowel
  - An electric hot air torch or blow torch.
- Procedure
  - Running the round tipped trowel along the joint to ensure that the join is not separating
  - Manually checking for wrinkles and bubbles.

Vacuum testing

The equipment shall comprise the following:

- A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole or valve assembly, and a vacuum gauge showing the pressure in the box.
- A steel vacuum tank and pump assembly equipped with a pressure controller and connections, unless an electrical assembly to be used.
- A rubber pressure/vacuum hose with fittings, pressure gauge linked to the window housing and connections.
- A soapy solution to be applied over seam area.

Each section of the join to be tested shall be tested to a vacuum pressure of at least minus 35 kPa.

Each section of seam shall be vacuum tested for a period of not less than 10 seconds by examining the geomembrane through the viewing window for the presence of soap bubbles. Adjoining area shall be tested with a minimum 75 mm overlap between sections.

Vacuum box testing will be over select 1.0 m lengths of join, with a minimum of one test per seam. If the join is longer than 30 m, then two tests must be carried out. Vacuum box testing is not required where ultra-sonic testing is selected as the preferred method.

5.2.2.3 Destructive Weld Continuity Testing

5.2.2.3.1 General

The Geosynthetics Installer shall recover weld samples, at locations selected by the GITA, for Destructive Testing (DT). The purpose of these tests is to evaluate field weld strength. Field weld strength testing shall be done as the welding work progresses, not at the completion of all field welds.

All destructive test samples shall be tested at an independent laboratory. The GITA will arrange for testing of these samples at an independent NATA-accredited laboratory.

5.2.2.3.2 Location and Frequency

DT samples shall be collected at an initial average frequency of one test location per 100 m of seam length for welding. As welding progresses the frequency of testing may be increased or decreased by the Superintendent in consultation with the GITA.

Note: The Geosynthetics Installer shall not be informed in advance of the locations where the samples shall be taken. The Superintendent reserves the right to increase the frequency depending on the test results of samples taken.

5.2.2.3.3 Field Destructive Sample Procedures

BGM samples shall be cut using an approved cutting method and approved equipment only.

Each sample shall be numbered, and the sample number and location identified on the panel layout drawing. These details shall also be clearly marked on the BGM adjacent to where the sample was retrieved (marked such that the subsequent repair does not cover these details).

Random samples shall be sent off site, by the GITA, to a NATA-accredited laboratory for confirmation testing.

Defects in the BGM resulting from destructive weld sampling shall be immediately repaired and tested in accordance with this Specification. Cuts to remove the samples shall be rounded to prevent stress concentrations in the BGM.

BGM samples shall be cleaned from any soil or debris once recovered. Samples shall remain flat and not be rolled up and shall be covered with wax paper or other approved material to avoid the samples sticking to each other.

5.2.2.3.4 Size of Samples

The samples shall be minimum 0.3 m wide (across the joined area 200 mm with 50 mm on either side) and a length of 0.7 m, with the weld centred lengthwise. The sample length may be increased to provide material for additional laboratory testing or archiving as directed by the Superintendent.

5.2.2.3.5 Preliminary Field Tests

From each DT sample, four specimens shall be tested in shear in the field prior to sending to the independent testing laboratory. Each weld sample must satisfy the shear criteria. All testing and evaluation shall be carried out in accordance with ASTM D 7056. The results of this testing shall be evaluated in accordance with the criteria as detailed in Section 5.2.2.3.6. If one of the four (4) field specimens (coupons) fails, the entire destructive test is considered fail and additional destructive test samples shall be taken in accordance with the procedures of this Technical Specification.

5.2.2.3.6 Laboratory and Field Testing Weld Evaluation Criteria

The standard critical shear test value shall be a minimum of 20 kN/m when tested in accordance with ASTM D 7056. The specimen shall fail in the BGM sheet and not in the weld area.

5.2.2.3.7 Failed Destructive Sample Procedure

All failed destructive welds that are to be reconstructed shall be capped to the full length of the panel seam in which the DT was recovered from. Caps shall only be carried out with the approval of the Superintendent and extend a minimum of 500 mm beyond the limits of the defective weld. The Geosynthetics Installer shall trace deficient welds by taking specimens for field testing on the two adjacent panel seams. The Geosynthetics Installer shall continue to obtain one specimen on adjacent panel seams in both directions until it has confidence that destructive samples which will pass laboratory testing can be obtained

5.3 Unit 11 Geonet

The Unit 11 Geonet is to be installed above the Unit 10 – BGM. Geonet must only be installed after the acceptance of the BGM layer by the GITA.

5.3.1 Installation by Subcontractor

The Geonet must be placed using a spreader bar to ensure minimum deformation during handling. The Geosynthetics Installation Contractor may opt to deploy the Geonet by out-rolling it manually over the geomembrane surface if it can be demonstrated to the GITA that it can be carried out safely and with appropriate measures to ensure low risk of damage to the underlying geosynthetic material.

The GITA shall inspect the Geonet as it is rolled out on the surface. This constitutes an inspection point and the GITA is required to be notified 48 hours in advance of commencing or recommencing the activity.

Placement of the Geonet shall meet the following installation requirements:

- The rolls are to be placed in such a manner as to minimise seaming and ensure no cross-slope seams are created.
- Geonet must be installed such that the ribs of each panel are orientated in the same direction as the flow direction. Panels must be deployed parallel with the slope direction.
- Temporary ballasting must be used to prevent wind uplift.
- On slopes, the ends of the geonet panels shall be shingled down (roof tile effect) in the direction of the slope.
- The overlap between adjacent panels of Unit 11 Geonet shall be joined at approximately 2 m intervals with nylon cable ties.
- The Geonet panels on slopes must extend at least 1 m past the toe of batters.
- For transverse joints, the Geonet must be overlapped by 200 mm and joined at approximately 300 mm centres with UV resistant nylon cable ties.

The following installation steps are recommended for the installation of the Geonet:

- Remove any loose material on the surface of the BGM.
- The Geonet shall be installed flush with the underlying subgrade surface.

5.3.2 Transportation, Labelling, Handling and Storage

The Unit 11 Geonet delivered to site shall be unloaded with equipment that shall not damage the Geonet. A spreader bar or other approved equipment by the Superintendent shall be used to handle the rolls of Geonet.

The Geonet shall be protected from ultraviolet light exposure, precipitation or other inundation, spills of hydrocarbons, mud, dirt, dust, puncture, cutting or other damaging deleterious conditions during delivery, storage and handling.

All rolls shall be stored off the ground on a hard, dry, free-draining surface, with suitable bearers at closely spaced centres, suitably protected from runoff, hydrocarbon spills, and other damage.

The Geosynthetics Installation Contractor shall be responsible for the storage of the materials for the Works.

5.3.3 Repairs

Rolls or panels of Unit 11 Geonet that have been damaged or have identified defects shall be brought to the attention of the GITA, who shall judge if the panel or roll is to be removed from site or may be repaired.

Should the GITA assess the geonet to be crushed or damaged, the following procedure shall be undertaken:

- The extent of the damaged geonet core shall be identified and marked out.
- The full panel width of the Geonet extent shall be cut and the damaged panel removed.
- A new panel of Geonet shall be installed in accordance with Section 5.3.1 of this Specification.

5.4 Unit 12 HDPE Geomembrane Liner

5.4.1 Installation by Subcontractor

The Works described below shall be undertaken by a Geosynthetics Installer as defined in Table 1 of the Specification.

The Contractor shall use the Geosynthetics Installer and the Geosynthetics Installer's key personnel to test and install the Unit 12 HDPE Geomembrane. The Contractor is responsible for all aspects of the Geosynthetics Installer's work. Any proposed change to the Unit 12 HDPE Geomembrane installation shall be subject to written approval from the Superintendent.

5.4.2 Transportation, Labelling, Handling and Storage

The Contractor shall be responsible for the off loading, on-site transportation and on-site storage of the Unit 12 HDPE Geomembrane to site. Rolls shall be stacked to provide access for roll identification and sampling for conformance testing. The integrity and legibility of roll labels must be maintained during storage. Unit 12 HDPE Geomembrane materials shall be stored in accordance with the Contractor's Quality Plan (refer to Section 1.18.2) and the Manufacturer's recommendations. This may include covering of Unit 12 HDPE Geomembrane rolls.

5.4.3 Placement

5.4.3.1 Layout Drawings

The Contractor shall present the Superintendent with its proposed Unit 12 HDPE Geomembrane Panel Layout Drawings as part of the method statement for Construction of pond liners (refer to Section 1.26) at least 5 days before installation starts, for review by the Superintendent. The drawings shall indicate the panel configuration, seam layout, the location and layout of complicated seams, the location of Unit 12 HDPE Geomembrane and the staging/direction of deployment. The layout drawings shall be suitable for use as construction drawings, shall be to scale and include dimensions and details.

Panels of Unit 12 HDPE Geomembrane installed on side slopes must extend on to the cell floor by not less than 1 m. The Superintendent must approve the drawings before installation commences.

5.4.3.2 Panel Identification

A field panel is the unit area of Unit 12 HDPE Geomembrane to be welded in the field and shall be bounded by field welds or anchor trenches. Each field panel shall be numbered and the panel layout drawings (refer to Section 5.3.3.1) shall show the panel numbers and the dimensions and area of each panel.

5.4.3.3 Field Panel Placement

Under no circumstances shall 4 field panels be placed so that the boundaries intersect at one point (cross seam). A minimum 200 mm shall be required to offset the occurrence of a cross seam.

5.4.3.4 Installation Schedule

Field panels shall be installed at the location and positions indicated in the panel layout drawings (refer to Section 5.4.3.1) approved by the Superintendent and using any one of the following schedules:

- Field panels for one day's installation may be placed prior to field welding (to protect the subgrade from erosion by rain, or desiccation).

  and/or

- Field panels are placed one at a time and welded when equilibrium temperature is achieved between panels (to minimise the number of unwelded field panels exposed to wind).

Panel placement shall take into account forecast weather conditions such as rain or high winds so as to manage the risk of possible damage from these conditions.

5.4.3.5 Method of Placement

The Contractor shall ensure that:

- No more geomembrane is deployed at any one time than can be reasonably welded in one day.
- Geomembrane rolls shall be unrolled in accordance with the instructions and the direction shown on the wrapping.
- No equipment used shall damage the geomembrane by handling, trafficking, leakage of hydrocarbons or other means.
- No materials shall be dragged or pushed along the surface of the geomembrane. Geomembrane damaged by this process shall be considered to be installation damage and the GITA shall advise the Superintendent whether the damaged area should be patched, capped or replaced.
- Personnel working on the geomembrane shall not smoke, wear studded footwear, or engage in other activities that could damage the geomembrane. The Contractor shall protect the geomembrane from damage by equipment or personnel traffic associated with construction.
- Methods used to unroll panels shall not cause scratches or crimps in the geomembrane and shall not damage the underlying materials.
- A geomembrane roll shall be unrolled in a controlled manner. A roll shall not be released to unroll freely down slopes.
- Geomembrane shall be cut with an approved knife with a retractable hooked blade to manage the risk of scoring the surface. Foldable bladed knives shall not be permitted. Cutting tools shall not be placed on the geomembrane surface, and shall be stored in secure containers to prevent accidental damage to the liner system.

- The prepared surface underlying the geomembrane shall not be allowed to deteriorate and shall be maintained in a condition suitable for geomembrane placement.
- Methods used to place panels shall preclude folds, wrinkles that may become folds, bridging (trampolining) and differential wrinkles between adjacent panels. Geomembrane panels placed on the slopes shall have no cross-slope seams. That is, panels must extend continuously from the crest to at least 1 m beyond the toe of the slope.
- During construction sand bags and/or rolls of geosynthetics shall be applied to prevent uplift or disturbance during high wind conditions. The bags and/or rolls shall be spread out along the free edges and shall not damage the geomembrane.
- All sandbags shall be fastened with nylon cable ties. Care shall be taken that soil used to fill the sandbags does not spill onto nor damage the geomembrane. Any areas of spillage, as determined by the Superintendent observed on the geomembrane shall be promptly swept up by hand brooms and removed.
- Care shall be taken that material in the anchor trenches does not spill onto the geomembrane.
- Joints shall be orientated so that overlaps are in the down slope direction (roof tile effect).

5.4.4 Damage and Defects

The supply of the geomembrane is the responsibility of the Contractor. Two types of defects may occur in the geomembrane; manufacturing defects which exist in the geomembrane as delivered to the Site and defects related to the installation of the geomembrane.

The Geosynthetics Installer is required to allow for the repair of the manufacturing defects and of installation defects. The following section clarifies the differences and limits related to different types of defects.

The following manufacturing defects shall apply.

5.4.4.1 Fisheye

A gel is also referred to as a “fisheye”, which is a thinning of the geomembrane. The specified minimum thickness of the geomembrane also applies to “fisheyes”. The size of the fisheye is of no consequence, as it is the thinning or absence of the geomembrane inside the fisheye, which is of concern. Geomembrane with ‘fisheye’ defects shall be removed and replaced.

5.4.4.2 Surface Blemishes

Surface blemishes are considered to be areas where the resin has not been properly mixed or filler can be noted on the geomembrane. The colour and surface texture of the geomembrane shall normally be uniform and consistent. Where changes occur in the surface texture or colour the Contractor shall request the GITA to inspect the area. If the area is rejected as unacceptable, then the section of the geomembrane roll shall be removed and replaced, and be treated as a manufacturing defect.

5.4.4.3 Scratches

Straight-line scratches that penetrate the geomembrane (approximately 0.1 mm) shall be pointed out to the GITA for consideration. The GITA shall inspect the deployment equipment and the shape of the defect to decide if it is a manufacture defect. The GITA decision shall be final. The roll length where such a defect occurs shall, if instructed by the GITA, be cut out and removed from site. The removed length of roll shall constitute one defect.

Defects in the geomembrane that result in non-ductile failure of the sheet shall be considered unacceptable. The acceptance of a scratch shall also be decided on this basis, and where considered appropriate the GITA shall instruct coupons to be recovered from the suspect area and be subject to tensile testing, to demonstrate whether the scratch results in ductile or non-ductile behaviour. Defects shall be capped.

5.4.4.4 Non-uniform Surface Texture

Geomembrane rolls which present a non-uniform pattern or intensity of texturing shall be considered as follows:

- If the texturing on both surfaces of the geomembrane sheet is similar, the sheet shall be accepted.
- If the texturing on the surfaces varies to the extent that the surface roughness of the surfaces is significantly different, the geomembrane shall be rejected. A difference in surface roughness over 4 m^2 is considered significant. The difference shall be decided by the GITA using a visual assessment, and shall be final.

5.4.4.5 Repair of Defects

The GITA shall mark defects as either manufacture or installation defects. The GITA shall record the manufacture and installation defects on a layout drawing.

All defects shall be patched or capped and subject to Quality Control (QC) testing, reporting and documentation by the Geosynthetics Installer. Repair of defects is part of the Geosynthetics Installers responsibility.

Inspections shall be carried out in daylight. The responsibility of identification of defects remains with the Geosynthetics Installer, but the type of defect is to be decided by the GITA. The risk of time delays is the responsibility of the Geosynthetics Installer, and it shall program any repairs to ensure the liner is completed on time.

5.4.5 Field Welding

5.4.5.1 Requirements of Personnel

Personnel performing welding operations shall be qualified as indicated below.

- Shall be qualified by experience or by successfully passing welding tests and at least one welder shall have welded a minimum of 100,000 m^2 of geomembrane using the same type of welding apparatus in use at the site.
- The Weld Foreman, most experienced welder, shall directly supervise less experienced welders, as required.
- No field welding shall take place unless the Weld Foreman is present.

5.4.5.2 Welding Equipment and Methods

5.4.5.2.1 Approved Processes for Field Welding

Only extrusion welding or fusion welding using equipment approved by make and model shall be used.

The Contractor shall maintain at least one spare, operable welding unit of each type employed on the project site at all times.

5.4.5.2.2 Fusion Welding Process

The preferred welding method to be employed shall be the dual track fusion welding process. Extrusion welding shall be used for Unit 12 HDPE Geomembrane repairs. The fusion-welding apparatus must be automated vehicular-mounted devices. The fusion-welding apparatus shall be equipped with gauges giving the applicable temperatures, speed and pressures. A temporary movable protective layer shall be used directly below each overlap of geomembrane that is to be welded to prevent build-up of moisture between the sheets.

Fusion welded seams shall be formed using a slip sheet below the weld to reduce the risk of sharp particles or mud being trapped in the underside of the welder, resulting in scoring of the underside of the geomembrane or low strength seams.

5.4.5.2.3 Extrusion Welding Process

The extrusion apparatus shall be equipped with gauges giving the temperature in the apparatus and at the nozzle. The extruder shall be purged before beginning a weld and until all heat-degraded extrudate has been removed from the barrel. Whenever the extruder is stopped, the barrel shall be purged of all heat degraded extrudate.

5.4.5.2.4 Protection of Geomembrane

The electric generator shall be mounted on a wheeled trolley so that it is not dragged across the geomembrane. A smooth insulating plate or fabric shall be placed beneath the hot welding apparatus after usage to protect the geomembrane. The wheeled trolley shall not be moved onto the geomembrane without inspection of the wheels to ensure no trapped particles pose a puncture risk to the geomembrane. Refuelling shall not spill fuel onto or damage the geomembrane.

5.4.5.3 Seam Layout

No cross-joints shall be allowed unless approved by the Designer. All fusion joints between panel ends are to form T-joints, with panel layouts being staggered to achieve this. All T-joins, defects, etc shall be patched and be subject to quality testing. The minimum distance between T seams shall be 200 mm.

All seams and joints shall be numbered or named by the Geosynthetics Installer which shall be cross-referenced to field notes and records of the Contractor. Seam names or numbers shall be marked on the seam layout drawing, and altered as required on the As-Built drawings.

5.4.5.4 Weather Conditions for Welding

Geomembrane jointing and welding shall not be started if the geomembrane temperature is below 10ºC or above 35ºC, unless otherwise authorised by the GITA. Geomembrane jointing shall not be undertaken in the rain, in the presence of excessive moisture (e.g. fog, dew), in an area of ponded water, or during periods of high wind or excessive dust. If welding is permitted during high temperature days, the Geosynthetics Installer shall demonstrate to GITA that the intended welder settings do not result in so called ‘Hot Weather’ seams. This shall be demonstrated on trial samples where both sides of the seam can be inspected and shall be prepared and welded in the field on geomembrane that has been exposed to the weather for at least one hour.

5.4.5.5 Weld Preparation

Prior to welding, the weld area shall be cleaned and free of moisture, dust, dirt, debris, markings and foreign material.

If seam overlap abrading is required, the process shall be completed within one hour of the welding operation and in a way that does not damage the geomembrane. Abrasion of the geomembrane surface shall not extend outside the weld bead or weld surface area. Seams shall be aligned to minimise the number of wrinkles.

Artificially induced cooling of the extrudate welds using water or other means is not permitted. Care shall be exercised to ensure that non-destructive testing of the extrudate and/or other conditions does not cause artificial cooling of the weld.

The edge flap of fusion seams shall not be ripped from the seam to inspect the “squeeze-out” from the weld. Any required removal of geomembrane material shall be carried out by careful cutting.

The Contractor shall record the following information on the geomembrane surface adjacent to the weld:

- Unique seam number.
- Welding device number and operating temperature.
- Welding technician’s initials.
- Date and time.

The information shall be recorded in permanent ink to ensure the information is legible for the duration of the Works.

5.4.5.6 Overlapping and Temporary Bonding

Panels of geomembrane shall be overlapped by a minimum of 75 mm for extrusion welding and 125 mm for fusion welding. The Geosynthetics Installer shall make appropriate allowance for the effect of shrinkage of panels related to changes in temperature, to ensure the required overlap during welding. The overlap shall be sufficient to allow peel tests to be performed on the weld, and to provide enough space to form a reliable air channel between dual fusion welds for testing.

The procedure used to temporarily bond adjacent panels together shall not damage the geomembrane in particular; the temperature of the air at the nozzle of any spot welding apparatus shall be controlled such that the geomembrane is not damaged.

5.4.5.7 General Welding Procedures

The general welding procedure used by the Contractor shall be as follows:

- Welding shall extend to the outside edge of panels to be placed in the anchor trench.
- Ends of the air channel of dual fusion welds extending into anchor trenches shall be welded closed.
- If required, a firm substrate shall be provided by using a flat board, piece of geomembrane, a conveyor belt, or similar hard surface directly under the seam overlap to achieve proper support.
- Fish-mouths or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle to achieve a flat overlap. The cut fish-mouths or wrinkles shall be welded and then be patched with an oval or round patch of the same geomembrane extending a minimum of 150 mm beyond the cut in all directions.
- All cuts and patches shall be formed with rounded edges and ends, to prevent stress concentrations in the geomembrane. All cuts shall be removed or be ended off with a round cut-out.

5.4.6 Testing

5.4.6.1 Trial Welds

Each welding technician shall qualify to operate on a daily basis, by performing a trial weld prior to welding activities or at times designated by the GITA. These trial welds shall be performed using each type of welding device to be employed by the welding technician during that period. Additionally, a trial weld shall be made using each welding device on resumption of work after breaks, or at an interval of no greater than 5 hours, whichever is less. A trial weld may also be required if ambient conditions change significantly. During hot weather welding (ambient temperature higher than 35°C) trial welds shall be carried out every three hours. The GITA may also require that a trial weld be performed using each device at the conclusion of welding activities.

Welding devices that have not produced a passing trial weld will not be permitted to perform production welding.

Trial welds shall be made on “fragment” pieces of geomembrane liner to verify that welding conditions are adequate. The trial weld sample shall be at least 0.3 m wide and 1.5 m long for fusion welds or 1.0 m long for extrusion welds with 125 mm overlap, with the weld centred length-wise along the long side. All trial welds shall be performed under the same weather and subgrade conditions as production welding.

Three specimens each (25 mm) wide shall be cut from the trial weld sample by the Geosynthetics Installer - one near each end and one near the mid-point. The two near end specimens shall be tested in peel and the mid-point sample tested in shear. All test results shall be recorded, including failed and passed tests.

All trial weld specimens shall be tested in the field by the Geosynthetics Installer in the presence of the GITA, using an electrically operated tensiometer where the force exerted is displayed. The Geosynthetics Installer shall supply evidence demonstrating that the tensiometer has been calibrated within the previous 12-month period. The separation test rate shall be approved by the GITA, and shall not be greater than 50 mm/min.

5.4.6.1.1 Trial weld acceptance criteria for Unit 12 HDPE Geomembrane

- Peel Test

  Both tracks of dual-track fusion welds shall be tested for peel adhesion. Peel strength of dual-track fusion welds shall meet at least 65% of the tensile strength of the parent geomembrane material where it fails in the material. If either track fails within the weld, the test specimen is considered to have failed. Peel strength of extrusion welds shall meet at least 60% of the tensile strength of the parent geomembrane material where it fails in the material.

- Shear Test

  The shear test specimen shall, at a minimum, meet a strength of ninety five percent (95%) of the tensile yield strength of the parent geomembrane material where it fails in the material (i.e. film tear bond).

The strength of the parent geomembrane material shall be determined before each trial weld by cutting one 25 mm wide specimen with a dye from one of the “fragment” pieces of geomembrane that has been used to construct the trial weld. This procedure provides “one for one” testing and eliminates the effect of temperature or variability in the material influencing the results of the trial weld.

Alternatively, if the tensiometer is calibrated to reliably display the strength value of the seam test, then the minimum specified yield strength of the geomembrane in Table 19 may be used for comparison of the seam test results. It is the Contractor’s responsibility to satisfy the Superintendent that the tensiometer readout and the procedure to prepare the specimen results is a reliable reflection of the true strength value of the seam.

A specimen will be deemed to have failed if:

- It fails in the weld (i.e. the weld is weaker than the material and does not hold).
- It fails in peel at less than 65% or 60% of the parent materials tensile yield strength depending on weld type as outlined above.
- It fails in shear at less than 95% of the parent material's tensile yield strength.

If any one of the three specimens fails, the entire trial weld is considered to have failed.

In the event that a trial weld fails, the entire trial weld procedure shall be repeated after the appropriate adjustments to the welding device and/or operator has been made. If a second trial weld fails the welding device and/or the welding technician shall be rejected and shall not be used for welding until such time as the deficiencies are resolved, verification of the resolution is provided, and a successful trial weld performed.

5.4.6.2 Non-destructive Weld Continuity Testing

5.4.6.2.1 General

The Geosynthetics Installer shall non-destructively test all field and factory welds over their full length using a vacuum test unit, air pressure test (for double fusion welds only), or other methods approved by the Designer. Vacuum testing and air pressure testing are described below. Spark Testing may be undertaken and shall be carried out in accordance with ASTM D 6365. The purpose of the non-destructive test is to check the continuity of welds. Continuity testing shall be done as the welding work progresses to identify issues early and reduce the risk of large portions of welds requiring remediation. Testing of welds shall not be delayed more than 3 days of welding. Any welds that fail non-destructive testing shall be repaired in accordance with the Specification. Welds, which cannot be non-destructively tested because of seam geometry, shall be double welded or capped.

All test equipment shall be in calibration and conform to manufacturer's specifications. The Geosynthetics Installer shall submit current calibration certificates.

The Geosynthetics Installer shall demonstrate to the GITA at the beginning of the job, and as otherwise directed by the GITA, that the testing equipment is in good working order by testing a test seam with a defect.

5.4.6.2.2 Spark Testing

The procedure for Spark Testing shall be as follows;

1) As the weld is fabricated a continuous electrically conductive wire is to be located in the lapped area of the panels at a distance of 2 mm to 5 mm from the edge of the top panel of membrane.
2) Prior to testing it is necessary to connect the conductive material installed in the field seam to the negative terminal of the voltage source. This is typically the subgrade under the geomembrane.
3) Set the voltage source to the appropriate voltage needed for the expected distance to the conductive wire. The user should verify that the test voltage will not damage the geomembrane.
4) Check that the field seam and areas adjacent to the seams are dry prior to testing.
5) Place the voltage application connected to the positive terminal of the voltage source.
6) Move the voltage applicator along the seam at a uniform rate of 6 m/min. The voltage applicator must make intimate contact with the seam inspected. Both edges of the extrusion welds are to be tested.
7) As the test progresses, the generation of a spark indicates a suspect area in the seam.
8) The suspect area is to be marked for repair.

5.4.6.2.3 Vacuum Testing

The equipment shall comprise the following:

1) A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole or valve assembly, and a vacuum gauge showing the pressure in the box.
2) A steel vacuum tank and pump assembly equipped with a pressure controller and connections.
3) A rubber pressure/vacuum hose with fittings, pressure gauge linked to the window housing and connections.
4) A soapy solution to be applied over seam area.

Each section of the weld to be tested shall be tested to a pressure of at least minus 35 kPa.

Each section of seam shall be vacuum tested for a period of not less than 10 seconds by examining the geomembrane through the viewing window for the presence of soap bubbles. Adjoining area shall to be tested with a minimum 75 mm overlap between sections.

5.4.6.2.4 Air Pressure Testing

The following procedures are applicable only to those processes that produce a double weld with an enclosed air channel. All double welds with an enclosed air channel shall be air pressure tested.

The equipment shall be comprised of the following:

1) An air pump (manual or motor driven) capable of generating and sustaining a pressure of 350 kPa.
2) A rubber hose with fittings and connections.
3) A sharp hollow needle or other approved pressure feed device.
4) A calibrated pressure gauge capable of reading pressures up to 450 kPa, with a tolerance of less than 5 kPa.

The following procedures shall be used:

1) Seal both ends of the weld to be tested by grinding through the upper panel and sealing the air channel by extrusion welding.
2) Insert needle with pressure gauge, or other approved pressure feed device within 300mm of one of the sealed ends, into the air channel created by the fusion weld.
3) Energise the air pump and pressurise the channel to between 300 kPa to 350 kPa. Close the valve and sustain the pressure for a minimum of 5 minutes. The Geosynthetics Installer may propose a greater test pressure with shorter periods of observation for consideration by the GITA. A pressure drop of less than 15 kPa is allowable, but the air pressure is still required to stabilise for a minimum of 5 minutes.
4) If loss of pressure exceeds 15 kPa, or does not stabilise, locate faulty area and repair in accordance with this section. If, in the judgement of the GITA, significant changes in geomembrane temperature occur during the test (e.g., due to cloud cover), the test shall be repeated after the geomembrane temperature has stabilised.
5) Cut end of weld opposite to the pressure gauge and observe that the pressure drops. If the pressure does not drop, locate the obstruction(s) in the weld, repair, and retest weld.
6) Remove needle or other approved pressure feed device and repair all holes and damage made to the air channel by extrusion welding over the damage.

Alternative testing procedures may be considered by the Superintendent based on submission of relevant information by the Geosynthetics Installer. If an alternative testing procedure is to be considered by the Geosynthetics Installer shall submit information to the Superintendent at least 14 days before the procedure is to be used.

5.4.6.3 Destructive Weld Continuity Testing

The Geosynthetics Installer shall recover field weld samples for destructive testing at locations selected by the GITA. The purpose of these tests is to evaluate field weld strength and integrity. Field weld testing shall be done as the welding work progresses, not at the completion of all field welding. The Superintendent will arrange for testing of the samples at an independent laboratory.

5.4.6.3.1 Location and Frequency

Destructive test samples shall be collected at an initial average frequency of one test location per 100 m of seam length. As welding progresses the frequency of testing may be increased or decreased by the Superintendent in consultation with the GITA based on the performance of:

- Trial Welds.
- Previous destructive testing.
- Air Pressure testing.

Test locations shall be determined during welding, and may be prompted by suspicion of excess crystallinity, contamination, offset welds, or any other potential cause of imperfect welding. The Geosynthetics Installer shall not be informed in advance of the locations where the samples will be taken. The Superintendent reserves the right to increase the frequency depending on the test results of samples taken.

5.4.6.3.2 Sampling Procedure

The Geosynthetics Installer shall cut samples at locations designated by the GITA as welding progresses to obtain laboratory test results before the geomembrane is covered by another material. Each sample shall be numbered and the sample number and location identified on the panel layout drawing.

All holes in the geomembrane resulting from destructive weld sampling shall be immediately repaired and tested in accordance with repair procedures in the Specification. Cuts to remove the samples shall be rounded to prevent stress concentrations in the geomembrane.

5.4.6.3.3 Size of Samples

The samples shall be minimum 0.3 m wide by 0.6 m long with the weld centred length-wise. The sample length shall be increased to provide material for additional laboratory testing or archiving. Two specimens shall be cut from each end of the sample for preliminary field tests. Each portion of the test sample shall be labelled with a unique number for the sample, and referenced to the joint number from where the sample was taken. The sample number shall be noted on the As-Built drawings. The GITA may direct the Contractor to reduce the length of the sample removed from the welds, if the GITA is satisfied that field testing indicates high quality welds.

5.4.6.3.4 Weld Destructive Tests

- Preliminary Field Testing

  Two specimens, one from each end of the weld destructive sample, shall be removed and tested for peel adhesion by the Geosynthetics Installer in accordance with ASTM D6392. The results of this testing shall be evaluated in accordance with the criteria as detailed under ‘Trial weld acceptance criteria for Unit 12 HDPE Geomembrane’ in Section 5.3.6.1 of the Specification. If either of the two field specimens fails, the entire

destructive test is considered to fail and additional destructive test samples shall be taken in accordance with the procedures of the Specification.

- Laboratory Weld Sample Destructive Testing

  The destructive weld testing will be performed in an off-site geosynthetic testing laboratory, to be nominated by the Superintendent. Typically, tests performed by the laboratory shall be completed and the results reported to the Superintendent within 72 hours of receipt of samples at the laboratory.

  Laboratory destructive testing shall be carried out on at least 10% of the destructive weld samples of the project, or at least 5 samples, whichever results on the greater number of tests.

  Tests shall be performed on 10 specimens cut from each destructive weld sample. From each sample, 5 specimens shall be tested in shear and 5 specimens shall be tested in peel. The shear and peel specimens shall be selected from the sample alternately, so that no two adjacent specimens are tested in the same mode.

  Tests shall include a plot of load versus elongation for each specimen and report the strength and failure mode.

  The scope of laboratory testing can be increased by the GITA based on field observations and the results of field testing.

- Laboratory Testing Weld Evaluation Criteria

  Each weld sample must satisfy both the shear and peel criteria. All testing and evaluation shall be carried out in accordance with ASTM D 6392.

5.4.6.3.5 Destructive weld acceptance criteria

- Shear

  The weld strength shall be, at a minimum, equal to 95% of the rated yield tensile strength of the geomembrane sheet, as specified in the minimum property values provided by the Contractor from the geomembrane manufacturer.

- Peel Adhesion

  The weld peel strength for fusion welds shall be equal to or greater than 65% of the rated tensile yield strength of the geomembrane sheet, as specified in the minimum property values provided by the Contractor from the geomembrane manufacturer in accordance with the Specification. For extrusion welds, the weld peel strength shall be equal to or greater than 60% of the rated tensile yield strength of the geomembrane sheet.

For both shear and peel tests, where the strength is measured to be less than the acceptance criteria above, the testing laboratory shall test the tensile yield strength of a sample of geomembrane adjacent to the seam, sampled at least 50 mm from the weld area of the seam. If the value is lower, it shall be regarded as the rated tensile yield strength of the material.

For both shear and peel tests, the specimen shall fail in the geomembrane sheet, not in the weld area. This is referred to as “film tear bond” (FTB). The specimen shall be defined as failing in the weld if any portion of the weld exhibits separation across more than 10% of the width. Each track of a dual-track fusion weld shall be considered to be a separate weld for the purpose of calculating the percentage separation. If more than one specimen fails in shear, the entire weld destructive test sample shall be considered as failing.

Weld sample specimens shall deform in a ductile manner. The deformation of test specimens shall be assessed by the Superintendent, considering the parent material properties, the type of weld, the type of weld specimen test and the condition of the weld after the test.

5.4.6.3.6 Failed Destructive Sample Procedure

The Geosynthetics Installer shall reconstruct the deficient weld once the extent has been determined. All welds that are to be reconstructed shall be bound by passing destructive tests. The Geosynthetics Installer shall trace deficient welds by taking specimens for field testing or by obtaining additional weld destructive samples at a nominal of 5 m intervals in both directions along the deficient weld from the failure location. If tracing by taking field specimens is chosen, the Geosynthetics Installer shall continue to obtain specimens from the weld at 3 m intervals until it has confidence that destructive samples which will pass laboratory testing can be obtained. A full laboratory sample will then be taken at that location and tested. If one or both of these samples fail the laboratory test, then the procedure is repeated in that direction until passing laboratory results are obtained. For the purposes of tracing a weld, the weld is considered to be the path of the given fusion welding apparatus or extrusion welding device/technician combination and may, if necessary, extend beyond any given welding period. Tracing which requires obtaining more than 2 specimens in either direction from the location of the initial failed destructive weld sample shall be brought to the attention of the Superintendent and the process approved by the Superintendent prior to continuing. A review of the Geosynthetics Installer's procedures and performance may be conducted.

Alternatively, the Geosynthetics Installer may elect to cap the full length of the weld if they do not choose to trace the deficient weld.

5.4.7 Repairs

5.4.7.1 General

All weld and non-weld areas of the geomembrane shall be visually inspected by the Geosynthetics Installer for signs of damage, defective welds, blisters, punctures, undispersed raw materials, and any sign of contamination by foreign matter. Any defective or flawed areas observed shall be marked, repaired, tested, or removed from the installation and disposed of.

Unless otherwise approved by the GITA, all air channels produced by the dual track fusion welding process shall be sealed at both ends and at any location where the air channel is severed and made discontinuous. The method of sealing shall be agreed between the Geosynthetics Installer and the GITA.

All repairs shall be subjected to quality testing either non-destructively or destructively as directed by the GITA.

The repair procedures shall be in accordance with the Quality Plan (refer to Section 1.18.2). The minimum repair methodologies are described in the Specification.

Any repairs (patches, caps, etc.) may, at the discretion of the GITA, be destructively tested. Where in the opinion of the GITA a liner panel requires an unacceptably high number of patches, the panel shall be removed and replaced. As a guide, a patch density within the panel, excluding patches for joints, of more than one per 50 m length of panel, or per 300 m^2 of liner, is considered the maximum. This may be varied at the discretion of the GITA depending on the layout of panels.

All cuts made in the geomembrane shall be ended in a round eye, and any cut-out shall be formed with rounded corners to prevent stress concentrations in the geomembrane.

5.4.7.2 Patching

Patches shall be used to repair defects such as holes (including areas from which destructive test samples were obtained) and pinholes (exclusive of non-destructive testing air pressure needle holes) which penetrate the entire geomembrane thickness, tears and crazing. Small surface blemishes and localised flaws which do not penetrate the entire thickness of the geomembrane shall also be patched.

Areas of crazing shall be cut longitudinally (along the length). The ends of all holes shall be rounded, to prevent further propagation, prior to patching. Patches may be used to cover areas of undispersed raw material or contaminated by foreign substances (gasoline, oil, etc.), if approved by the GITA. Patches shall extend a minimum of 150 mm beyond the limits of the defect and all corners of patches shall be rounded. Patches shall follow the contour of the defect area and remain free of crimping or pinching. The geomembrane material used for patches must, at a minimum, meet the requirements of the Specification.

Patches and defect areas shall be free of dirt, moisture, debris and markings. Patches shall be temporarily bonded by heat welding. Chemical adhesives and tape are prohibited. The perimeter of the patch shall be abraded with a hand-held grinder to produce a bevelled edge. Patches shall be temporarily installed by heat welding along the entire perimeter of the patch and defect areas. The patch shall be installed flat along all edges with no wrinkles or folds. The patch weld area shall be abraded no more than 1 hour in advance of permanent welding. Heat welding and abrasion shall not cause excessive melting, wear or puncturing of the geomembrane material; such occurrences shall be considered defects and shall be repaired by patching.

Patching or repairs that require more than two passes of a welding procedure shall be considered as a defect, and be covered by a patch. Patches covering parts of other patches are not acceptable.

5.4.7.2.1 Capping

A cap is a patch of extended length and may be used to repair failed welds. Caps shall extend a minimum of 150 mm beyond the limits of the defective weld and all corners shall be rounded. Caps shall be installed as detailed in the Specification for patches.

A cap used to repair a failed weld or portion of weld shall be destructively tested if it exceeds 35 m in length or if the weld is of questionable quality. Caps over failed welds shall be carried out only with the approval of the GITA if no other method of repair is feasible. Where welds are being repaired by caps, in general, the failed weld shall be cut out, and the cap is welded using fusion welding over most of the joint. The length of extrusion weld required to close-off the cap shall be kept to a minimum, and shall be closed-off after the fusion weld has been pressure tested.

Where a length of dual-track fusion weld that is less than 10 m is not holding air when tested non-destructively by the air pressure testing method, the weld may be repaired by bevelling the edge, abrading the sheet surface, and applying an extrusion weld along the exposed edge (flap) of the seam. Failed welds repaired in this manner must conform to the requirements of the Specification and be vacuum box tested. If the length of the weld exceeds 10 m, and the flap is not wide enough to allow destructive testing of the extrusion weld (without first testing through the fusion weld), then the weld must be reconstructed by capping.

5.4.7.2.2 Grinding and Welding

Grinding and extrusion welding shall be used to repair sections of defective extrusion weld less than 0.3 m in length. Areas requiring repair shall be abraded no more than 1 hour prior to the repair being made.

5.4.7.2.3 Geomembrane Wrinkles and Bridging

Geomembrane wrinkle and bridge size and extent shall be minimised to the satisfaction of the GITA. Wherever possible wrinkles shall be kept small and spread over the panel. In general, wrinkles which, when loaded, will result in a fold in the geomembrane are too large. Wrinkles or bridging larger than 300 mm high shall be cut and fusion welded as a seam if the overlap is sufficient, in accordance with the Specification. Where the overlap is not sufficient, the wrinkle shall be cut and patched or capped as detailed in the Specification. Whenever it is not possible to manage wrinkles to less than specified, wrinkles shall be combined through accumulation so as to minimise the number of repairs being made.

The Contractor shall submit a method statement to the Superintendent for approval to manage the risk of wrinkles in the permanent works. The Contractor shall consider the following:

- The methodology and timing of placing material over the geomembrane to minimise wrinkles.
- Covering in cooler periods.
- Displacing the trapped air under the liner to an area where the air can be released from below the liner. This is generally achieved using a vent flap, to be formed at a location in the liner agreed with the Superintendent.

5.4.8 Site Management

Site management during installation of geomembrane shall protect the integrity of the geomembrane. Materials that could potentially damage the geomembrane shall not be present in the works. For example, offcuts from geomembrane shall be collected and removed from the works as they are created.

5.5 Anchor Trenches

Anchor trenches shall be used to constrain deployed panels of Unit 10 BGM, Unit 11 Geonet and Unit 12 HDPE Geomembrane on the inner embankment batters of the ponds as shown on the Drawings. The anchor trenches shall also be used to constrain Unit 13 Cushion Geotextile and Unit 9 Separation Geotextile placed along the alignment of the Unit 17 Riser Pipe.

The anchor trenches shall be excavated to the minimum depth, width and offset from the inner crest indicated on the Drawings prior to placement of the Unit 10 BGM.

The inside crest of the anchor trenches shall be rounded off to facilitate the placement of the geosynthetic materials over the edge of the trench wall in a manner to the satisfaction of the GITA to prevent damage to the geosynthetics. Hand methods may be required to smooth the rounded edge to the satisfaction of the GITA.

Loose soil and ponded water shall not be permitted in the anchor trenches. Anchor trenches shall be constructed and maintained so as to provide for free flow drainage of surface water and to prevent ponding in or adjacent to anchor trenches. Any sharp or angular particles shall be removed from the trenches prior to installation of geosynthetics.

The excavation of the anchor trenches shall be presented to the Superintendent for inspection and approval before backfilling commences.

The geosynthetics placed in the anchor trenches shall extend down the side and across the base of the trench in accordance with the Drawings.

5.6 Backfill of Anchor Trenches with Unit 6 Cement Stabilised Sand

The methodology for backfill of the anchor trenches shall be approved by the Designer and the Superintendent. Backfill of the anchor trenches shall be placed carefully over the placed Unit 10 BGM, Unit 12 HDPE Geomembrane using Unit 6 Cement Stabilised Sand as backfill.

Placed backfill shall be free from lenses or pockets that differ substantially in composition, texture, moisture content or density from the surrounding material. If the Contractor detects material changes or variations, it shall notify the Superintendent who shall assess the material for suitability.

The surface of placed Unit 6 Cement Stabilised Sand shall be shaped to prevent ponding of water on the surface of the layer.

The integrity of the completed backfill shall be maintained by the Contractor. This includes limiting traffic movements on completed works and prevention of disturbance, excessive wetting, and erosion. Should the placed material be disturbed, excessively wetted, or eroded, as determined by the Superintendent or the GITA, then the Contractor shall rework material to the satisfaction of the Superintendent and the GITA.

Backfill of the anchor trenches shall be staged to facilitate installation of the floating covers.

Where the anchor trench is without backfill or partially backfilled, the Contractor shall install temporary ballast to manage the risk of pull-out of the installed Unit 10 BGM and Unit 12 HDPE Geomembrane prior to installation of the floating cover and full backfilling of the anchor trench.

The methodology for staging backfill and geosynthetics placement shall be reviewed by the Designer prior to implementation.

The Superintendent shall be present during placement and any removal of backfill in the anchor trenches.

6.0 CONSTRUCTION OF THE SUMPS AND RISERS

6.1 General

The sumps shall be constructed in accordance with the Drawings, including the following:

- The sump is located at the lowest corner of the pond. Sump riser pipes shall be extended to above the elevation of the final constructed surface as per the Drawings.
- The groundwater drainage system shall terminate outside the sumps.
- The pond liners shall extend to the sumps and be constructed as described in Section 5.0 with Unit 2 Select Fill, Unit 10 BGM, Unit 11 Geonet and Unit 12 HDPE Geomembrane.
- Unit 13 Cushion Geotextile shall be placed on the internal batter along the alignment of the Unit 17 Riser Pipe and in the sump as shown in the Drawings and in accordance with Section 6.2. Unit 13 Cushion Geotextile is to protect the underlying Unit 12 HDPE Geomembrane from damage by the Unit 5 Sump Drainage Aggregate and the pre-cast concrete box. The extent of the Unit 13 Cushion Geotextile must include the full area to be covered with Unit 5 Sump Drainage Aggregate.
- The Unit 17 Riser Pipe shall be secured at the crest of the pond with a concrete wing wall on a cast in-situ concrete slab as per the Drawings, including the following:
  - The cast in-situ concrete slab shall be constructed with Unit 20 Concrete in accordance with the specifications provided in the Drawings. The top of the concrete slab shall finish flush with the embankment crest. The top of the concrete headwall that connects to the floating cover shall have a smooth finish and be constructed within the tolerances specified in the Drawings.
  - The pipe penetrated diameter through the concrete headwall shall be greater than the diameter of the Unit 17 Riser Pipe to allow for expansion and contraction movement of the pipe.
  - All concrete and formwork shall be in accordance with AS 1379.
- Unit 17 Riser Pipe for the leachate extraction riser pipe shall be secured at the base of the sump in the pre-cast concrete box.
- Unit 5 Sump Drainage Aggregate shall be placed as backfill around the Unit 17 Riser Pipe and pre-cast concrete box (leachate extraction riser only) in the sump, and as cover over the Unit 17 Riser Pipe up the internal batter extending 300 mm above the top row of pipe perforations. The Unit 5 Sump Drainage Aggregate shall be placed in accordance with Section 6.3. The interface between the Unit 5 Sump

Drainage Aggregate and the Unit 6 – Cement Stabilised Sand shall be separated with Unit 9 – Separation Geotextile to prevent the flowable material ingress into the aggregate voids.

- Unit 6 – Cement Stabilised Sand shall be placed as cover over the Unit 17 Riser Pipe up the internal batter to form a planar surface that finishes flush with the Unit 12 HDPE Geomembrane at the crest. The planar surface is required to facilitate construction of the floating cover. A 1 m wide and 100 mm thick mesh reinforced concrete strip shall be placed above the pipe to prevent cracking associated with thermal expansion of the Unit 17 Riser Pipe.
- Unit 13 Cushion Geotextile shall be placed between Unit 5 Sump Drainage Aggregate and the Unit 12 HDPE Geomembrane on the internal batter and in the sump. Construction of the Unit 13 Cushion Geotextile shall be in accordance with Section 6.2 and shall include wrapping the Unit 13 Cushion Geotextile over the edges of the Unit 5 Sump Drainage Aggregate as indicated in the Drawings. The Unit 13 Cushion Geotextile may need to be positioned prior to completing placement of the Unit 5 Sump Drainage Aggregate to achieve the required edge details.

6.2 Unit 13 Cushion Geotextile

6.2.1 Transportation, Handling and Storage

All on-site transportation, storage and handling of the Unit 13 Cushion Geotextile will be the responsibility of the Contractor. During storage, the cushion geotextile shall be protected from ultraviolet light exposure, precipitation or other inundation, spills of hydrocarbons, mud, dirt, dust, puncture, cutting or other damaging deleterious conditions.

Rolls of cushion geotextile shall be inspected by the GITA for foreign inclusions such as broken needles, staples on the core tube or any other hard material that may compromise the function of the cushion geotextile and the underlying Unit 12 HDPE Geomembrane. The foreign materials shall be removed and stored in sealed bags.

Material damaged during storage and handling shall be rejected by the Superintendent and be removed from site and replaced at the Contractor’s expense.

The Contractor shall handle all cushion geotextile in a manner to ensure it is not damaged and shall comply with the following:

- All cushion geotextile shall be weighted with sandbags or equivalent until covered with overlying materials.
- Cushion geotextile shall be cut using an approved cutting method and approved equipment only. Care shall be taken to protect the underlying geosynthetics from damage which could be caused to them by cutting the cushion geotextile.
- During placement, care shall be taken not to entrap soil, stones, excessive dust, or moisture that could damage either the cushion geotextile or the underlying geosynthetics, or clog the cushion geotextile, or hamper subsequent seaming or joining. The underlying Unit 12 HDPE Geomembrane shall be swept prior to installation of the cushion geotextile.
- Cushion geotextile shall be examined over the entire surface after installation, to ensure that no potentially harmful foreign objects are present. Any foreign objects encountered shall be removed or the geotextile shall be replaced.
- Any spreader bar used to deploy the geotextile shall include adequate measures to prevent scoring of the underlying geosynthetics and these will be inspected every day by the GITA.

6.2.2 Seams and Overlaps

Unit 13 Cushion Geotextile shall be joined according to the following requirements:

- Areas to be joined shall be clean and free of foreign matter.
- No cross-slope joints shall be allowed on slopes.
- Geotextile joints shall be overlapped by 100 mm and be heat bonded with a welder specifically designed for geotextile seaming.
- Any blow holes or damage caused by the heat bonding shall be patched by Unit 13 Cushion Geotextile (see Section 6.2.3 Repairs).

6.2.3 Repairs

Any holes or tears in the Unit 13 Cushion Geotextile shall be repaired as follows:

- Soil or other material that may have penetrated the torn cushion geotextile shall first be removed.
- On slopes, a patch made from the same Unit 13 Cushion Geotextile, shall be heat bonded into place (with at least 200 mm overlap to any edge). Should any tear exceed 10% of the width of the roll, that roll shall be removed from the Works and replaced.
- Elsewhere, a patch made from the same Unit 13 Cushion Geotextile shall be spot-seamed in place with a minimum of 200 mm overlap in all directions.

6.3 Unit 5 Sump Drainage Aggregate Placement

The Contractor shall be responsible for the selection, loading and transport of the Unit 5 Sump Drainage Aggregate from the source location, and placement of the aggregate on the internal batters along the alignment of the Unit 17 Riser Pipe and in the sumps.

Placement of the Unit 5 Sump Drainage Aggregate shall consider the installation of, and protection of the geosynthetic materials. The Contractor shall consider the following for supply and placement of the aggregate:

- Protection of the integrity of the underlying materials including the Unit 13 Cushion Geotextile, Unit 12 HDPE Geomembrane, Unit 11 Geonet and Unit 10 BGM.
- Considerations and limitations on access over areas underlain by geosynthetic materials.
- Potential for breakdown of the aggregate during handling and placement and the generation of fine grained particles that may not comply with the specified requirements.
- Non-uniform particle size distribution during production, stockpiling, handling and placement. This includes accumulation of fine grained particles in localised locations that do not comply with the specified requirements.
- Potential inclusion of non-conforming materials during the loading of the aggregate at the source or stockpile.
- Carrying out corrective action for non-conformances in particle size distribution in the placed material. This includes consideration of the protection of the integrity of the Unit 13 Cushion Geotextile, Unit 12 HDPE Geomembrane, Unit 11 Geonet and Unit 10 BGM.

Unit 5 Sump Drainage Aggregate shall be placed on top of the Unit 13 Cushion Geotextile overlying the Unit 12 HDPE Geomembrane to form a continuous backfill around the Unit 17 Riser Pipe and pre-cast concrete box (leachate extraction riser only), as shown on the Drawings. The Contractor shall take care to ensure that the Unit 5 Sump Drainage Aggregate is worked around the Unit 17 Riser Pipe to provide uniform support around the pipe.

Placement of the Unit 5 Sump Drainage Aggregate shall not impact on the integrity of the underlying liner system, nor the Unit 17 Riser Pipe.

The Unit 5 Sump Drainage Aggregate shall be placed in a manner so as to ensure uniform particle size distribution.

The Unit 5 Sump Drainage Aggregate shall be handled and spread in a manner so as to manage the risk of particle crushing or abrasion to a practical minimum. Spreading of the aggregate to the required shall be carried out with low bearing pressure equipment.

The placement shall be carried out so that trapped air under the geomembrane is directed to vent flaps at the edge of the works and so that wrinkles in the geomembrane do not form creases or similar.

Vehicles are not permitted to traffic on the surface of the Unit 13 Cushion Geotextile or Unit 12 HDPE Geomembrane. Sequencing of the Works, and the methodologies for transport of Unit 5 Sump Drainage Aggregate to the sumps, and for placement of the Unit 5 Sump Drainage Aggregate in the sumps, shall consider these limitations on vehicle access.

Spreading of Unit 5 Sump Drainage Aggregate shall be carried out to prevent stretching, tearing, distortion or other damage to the Unit 13 Cushion Geotextile and Unit 12 HDPE Geomembrane. Blades of construction equipment that are used to place and spread the aggregate shall not move within 200 mm of the surface of the geosynthetic layers.

Aggregate shall be carefully placed around the Unit 17 Riser Pipe and the pre-cast concrete box (leachate extraction riser only). The aggregate shall be shaped to a planar surface finished flush with the Unit 12 HDPE Geomembrane at the crest. The planar surface is required to facilitate construction of the floating cover.

Locking of tracks of excavators shall be prohibited. Stopping shall be carried out slowly. Where sudden stoppage of a vehicle was required, the underlying geosynthetics shall be exposed to assess if damage has occurred.

The GITA shall be present on site to view the placement of the Unit 5 Sump Drainage Aggregate. Where damage occurs to the underlying materials, the Superintendent shall direct the Contractor on the actions required for repair.

7.0 CONSTRUCTION OF THE LEACHATE INLET PIPE

7.1 General

The leachate inlet pipe shall be constructed in accordance with the Drawings, including the following:

- The leachate inlet pipe is located at the south-east corner of the pond. Unit 18 Leachate Inlet Pipe shall be extended to above the elevation of the final constructed surface as per the Drawings.
- The pond liners shall extend to the anchor trench and be constructed as described in Section 5.0 with Unit 2 Select Fill, Unit 10 BGM, Unit 11 Geonet and Unit 12 HDPE Geomembrane.

- Unit 13 Cushion Geotextile shall be placed on the internal batter along the alignment of the Unit 18 Leachate Inlet Pipe as shown in the Drawings. Unit 13 Cushion Geotextile is to protect the underlying Unit 12 HDPE Geomembrane from damage by the Unit 5 Sump Drainage Aggregate. The extent of the Unit 13 Cushion Geotextile must include the full area to be covered with Unit 5 Sump Drainage Aggregate. Unit 13 Cushion Geotextile shall also envelope the gravel as shown in the Drawings to protect the floating cover. Unit 13 Cushion Geotextile shall be placed in accordance with Section 6.2
- The Unit 18 Leachate Inlet Pipe shall be secured at the crest of the pond with a concrete head wall as per the Drawings, including the following:
  - The cast in-situ concrete headwall shall be constructed with Unit 20 Concrete in accordance with the specifications provided in the Drawings. The top of the concrete footing shall finish flush with the embankment crest. The top of the concrete headwall that connects to the floating cover shall have a smooth finish and be constructed within the tolerances specified in the Drawings.
  - The head wall shall be a precast concrete stormwater product with minimum properties of Unit 20 Concrete. The pipe penetrated diameter shall be greater than the diameter of the Unit 18 Leachate Inlet Pipe to allow for expansion and contraction movement of the pipe.
  - The precast concrete head wall shall be bolted onto the cast in-situ concrete slab using a stainless steel plate and bolt assembly subject to the approval of the Superintendent.
  - All concrete and formwork shall be in accordance with AS 1379.
- Unit 6 – Cement Stabilised Sand shall be placed as cover over the Unit 18 Leachate Inlet Pipe up the internal batter to form a planar surface that finishes flush with the Unit 12 HDPE Geomembrane at the crest. The planar surface is required to facilitate construction of the floating cover.

8.0 CONSTRUCTION OF THE EMERGENCY LEACHATE OVERFLOW SYSTEM

The emergency leachate overflow system shall be constructed in accordance with the Drawings, including the following:

- The concrete overflow weir box and outlet pipe shall be excavated into the embankment.
- The concrete overflow weir box shall be constructed as follows:
  - The concrete weir box can be pre-cast or cast insitu. The concrete weir box shall be constructed with Unit 20 Concrete in accordance with the specifications provided in the Drawings. The top of the concrete shall finish flush with the Unit 2 Select Fill surface on the batter. The top of the concrete headwall that connects to the liner system shall have a smooth finish and be constructed within the tolerances specified in the Drawings. The outside edge of the concrete box shall be chamfered.
  - All concrete and formwork shall be in accordance with AS 1379.
  - Unit 19 Overflow Pipe shall be cast into the concrete weir box. This shall be cast around the outlet pipe when the outlet pipe is at its most contracted state (early morning when temperature is low).
- The pond liners shall be fixed to the concrete weir box using batten bar method as shown in the Drawings and to the details as follows:
  - Perforations shall be made in the Unit 10 BGM at bolt locations. Perforations shall be round, neat and only be marginally greater than the bolt size.

- The full panel of Unit 10 BGM shall be placed over the top of concrete weir box and then cut from the concrete weir box void to the dimensions shown in the Drawings. Bitumseal (or approved alternative) shall then be applied between the BGM and the concrete surface to create a seal. The BGM is required to be flat against the concrete, with no wrinkles.
- A 4 mm thick HDPE plate shall be installed above Unit 10 BGM and perforated at bolt locations.
- The full panel of Unit 11 Geonet shall be placed over the top of the concrete weir box and then cut from the concrete weir box void along the outside edge of the HDPE plate to allow heat bonding of the Unit 11 Geonet to the HDPE plate.
- The full panel of Unit 12 HDPE shall be placed over the top of concrete weir box and then cut from the concrete weir box void to the dimensions shown in the Drawings. The HDPE is required to include neat round perforations at the batten bar bolts and be flat against the concrete, with no wrinkles or fish mouths.
- The batten bar and EPDM strip shall then be placed and then fixed to the bolts with washer and nut. The edges of the batten bars shall be rounded and neat with no sharp edges that may impact the integrity of the floating cover. Perforations in the batten bar and EPDM strip shall be made at bolt locations and shall only be marginally greater than the bolt size.
- All top of bolts shall be capped with plastic covers to protect the floating cover.
- The as-constructed seal shall be tested using vacuum box method (refer Section 5.4.6.2.3) or approved equivalent. If air egress is detected, it shall be rectified using a method approved by the GITA.

- The FRP Grate shall be made from high chemical resistant resin (vinyl ester or approved alternative) and shall be manufactured to a smooth and flat finished surface. The FRP Grate shall be cut/supplied to fill the area within the rebated concrete edge and shall be fixed to the concrete with ‘M’ type clips with concrete fasteners as per manufacturers recommendation.
- The outlet pipe shall be backfilled with Unit 6 – Cement Stabilised Sand to provide uniform support around the pipe.

9.0 CONSTRUCTION OF ACCESS RAMP AND CREST PROTECTION SURFACE

The access ramp shall be constructed with Unit 1 Engineered Fill in accordance with requirements for construction of the embankments (refer to Section 3.3). Guide posts shall be installed at the outer edge of the access ramp and around the pond crest as indicated in the Drawings.

The Unit 8 Pavement Material shall be used to provide erosion protection and as a surface for controlled traffic access on selected portions of the crests of the ponds, as indicated on the Drawings. The material shall be compacted to a minimum dry density ratio of 96% relative to Modified Compaction.

A post and chain marker fence shall be constructed as edge protection between a minimum 0.5 m from the outside edge of the anchor trench as shown in the Drawings. The location of the marker fence shall be constructed as indicated on the Drawings. The marker fence is to protect pond liner materials and anchor trenches from damage by vehicles and equipment accessing the paved area. The marker fence shall be installed as the paved areas are constructed and as approved by the Superintendent.

A chainlink fence shall be installed around the pond to prevent fauna entry. The fence type and alignment shall be approved by the Superintendent.

10.0 CONSTRUCTION OF SPILLWAYS AND SURFACE WATER DRAINS

10.1 General

The Contractor must excavate and shape spillways and surface water drains and place materials in them as indicated on the Drawings, or as otherwise approved by the Superintendent.

The external spillway shall be constructed as indicated on the drawings: excavation to subgrade level, construction of the concrete slab, placement of Unit 9 Separation Geotextile in the spillway and secure at the sides, and Unit 7 Riprap over the Unit 9 Separation Geotextile. The concrete slab shall be constructed with Unit 20 Concrete in accordance with the specifications provided in the Drawings. The top of the concrete shall finish flush with the embankment crest. All concrete and formwork shall be in accordance with AS 1379.

The surface water drains shall be constructed as indicated on the drawings: excavation to subgrade level, placement of Unit 3 Topsoil and Unit 14 Erosion Protection in the areas shown, placement of Unit 9 Separation Geotextile and Unit 7 Riprap in the areas shown on the Drawings.

Installation of the Unit 9 Separation Geotextile shall meet the requirements of Section 4.4. Unit 7 Riprap shall be placed over the Unit 9 Separation Geotextile in accordance with the Drawings and Section 10.2.

The gabion basket shall be placed across the spillway channel as shown in the Drawings.

Care must be taken when working in the spillway areas to prevent damage to the geosynthetics, including those on the pond batters below the spillways.

10.2 Unit 7 Riprap Placement

Unit 7 Riprap shall be placed on top of the Unit 9 Separation Geotextile beneath the spillways and surface water drains as shown on the Drawings.

Spreading of Unit 7 Riprap shall be carried out to prevent stretching, tearing, distortion or other damage to the Unit 9 Separation Geotextile. Blades of construction equipment that are used to place and spread the aggregate shall not move within 200 mm of the surface of the underlying Unit 9 Separation Geotextile.

Where a dozing action is used, the Unit 7 Riprap material shall be rolled off the end of the layer to prevent tensioning the Unit 9 Separation Geotextile that may occur if the aggregate is just pushed off the end of the layer.

Vehicles are not permitted to traffic on the surface of the Unit 9 Separation Geotextile. Sequencing of the Works and the methodology for placement of the Unit 7 Riprap, shall consider these limitations on vehicle access.

The Superintendent shall be present on site to view the placement of the Unit 7 Riprap. Where damage occurs to the underlying materials, the Superintendent shall direct the Contractor on the actions required for repair.



golder.com

EcOz Environmental Consultants

EcOz Pty Ltd.
ABN 81 143 989 039

Level 1, 70 Cavenagh St,
GPO Box 381,
Darwin, NT 0801

T: +61 8 8981 1100
E: ecoz@ecoz.com.au

www.ecoz.com.au

APPROVED COMPANY ISO 14001 Environmental Management Systems
QMS Certification Services

APPROVED COMPANY AS/NZS 4801 Occupational Health & Safety Management Systems
QMS Certification Services

APPROVED COMPANY ISO 9001 Quality Management Systems
QMS Certification Services

Appendix B2 WQMP

Water Quality Monitoring Plan

Shoal Bay Waste Management Facility

City of Darwin



www.ecoz.com.au

DOCUMENT CONTROL RECORD

Job	EZ22109
Document ID	217509-11
Author(s)	Jack Dymalla, Paula Martinez

DOCUMENT HISTORY

Rev	Reviewed by	Approved by	Issued to	Date
1	Emma Lewis	Emma Lewis	City of Darwin	11/08/2020
2	Emma Lewis	Emma Lewis	City of Darwin	11/08/2022
3	City of Darwin	City of Darwin	City of Darwin	11/01/2023

Recipients are responsible for eliminating all superseded documents in their possession.

EcOz Pty Ltd.
ABN: 81 143 989 039
Level 1, 70 Cavenagh Street
DARWIN NT 0800
GPO Box 381, Darwin NT 0800

Telephone: +61 8 8981 1100
Email: ecoz@ecoz.com.au
Internet: www.ecoz.com.au

RELIANCE, USES and LIMITATIONS

This report is copyright and is to be used only for its intended purpose by the intended recipient, and is not to be copied or used in any other way. The report may be relied upon for its intended purpose within the limits of the following disclaimer.

This study, report and analyses have been based on the information available to EcOz Environmental Consultants at the time of preparation. EcOz Environmental Consultants accepts responsibility for the report and its conclusions to the extent that the information was sufficient and accurate at the time of preparation. EcOz Environmental Consultants does not take responsibility for errors and omissions due to incorrect information or information not available to EcOz Environmental Consultants at the time of preparation of the study, report or analyses.

TABLE OF CONTENTS

1 INTRODUCTION 1

1.1 Scope 1

1.2 Amendments 1

2 MONITORING PROGRAM 2

2.1 Monitoring Objectives 2

2.2 Monitoring Sites 2

2.2.1 Groundwater Monitoring Bores 2

2.2.2 Surface Water Sites 2

2.2.3 Leachate Sites 2

2.3 Analytes and Frequency of Sampling 7

3 SAMPLING METHODOLOGY 9

3.1 Groundwater sampling 9

3.2 Surface water and leachate sampling 9

3.3 Quality Assurance / Quality Control 10

4 REPORTING 11

4.1 Exceedance Notification 11

4.2 Annual Reporting 11

5 REFERENCES 12

Tables

Table 2-1 Groundwater monitoring bore details. 4

Table 2-2. Surface water and leachate monitoring site details. 6

Table 2-3. Monitoring program sampling frequency and analytes for groundwater 7

Table 2-4. Monitoring program sampling frequency and analytes for surface water 7

Table 2-5. Monitoring program sampling frequency and analytes for leachate 8

Table 2-6. Monitoring program sampling frequency and analytes for the lined treated leachate wetland 8

Figures

Figure 2-1. Map of SBWMF layout and monitoring site locations 3

ACRONYMS AND ABBREVIATIONS

BTEXN	benzene, toluene, ethylbenzene, xylene, naphthalene
CoD	City of Darwin
COD	chemical oxygen demand
DO	dissolved oxygen
EC	electrical conductivity
EcOz	EcOz Environmental Consultants
EPA	Environment Protection Authority
EPL	Environment Protection License
LTP	leachate treatment plant
mBTOC	metres below top of casing
mBGL	metres below ground level
NH_4	ammonium ion
NH_3	ammonia ion
NO_2	nitrite
NO_3	nitratee
NO_x	nitrate NO_3 + nitrite NO_2
NT	Northern Territory
PFAS	per and poly-fluoroalkyl substances
SBWMF	Shoal Bay Waste Management Facility
SWL	standing water level
TDS	total dissolved solids
TN	total nitrogen
TP	total phosphorus
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TRH	total recoverable hydrocarbons NEMP 2013 fractions
WQMP	Water Quality Monitoring Plan

1 INTRODUCTION

EcOz Environmental Consultants (EcOz) was engaged by City of Darwin (CoD) to develop a Water Quality Monitoring Plan (WQMP) for the Shoal Bay Waste Management Facility (SBWMF) as required by the Northern Territory (NT) Environment Protection Authority (EPA), 2013. *Guidelines for the Sitting, Design and Management of Solid Waste Disposal Sites in the Northern Territory*, and pursuant to Environment Protection Licence (EPL) EPL188-03 issued by the NT EPA.

CoD operate the SBWMF located 13 km north-east of Darwin City within Lot 3952, Town of Sanderson, in the suburb of Holmes. This facility is the main municipal waste resource recovery and disposal site servicing domestic and commercial customers in the Darwin area.

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 800 m to the south-west with a bushland buffer in between.

Water quality monitoring is undertaken on a regular basis at the SBWMF, to detect if contaminants from the landfills, or associated operations, are present in groundwater and/or surface water.

1.1 Scope

This WQMP includes:

- Monitoring objectives
- Details of monitoring sites
- List of analytes
- Frequency of sampling
- Sampling methodology
- Quality assurance/Quality Control requirements
- Analysis and reporting requirements

1.2 Amendments

This WQMP has been prepared as an update to the previous Shoal Bay Water Monitoring Plan (URS 2016). Changes to this WQMP as compared to the URS 2016 plan comprise;

- Amended site information to reflect current site conditions
- Amended monitoring sites to remove old sites and add new sites
- Updated monitoring map
- Revised monitoring parameters and frequency as per recommendations in the EcOz historic data review (EcOz 2020).
- Amended surface water, leachate, and groundwater monitoring sites to reflect current site conditions and requirements of EPL188-03. This includes sites relevant to the recently completed leachate treatment plant (LTP) and planned Leachate Storage Pond 3.

2 MONITORING PROGRAM

2.1 Monitoring Objectives

In accordance with the NT EPA Guidelines this WQMP has the following objectives;

- To monitor leachate production and composition
- To determine the effects on the environment due to landfill on groundwater and surface water.
- To check compliance with regulatory requirements
- To identify the need for remedial/mitigation measures

To achieve these objectives, this WQMP incorporates water quality monitoring for groundwater, surface water and leachate.

2.2 Monitoring Sites

Monitoring sites include 44 groundwater bores, 11 surface water sites and 12 leachate sites. Figure 2-1 shows monitoring site locations.

2.2.1 Groundwater Monitoring Bores

The 44 groundwater monitoring bores are detailed in Table 2-1. This bore network aims to allow detection of landfill leachate, or other contaminants, migrating from the site in groundwater to areas down-gradient. Groundwater monitoring bores surround the entire site; both up-gradient (south) and down-gradient (west, north, and east). There are also some bores centrally located within the site. Most bore locations include a shallow bore, screened between 1.5 and 3 m below ground level (mBGL), and a deeper bore, screened between 9 and 12 mBGL. Some sites also include a deep bore up to 30 m deep.

2.2.2 Surface Water Sites

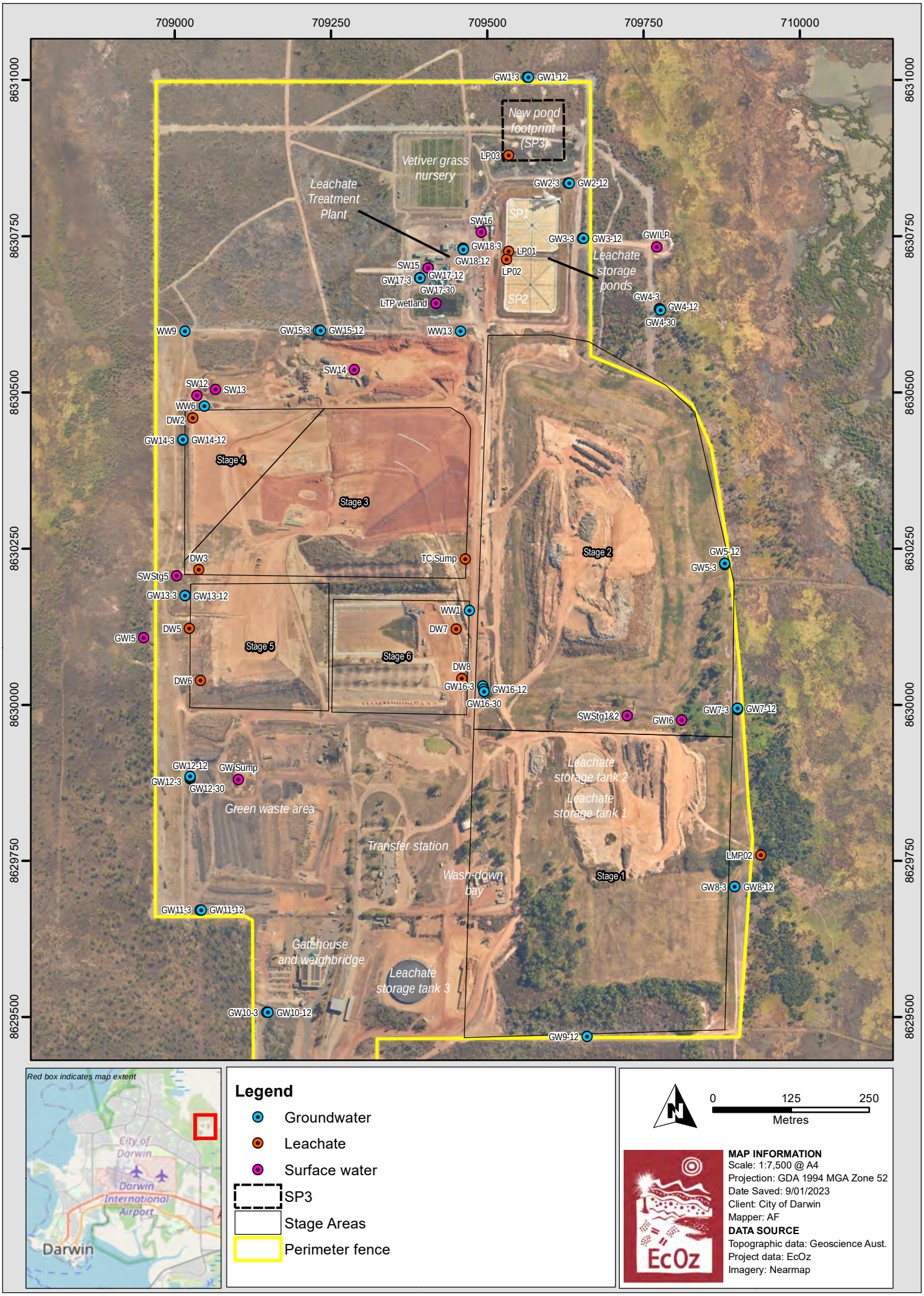
Surface water monitoring aims to detect any landfill leachate, or other contaminants, in surface water runoff that could potentially flow offsite to environments downstream. Surface water monitoring site details are provided in Table 2-2.

Although currently included in the surface water monitoring sites, GWI5 and GWI6 represent groundwater drained from underneath Stages 5/6 and Stage 2 discharged at the surface. Previously, these sites have been treated as groundwater monitoring sites and referred to as GW19 and GW20 respectively (Cardno 2022).

2.2.3 Leachate Sites

Leachate sampling aims to allow the characterisation of contaminant concentrations in leachate for comparison with groundwater and surface water results. Leachate monitoring site details are provided in Table 2-2.

Sampling of the treated leachate in the LTP lined wetland is also undertaken.



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

Table 2-1 Groundwater monitoring bore details.

Bore ID	Easting	Northing	Location	TOC[3] outer elevation mAHD	TOC[2] elevation mAHD	Ground elevation mAHD	Screened interval mBGL	Screened lithology
GW1-3	709564	8631004	On floodplain, 190 m north of leachate storage area	8.71	8.63	8.02	1.5-3	Siltstone
GW1-12	709566	8631004		8.71	8.59	8.00	9-12	Siltstone
GW2-3	709629	8630835	On north-east corner of leachate storage area	8.06	7.94	7.33	1.5-3	Siltstone
GW2-12	709631	8630835		8.08	7.94	7.28	9-12	Siltstone
GW3-3	709652	8630746	East of leachate storage area	9.94	9.80	9.12	1.5-3	Siltstone
GW3-12	709654	8630746		9.87	9.82	9.10	9-12	Siltstone
GW4-3	709775	8630634	On floodplain, north of Stage 2 landfill	5.65	5.49	4.88	1.5-3	Siltstone
GW4-12	709776	8630633		5.61	5.44	5.36	9-12	Siltstone
GW4-30	709777	8630631		5.50	5.20	5.33	15-21	Gravelly sand, Sandstone
GW5-3	709880	8630224	East of Stage 2 landfill	5.51	5.41	4.70	1.5-3	Siltstone
GW5-12	709880	8630226		5.48	5.33	4.70	9-12	Siltstone, Gravelly Clay
GW6-3	709464	8630022	Decommissioned when Stage 6 was constructed	N/A	N/A	N/A	N/A	Gravelly Sandy Silt, Siltstone
GW6-12	709464	8630021		N/A	N/A	N/A	N/A	Siltstone
GW6-30	709464	8630018		N/A	N/A	N/A	N/A	Siltstone, Sandstone
GW7-3	709900	8629992	South-east of Stage 2 and north-east of Stage 1	5.18	5.03	4.33	1.5-3	Siltstone
GW7-12	709900	8629994		5.16	5.08	4.33	9-12	Siltstone, Sandy Silt
GW8-3	709896	8629708	East of Stage 1	5.42	5.28	4.65	1.5-3	Claystone
GW8-12	709896	8629708		5.37	5.22	4.62	9.1-12.1	Claystone, Sandstone
GW9-12	709660	8629469	On southern boundary of SBWMF – up-gradient of all SBWMF operations and infrastructure	16.18	15.93	15.44	9-12	Siltstone
GW10-3	709147	8629507	South of SBWMF – up-gradient of all SBWMF operations and infrastructure	18.12	18.06	17.32	1.5-3	Siltstone
GW10-12	709149	8629507		18.13	17.98	17.37	9.1-12.1	Siltstone
GW11-3	709040	8629671	South-west corner of SBWMF	13.50	13.38	12.72	1.5-3	Siltstone
GW11-12	709042	8629671		13.52	13.38	12.84	9-12	Siltstone, Sandstone
GW12-3	709024	8629881	West of green waste area	12.20	12.07	11.44	1.5-3	Siltstone
GW12-12	709024	8629883		12.22	12.04	11.50	9-12	Siltstone
GW12-30	709024	8629885		12.21	12.05	11.55	24-30	Sandstone
GW13-3	709017	8630175	On south-west corner of Stage 3/4 and north-west corner of Stage 5 landfills	12.93	12.88	12.32	3-4.5	Siltstone
GW13-12	709016	8630174		12.91	12.86	12.25	10-13.5	Siltstone
GW14-3	709013	8630423	West of Stage 4 landfill	6.78	6.73	6.09	1.5-3	Siltstone
GW14-12	709013	8630424		6.77	6.64	6.08	9-12	Siltstone
GW15-3	709230	8630599	North of Stage 3/4 landfill	11.27	11.06	10.44	1.5-3	Siltstone
GW15-12	709233	8630599		11.20	11.04	10.44	9-12	Siltstone

Bore ID	Easting	Northing	Location	TOC[3] outer elevation mAHD	TOC[2] elevation mAHD	Ground elevation mAHD	Screened interval mBGL	Screened lithology
GW16-3	709493	8630030	East of Stage 5/6	TBC	14.55	TBC	1.5-3	Sandy Claystone
GW16-12	709494	8630025	East of Stage 5/6	TBC	14.61	TBC	9-12	Siltstone
GW16-30	709495	8630021	East of Stage 5/6	TBC	14.56	TBC	20-26	Siltstone
GW17-3	709386	8630672	Within the proposed treatment area	TBC	TBC	TBC	0.5-4	Siltstone
GW17-12	709384	8630672	Within the proposed treatment area	TBC	TBC	TBC	8-11	Sandy clay loam
GW17-30	709381	8630672	Within the proposed treatment area	TBC	TBC	TBC	27-30	Fine loamy sand
GW18-3	709464	8630729	Within the proposed treatment area	TBC	TBC	TBC	Tba	Tba
GW18-12	709464	8630728	Within the proposed treatment area	TBC	TBC	TBC	8-12	Sandy clay loam
WW1	709471	8630151	Between Stage 3 and Stage 2 landfills	-	16.60	15.90	0-6.3	-
WW6	709047	8630478	North-west corner of Stage 3/4 landfill	-	7.46	6.76	0-20.4	-
WW9	709016	8630598	North-west corner of SBWMF	-	7.09	6.39	1-9.8	Siltstone
WW13	709457	8630598	On northern boundary of SBWMF	+0.8	+0.7	Not available	1-10	Siltstone

TBC – To be confirmed

Table 2-2. Surface water and leachate monitoring site details.

Site ID	Easting	Northing	Location	Context
Surface Water Sites				
SWStg1&2	709724	8629982	Surface drain between Stage 1 and Stage 2	Receives surface water runoff from central SBWMF areas
SWStg5	709003	8630206	Northwest of Stage 5	Receives surface water runoff from central Stage 3 and Stage 5 landfills
GW Sump	709102	8629880	Sump within green waste processing and storage area	Receives surface water runoff from green waste processing and storage area. Possibly also surface runoff from the Stage 3 and 5 landfills.
SW12	709035	8630495	Catchment dam at base of northwest corner of Stage 3/4 landfill	Receives surface water runoff (and potentially seepage) from the northern and western sides of the Stage 3/4 landfill cells
SW13	709065	8630504		
SW14	709287	8630536	Catchment dam north of Stage 3/4 landfill	Receives surface water runoff (and potentially seepage) from the western landfill cells
SW15	709405	8630699	North of leachate treatment system	Receives runoff from the new leachate treatment plant
SW16	TBC	TBC	West of leachate treatment plant	Receives runoff from the new leachate treatment plant
GWILP	709771	8630733	East of leachate ponds	Receives surface runoff from existing leachate ponds
GWI5	708950	8630107	West of Stages 5 and 6	Ground water inception from stage 5
GWI6	709811	8629975	North-east of Stage 1	Groundwater inception from stage 6
Leachate Sites				
DW2	709029	8630459	Deleaching well on southwest corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells
DW3	709038	8630216	Deleaching well on northwest corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells
DW5	709023	8630122	Deleaching well on west side of Stage 5 landfill	Represents leachate from Stage 5 landfill cell
DW6	709041	8630039	Deleaching well on southwest corner of Stage 5 landfill	Represents leachate from Stage 5 landfill cell
DW7	709450	8630121	Deleaching well on east side of Stage 6 landfill	Represents leachate from Stage 6 landfill cell
DW8	709459	8630042	Deleaching well on east side of Stage 6 landfill	Represents leachate from Stage 6 landfill cell
TC Sump	709465	8630233	Sump on southeast corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells
LMP02	709938	8629759	East of Stage 1	Sump that receives leachate from Stage 1 and 2 landfills via an interception trench that runs north-south along the eastern edge of the Stage 1 and 2 landfills.
LP01	709534	8630726	Northern leachate storage pond	Represents leachate in northern storage pond
LP02	709531	8630713	Southern leachate storage pond	Represents leachate in southern storage pond
LP03	TBC	TBC	Pond 3	Represents leachate in pond 3
Treated Leachate Wetland Sites				
LTP wetland	TBC	TBC	Treated leachate wetland	Represents treated leachate water quality prior to irrigation

2.3 Analytes and Frequency of Sampling

The frequency of sampling in the Wet season and the Dry season are outlined in Table 2-3 to Table 2-6, along with details of the standard suite of analytes used across all sites.

Table 2-3. Monitoring program sampling frequency and analytes for groundwater

Analytes	Frequency (all monitoring bores)
Flow	M
Standing water level (SWL)	M
Field measurements (pH, EC, DO, temperature, REDOX) **Dissolved metals** (only boron, chromium, copper, lead, nickel, zinc) **Major ions** (CO_3, HCO_3, Ca, Mg, K, Na, Cl, SO_4) **Nutrients** (NH_3 as N, NO_3, NO_2, NO_X, TN, TP and FRP) **Other** (TOC, COD, TDS)	Q
Dissolved metals (only arsenic, cadmium, cobalt, lithium, vanadium) **Hydrocarbons** (TRH, BTEXN) **PFAS** (PFOS, PFOA) **Other** (organophosphate pesticides, organochlorine pesticides, polychlorinated biphenyls, tributyltin oxide, phenols, *E. Coli*, enterococci)	A

M – Monthly, Q-Quarterly (January, April, July and October), A-Annually

Table 2-4. Monitoring program sampling frequency and analytes for surface water

	Frequency								
Analytes	**SW12**	**SW13**	**SW14**	**SW15**	**SW16**	**GW Sump**	**SWStg1&2**	**SWStg5**	**GWILP**
Flow	-	-	-	-	-	-	M	M	C[1]
Water level	M	M	M	M	M	-	-	-	-
Field measurements (flow, water level, pH, EC, DO, temperature, turbidity)	M	M	M	M	M	M	M[2]	M[2]	Q
Dissolved and total metals/metalloids (only boron, chromium, copper, lead, nickel, zinc) **Other** (TOC, COD, TSS, TDS) **Major ions** (CO_3, HCO_3, Ca, Mg, K, Na, Cl, SO_4) **Nutrients** (NH_3 as N, NO_3, NO_2, NO_X, TN, TP and FRP)	M[2]	M[2]	M[2]	M[2]	M[2]	M[2]	M[2]	M[2]	Q
Dissolved and total (cadmium, cobalt) **Hydrocarbons** (TRH, BTEXN) **PFAS** (PFOS, PFOA)	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A[2]	A

M – Monthly, C- Continuous, Q-Quarterly (January, April, July and October), A-Annually
[1]Using a flow meter
[2]Only between October to April

Table 2-5. Monitoring program sampling frequency and analytes for leachate

		Frequency									
Analytes	**LP01**	**LP02**	**LP03**	**DW2**	**DW3**	**DW5**	**DW6**	**DW7**	**DW8**	**TC Sump**	**LMP02**
Flow	-	-	-		C[1]	C[1]	C[1]	C[1]	C[1]	C[1]	C[1]
Water level	M	M	M	M	M	M	M	M	M	M	M
Field measurements (flow, water level, pH, EC, DO, temperature, turbidity) **Dissolved and total metals/metalloids** (aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, nickel, selenium, vanadium, zinc) **Major ions** (CO_3, HCO_3, Ca, Mg, K, Na, Cl, SO_4) **Nutrients** (NH_3, NH_4, NO_3, NO_2, NO_X, TN, TP and FRP) **Hydrocarbons** (TRH, BTEXN) **PFAS** (PFOS, PFOA) **Other** (TOC, COD, TSS, TDS)	Q	Q	Q	B	B	B	B	B	B	B	B
Other (organophosphate pesticides, organochlorine pesticides, polychlorinated biphenyls, tributyltin oxide, phenols, *E. Coli*, enterococci)	A	A	A	-	-	-	-	-	-	-	-

M – Monthly, C- Continuous, Q-Quarterly (January, April, July and October), A-Annually
[1]Using a flow meter
[2]Only between October to April

Table 2-6. Monitoring program sampling frequency and analytes for the lined treated leachate wetland

	Frequency
Analytes	**LTP wetland**
Dissolved and total metals/metalloids (aluminium, arsenic, beryllium, boron, cadmium, chromium, cobalt, copper, fluoride, iron, lead, lithium, manganese, mercury, molybdenum, uranium, vanadium, zinc) **Other** (E.coli, electrical conductivity) **PFAS** (PFOS, PFOA) **Nutrients** (total nitrogen, total phosphorous, NH_3 as N, NO_3, NO_2, NO_X, TN, TP and FRP)	Q

Q-Quarterly (January, April, July and October)

3 SAMPLING METHODOLOGY

All sampling will comply with the Australian/New Zealand Standard on Water Quality Sampling - Part 1: *Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples* (AS/NZS 5667.1:1998).

Samples will be immediately chilled in eskies with ice bricks and delivered to a National Association of Testing Authorities (NATA) accredited laboratory each day.

3.1 Groundwater sampling

Groundwater sampling methods will comply with the Australian/New Zealand Standard on Water Quality Sampling – Part 11: *Guidance on sampling of groundwater* (AS/NZS 5667.11:1998). Groundwater sampling involves:

- The measurement of physical parameters (pH, temperature, EC, DO, REDOX) in groundwater using hand-held field water quality meters calibrated immediately prior to mobilisation to site, and
- The collection of groundwater into laboratory-supplied sample bottles for sending to the laboratory for analysis.

Samples will be collected from groundwater bodies using a micropurge/low-flow bladder pump in the first instance, or with manual bailers if groundwater yields are insufficient to allow pumping. The micropurge/low-flow sampling set up is proven for minimal effect on water chemistry and obtaining representative samples (Sundaram 2009). If manual bailing is required, disposable Clear-View PVC bailers will be used; a new bailer for each bore.

In order to gain a representative sample of the surrounding groundwater aquifer quality and not stagnant water contained within the bore, the pump is lowered to within the screened interval, and the rate of pumping matched to the groundwater recharge rate; confirmed by constant monitoring of the standing water level (SWL), which must remain stable. Water quality parameters (pH, temperature, EC, DO, ORP) are constantly monitored in the groundwater as it is pumped from the bore using water quality meters that have been calibrated immediately prior to mobilisation to site. Pumping is continued until readings stabilise i.e. until three consecutive readings of all parameters measured at 5 minute intervals stabilise to within 5% of each other. This usually takes at least 30 minutes of pumping. Low dissolved oxygen (DO) and negative oxidation reduction potential (ORP) are also indicators of fresh groundwater, and not water from within the bore casing which is in contact with the air. Once stable readings are achieved, samples for laboratory analysis are collected directly into laboratory-supplied bottles.

When using manual bailers, a dedicated bailer is used for each bore, and the bore is purged until dry and then sampled once the bore has recharged and SWL has returned to its original level. If recharge in the bore means it doesn't completely empty, then three times volumes worth of standing water in the bore must be removed and the original standing water level allowed to return prior to sampling.

Samples for metals analysis will be field-filtered using a new disposable syringe and filter (0.45 µm) for each sample.

3.2 Surface water and leachate sampling

Surface water and leachate sampling methods will comply with the Australian/New Zealand Standard on Water Quality Sampling - Part 6: *Guidance on sampling of rivers and streams* (AS/NZS 5667.6:1998), Part 4: *Guidance on sampling from lakes, natural and man-made* (AS/NZS 5667.4:1998), and Part 10: *Guidance on sampling of waste waters* (AN/NZS 5667.10:1998).

Surface water and leachate sampling involves:

- The measurement of physical parameters (pH, temperature, EC, DO, turbidity) using hand-held field water quality meters calibrated immediately prior to mobilisation to site, and
- The collection of water into laboratory-supplied sample bottles for sending to the laboratory for analysis.

The specific method of sampling differs depending on the water source. The five different types of water sources and corresponding sampling methods are:

- Surface water bodies, ponds, and drains with safe direct access – will be sampled directly by placing field water quality meters into the water body for physical parameters, and collecting water samples for laboratory analysis directly into the laboratory-supplied sample bottles (note for bottles with preservative, sample will be decanted into the bottle from one of the unpreserved laboratory-supplied bottles to prevent loss of preservative).
- Surface water bodies, ponds, and drains without safe direct access – will be sampled using a clean, decontaminated jug on a pole, and the physical parameters measured immediately from within the jug. The jug on a pole will then be rinsed in the sample water several times prior to collecting sample for decanting into the laboratory-supplied sample containers for lab analysis.
- Sumps without a pump – will be sampled using a clean, decontaminated jug on a pole (as explained above) or a dedicated bailer. When using a bailer, the sample is decanted into a clean, decontaminated jug for measuring physical parameters and the sample poured directly into laboratory-supplied sample containers for laboratory analysis.
- Sumps with a pump – will be sampled by turning the tap on and the sample going into a clean, decontaminated jug for measuring physical parameters and then poured directly from the tap into laboratory-supplied sample containers for laboratory analysis.
- Leachate risers – will be sampled using a submersible pump lowered into the riser with the sample going from the hose into a clean, decontaminated jug for measuring physical parameters and then directly from the hose into laboratory-supplied sample containers for laboratory analysis.

For surface water bodies and sumps sampled either directly or using a sample pole or bailer, samples will be collected approximately 0.3 m below the water surface. When collecting samples from flowing water bodies, the sample must be collected a reasonable distance from the water's edge and facing into the flow direction, keeping hands and sampler equipment downstream to prevent contamination.

Samples for metals analysis (both surface water and leachate) will be field-filtered using a new disposable syringe and filter (0.45 µm) for each sample.

3.3 Quality Assurance / Quality Control

QA/QC samples will comprise:

- Field duplicate samples at 1 per 10 water samples per monitoring event, to identify the variation in analyte concentrations between samples collected from the same location and/or the repeatability of laboratory analysis.
- Field triplicate (split) samples at 1 per 20 water samples per monitoring event, analysed by a second laboratory, to verify the analytical proficiency of the primary laboratory.

Samples will be analysed by a NATA accredited laboratory and laboratory certificates will be NATA endorsed reports. Upon receipt of the laboratory analytical results, the following elements will be assessed to ensure QA/QC of samples;

- Laboratory, field duplicates, and trip blanks
- Laboratory internal standards, calibration blanks, method blanks, matrix spike, duplicate and surrogate spikes etc
- The occurrence of apparent unusual or anomalous results, e.g. laboratory results that appear to be inconsistent with field observations or measurements.

4 REPORTING

The Australian and New Zealand Environment Conservation Council (ANZECC 2000) *Australian and New Zealand Guidelines for Marine and Freshwater Quality* trigger values for protection of 90 % of marine species have been adopted for reference when assessing the sample analytical results.

All electronic and hard copy files will be maintained electronically and/or in hardcopy to enable timely access. This includes all reports, laboratory analysis results, sampling documentation, chain of custody records, cad, GIS or surfer data and associated correspondence.

4.1 Exceedance Notification

The NT EPA will be notified in writing as soon as practicable (and in any case within 24 hrs) after becoming aware, when the guideline specified trigger values are exceeded;

- on three consecutive sampling occasions; or
- at greater than or equal to two times the trigger value; or
- at a median value for six consecutive monitoring results.

This notification should include as a minimum;

- when the exceedance was detected and by whom;
- the date and time of the exceedance;
- the actual and potential causes and contributing factors to the exceedance;
- the risk of environmental harm arising from the exceedance assessed in accordance with relevant standards as listed in the WQMP;
- the action(s) that have or will be undertaken to address the exceedance and/or environmental harm;
- if no action was taken, why no action was taken; and
- a date when an incident investigation report will be submitted to the NT EPA.

4.2 Annual Reporting

A completed Annual Return will be submitted via NT EPA Online within 10 business days after each anniversary date of EPL 188, which relates to the preceding 12 month period.

A completed Monitoring Report will be provided to the NT EPA, as prescribed by EPL 188, within 20 business days after each anniversary date of EPL 188.

This Monitoring Report should;

- be prepared in accordance with the requirements of the NT EPA *'Guideline for Reporting on Environmental Monitoring*';
- include tabulation of all monitoring data required as a condition of EPL 188;
- include long term trend analysis of monitoring data to demonstrate any environmental impact associated with the activity over a minimum period of three years (where the data is available); and
- include an assessment of environmental impact from the activity.

5 REFERENCES

ANZECC & AMRCANZ 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), Canberra.

ANZECC & AMRCANZ 2000, *Australian Guidelines for Water Quality Monitoring and Reporting*, National Water Quality Management Strategy Paper No 7, Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), Canberra.

Australian/New Zealand Standard on Water Quality Sampling - Part 1: *Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples* (AS/NZS 5667.1:1998), Standards Australia, New South Wales.

Australian Standard on Water Quality Sampling - Part 4: *Guidance on sampling from lakes, natural and man-made* (AS/NZS 5667.4:1998), Standards Australia, New South Wales.

Australian/New Zealand Standard on Water Quality Sampling - Part 6: *Guidance on sampling of rivers and streams* (AS/NZS 5667.6:1998), Standards Australia, New South Wales.

Australian Standard on Water Quality Sampling – Part 10: *Guidance on sampling of waste waters* (AN/NZS 5667.10:1998), Standards Australia, New South Wales.

Australian/New Zealand Standard on Water Quality Sampling – Part 11: *Guidance on sampling of groundwater* (AS/NZS 5667.11:1998), Standards Australia, New South Wales.

Cardno (2022). *Annual Monitoring Review – Shoal Bay Waste Management Facility, Soil and Water Monitoring Program*. [online] Available at https://ntepa.nt.gov.au/__data/assets/pdf_file/0013/1124050/epl188-monitoring-report-2022.pdf [Accessed 04 August 2022]

EcOz 2020, *Shoal Bay Waste Management Facility Water quality monitoring data review 2016 – 2020*, Report prepared for City of Darwin by EcOz Environmental Consultants, August 2020, Darwin

NT EPA 2021, *Environment Protection Licence EPL188-03*, Issued 2 July 2021, Expires 1 July 2026, Northern Territory Environment Protection Authority (NT EPA), Darwin, NT.

NT EPA 2013, *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites in the Northern Territory*, Northern Territory Environment Protection Authority (NT EPA), Darwin, NT.

Sundaram, B., Feitz, A., Caritat, P. de, Plazinska, A., Brodie, R., Coram, J. and Ransley, T., 2009. *Groundwater Sampling and Analysis – A Field Guide*. Geoscience Australia, Record 2009/27 95 pp.

Work Health and Safety (National Uniform Legislation) Act, and Work Health and Safety (National Uniform Legislation) Regulations, NT Government.

URS 2016, *Shoal Bay Waste Disposal Site Water Monitoring Plan*, March 2016, Report prepared for John Holland Pty Ltd, URS Australia, Darwin, NT.

EcOz Environmental Consultants

EcOz Pty Ltd.
ABN 81 143 989 039

Level 1, 70 Cavenagh St,
GPO Box 381,
Darwin, NT 0801

T: +61 8 8981 1100
E: ecoz@ecoz.com.au

www.ecoz.com.au

APPROVED COMPANY ISO 14001 Environmental Management Systems
QMS Certification Services

APPROVED COMPANY AS/NZS 4801 Occupational Health & Safety Management Systems
QMS Certification Services

APPROVED COMPANY ISO 9001 Quality Management Systems
QMS Certification Services

Appendix B3 Soil and Water MP

Soil and Water Monitoring Plan

Shoal Bay Waste Management Facility

City of Darwin



www.ecoz.com.au

DOCUMENT CONTROL RECORD

Job	EZ21059
Document ID	200168-17
Author(s)	Adele Faraone, Andrew Lewis

DOCUMENT HISTORY

Rev	Reviewed by	Approved by	Issued to	Date
DRAFT	Gisela Lamche	Gisela Lamche	City of Darwin	4 February 2021
1	Gisela Lamche	Gisela Lamche	City of Darwin	11 March 2021
2	Gisela Lamche	Gisela Lamche	City of Darwin	15 March 2021
3	Gisela Lamche	Gisela Lamche	City of Darwin	7 April 2021

Recipients are responsible for eliminating all superseded documents in their possession.

EcOz Pty Ltd.
ABN: 81 143 989 039
Level 1, 70 Cavenagh Street
DARWIN NT 0800
GPO Box 381, Darwin NT 0800

Telephone: +61 8 8981 1100
Email: ecoz@ecoz.com.au
Internet: www.ecoz.com.au

RELIANCE, USES and LIMITATIONS

This report is copyright and is to be used only for its intended purpose by the intended recipient, and is not to be copied or used in any other way. The report may be relied upon for its intended purpose within the limits of the following disclaimer.

This study, report and analyses have been based on the information available to EcOz Environmental Consultants at the time of preparation. EcOz Environmental Consultants accepts responsibility for the report and its conclusions to the extent that the information was sufficient and accurate at the time of preparation. EcOz Environmental Consultants does not take responsibility for errors and omissions due to incorrect information or information not available to EcOz Environmental Consultants at the time of preparation of the study, report or analyses.

TABLE OF CONTENTS

1 INTRODUCTION 1

1.1 Scope 1

1.2 Monitoring objectives 1

2 WATER MONITORING NETWORK 2

2.1 Sampling locations 2

2.2 Leachate monitoring 2

2.3 Groundwater monitoring 2

2.4 Stormwater and surface water monitoring 4

3 SOIL AND DEPOSITIONAL SAMPLING NETWORK 6

3.1 Sampling locations 6

4 ANALYTES AND FREQUENCY OF MONITORING 8

4.1 Ongoing monitoring 8

4.2 EPA304-01 monthly water monitoring 18

5 SAMPLING METHODS 19

5.1 Sample collection technique 19

5.1.1 Groundwater 19

5.1.2 Surface water and leachate 19

5.1.3 Soil sampling 21

5.1.4 Dust depositional sampling 21

5.2 Field records 22

5.3 Quality Assurance / Quality Control (QA/QC) 22

5.3.1 Water sampling 22

5.3.2 Soil sampling 22

5.4 Reporting 23

5.4.1 Exceedance Notification 24

5.4.2 Annual Reporting 24

6 REFERENCES 25

Tables

Table 2-1. Leachate monitoring details 2

Table 2-2. Groundwater bore monitoring details 3

Table 2-3. Stormwater and surface water monitoring details 4

Table 3-1. Soil and depositional sampling locations 6

Table 4-1. Leachate monitoring frequency and analytes (Amended from Attachment 6 of EPL188-01) 9

Table 4-2. Groundwater monitoring frequency and analytes (Amended from Attachment 4 of EPL188-01) 12

Table 4-3. Stormwater and surface water monitoring frequency and analytes (Attachment 3 of EPL188-01 and sites SW15 and SW16 of EPA304-01) 14

Table 4-4. Depositional monitoring frequency and analytes (Amended from Attachment 8 of EPL188-01) 17

Table 4-5. Soil monitoring frequency and analytes (Amended from Attachment 9 of EPL188-01) 17

Table 4-6. Monthly sampling of groundwater and surface water sites as per EPA304-01 for initial 12 months (April 2021 to March 2022) 18

Figures

Figure 2-1. Map of SBWMF layout and water monitoring site locations 5
Figure 3-1. Map of SBWMF layout and soil and depositional monitoring site locations 7

1 INTRODUCTION

EcOz Environmental Consultants (EcOz) was engaged by City of Darwin (CoD) to develop the Soil and Water Monitoring Plan (SWMP) for the Shoal Bay Waste Management Facility (SBWMF) as required by the Northern Territory (NT) Environmental Protection Authority (EPA), 2013 *Guidelines for the Sitting, Design and Management of Solid Waste Disposal Sites in the Northern Territory*, and pursuant to an environmental protection license (EPL) EPL188 issued by the NT EPA. The previous SWMP was developed by URS in 2016.

CoD operate the SBWMF located 13 km north-east of Darwin City within Lot 3952, Town of Sanderson, in the suburb of Holmes. This facility is the main municipal waste resource recovery and disposal site servicing domestic and commercial customers in the Darwin area.

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 800 m to the south-west with a bushland buffer in between.

Water quality monitoring is undertaken on a regular basis at the SBWMF, to detect if contaminants from the landfills, or associated operations, are present in groundwater or surface water.

Soil and depositional monitoring has been included in this monitoring plan as a further requirement for the EPL 188, updated in 2021.

1.1 Scope

This SWMP includes:

- Monitoring objectives
- Details of the sampling locations for leachate, groundwater, stormwater and surface water as well as soil and depositional sediment monitoring
- List of analytes to be tested and frequency of sampling
- Sampling methods
- Quality assurance / Quality control requirements
- Analysis and reporting requirements.

1.2 Monitoring objectives

In accordance with the NT EPA Guidelines this SWMP has the following objectives;

- To monitor leachate production and composition
- To determine the effects on the environment due to landfill on groundwater, surface water and soil
- To check compliance with regulatory requirements
- To identify the need for remedial/mitigation measures.

To achieve these objectives, this SWMP incorporates water quality monitoring for leachate, groundwater, stormwater and surface water as well as soil and depositional monitoring.

2 WATER MONITORING NETWORK

2.1 Sampling locations

Monitoring sites include 10 leachate sites, 43 groundwater sites and 9 stormwater and surface water sites. Figure 2-1 shows monitoring site locations. EPL 188 specifies 9 surface water locations (as per EPL 188 Attachment 3), two of which - GWI5 and GWI6 - were moved into the groundwater program and renamed GW19 and GW20. An additional two surface water sites (SW15, SW16) are part of EPA 304-01 (EPA 304-01 Attachment 1) and thus considered part of the regular long-term monitoring program and included in this SWMP. Please note that as part of the licence for the leachate treatment plant (EPA 304-01), these two new sites SW15 and SW16 will be required to be monitored monthly for the first 12 months (April 2021 to March 2022) and will then revert to the sampling regime similar to SW12-SW14 (Table 4-3).

2.2 Leachate monitoring

Leachate sampling aims to allow the characterisation of contaminant concentrations in leachate for comparison with groundwater and surface water results. Leachate monitoring site details are provided in Table 2-1.

Table 2-1. Leachate monitoring details

Site ID	Easting	Northing	Location	Context
LP01	709534	8630726	Northern leachate storage pond	Represents leachate in northern storage pond
LP02	709531	8630713	Southern leachate storage pond	Represents leachate in southern storage pond
DW2	709029	8630459	Deleaching well on northwest corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells
DW3	709038	8630216	Deleaching well on southwest corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells
DW5	709023	8630122	Deleaching well on west side of Stage 5 landfill	Represents leachate from Stage 5 landfill cell
DW6	709024	8630024	Deleaching well on southwest corner of Stage 5 landfill	Represents leachate from Stage 5 landfill cell
DW7	709450	8630121	Deleaching well on northeast corner of stage 6	Represents leachate from Stage 6 landfill cell
DW8	709459	8630042	Deleaching well on central east boundary of stage 6	Represents leachate from Stage 6 landfill cell
TC Sump	709465	8630233	Sump on southeast corner of Stage 3/4 landfill	Represents leachate from Stage 3/4 landfill cells
LMP02	709938	8629759	East of Stage 1	Sump that receives leachate from Stage 1 and 2 landfills via an interception trench that runs north-south along the eastern edge of the Stage 1 and 2 landfills.

2.3 Groundwater monitoring

The 43 groundwater monitoring locations are detailed in Table 2-2. Of these, 41 sites are bores while the remaining two sites are the two renamed sites (GWI5 to GW19 and GWI6 to GW20) that were moved from the surface water monitoring into the groundwater monitoring program as they represent water from underneath the two landfill stages and are not actually bores. The bore network aims to allow detection of landfill leachate, or other contaminants, migrating from the site in groundwater to areas down-gradient. Groundwater monitoring bores surround the entire site; both up-gradient (south) and down-gradient (west, north and east). There are also some bores centrally located within the site. Most bore locations include a

shallow bore, screened between 1.5 and 3 m below ground level (mBGL), and a deeper bore, screened between 9 and 12 mBGL. Some sites also include a deep bore up to 30 m deep. The two sites new to the groundwater monitoring program, GW19 and GW20, represent water from underneath landfill stage 5/6 and stage 2, respectively.

Table 2-2. Groundwater bore monitoring details

Bore ID	Easting	Northing	TOC elevation mAHD	Screened interval mBGL	Screened lithology
GW1-3	709564	8631004	8.63	1.5-3	Siltstone
GW1-12	709566	8631004	8.59	9-12	Siltstone
GW2-3	709629	8630835	7.94	1.5-3	Siltstone
GW2-12	709631	8630835	7.94	9-12	Siltstone
GW3-3	709652	8630746	9.80	1.5-3	Siltstone
GW3-12	709654	8630746	9.82	9-12	Siltstone
GW4-3	709775	8630634	5.49	1.5-3	Siltstone
GW4-12	709776	8630633	5.44	9-12	Siltstone
GW4-30	709777	8630631	5.20	15-21	Gravelly sand, Sandstone
GW5-3	709880	8630224	5.41	1.5-3	Siltstone
GW5-12	709880	8630226	5.33	9-12	Siltstone, Gravelly Clay
GW7-3	709900	8629992	5.03	1.5-3	Siltstone
GW7-12	709900	8629994	5.08	9-12	Siltstone, Sandy Silt
GW8-3	709896	8629708	5.28	1.5-3	Claystone
GW8-12	709896	8629708	5.22	9.1-12.1	Claystone, Sandstone
GW9-12	709660	8629469	15.93	9-12	Siltstone
GW10-3	709147	8629507	18.06	1.5-3	Siltstone
GW10-12	709149	8629507	17.98	9.1-12.1	Siltstone
GW11-3	709040	8629671	13.38	1.5-3	Siltstone
GW11-12	709042	8629671	13.38	9-12	Siltstone, Sandstone
GW12-3	709024	8629881	12.07	1.5-3	Siltstone
GW12-12	709024	8629883	12.04	9-12	Siltstone
GW12-30	709024	8629885	12.05	24-30	Sandstone
GW13-3	709017	8630175	12.88	3-4.5	Siltstone
GW13-12	709016	8630174	12.86	10-13.5	Siltstone
GW14-3	709013	8630423	6.73	1.5-3	Siltstone
GW14-12	709013	8630424	6.64	9-12	Siltstone
GW15-3	709230	8630599	11.06	1.5-3	Siltstone
GW15-12	709233	8630599	11.04	9-12	Siltstone
GW16-3	709493	8630030	TBC	1.5-3	Sandy Claystone
GW16-12	709494	8630025	TBC	9-12	Siltstone
GW16-30	709495	8630021	TBC	30	Siltstone
*GW17-3	709418	8630692	TBC	3	-

Bore ID	Easting	Northing	TOC elevation mAHD	Screened interval mBGL	Screened lithology
*GW17-12	709418	8630691-	TBC	12	-
*GW17-30	709418	8630691-	TBC	30	-
*GW18-3	709464	8630729-	TBC	3	-
*GW18-12	709464	8630728-	TBC	12	-
^GW19	708952	8630107	-	-	-
^GW20	709811	8629975	-	-	-
WW1	709471	8630151	16.60	0 - 6.3	-
WW6	709047	8630478	7.46	0 - 20.4	-
WW9	709016	8630598	7.09	1 - 9.8	Siltstone
WW13	709457	8630598	+0.7	1 - 10	Siltstone

**Note – locations are approximate only as bores are yet to be installed.*

^ GW19 and GW20 (renamed from GWI5 and GWI6) represent water from underneath the two landfill stages (stage 5/6 ad stage 2). As they are not actually bores, they do not have TOC and other bore related information.

2.4 Stormwater and surface water monitoring

Surface water monitoring aims to detect any land fill leachate, or other contaminants, in surface water runoff that could potentially flow offsite to environments downstream. Surface water monitoring site details are provided in Table 2-3.

Table 2-3. Stormwater and surface water monitoring details

Site ID	Easting	Northing	Location	Context
SW12	709035	8630495	Catchment basin at base of northwest corner of Stage 3/4 landfill	Receives surface water runoff (and potentially seepage) from the northern and western sides of the Stage 3/4 landfill cells
SW13	709065	8630504	Catchment basin at base of northwest corner of Stage 3/4 landfill	Receives surface water runoff (and potentially seepage) from the northern and western sides of the Stage 3/4 landfill cells
SW14	709287	8630536	Basin north of Stage ¾ landfill	Receives surface water runoff (and potentially seepage) from the western landfill cells
SW15	709405	8630699	North of leachate treatment plant	Receives runoff from leachate treatment plant
SW16	709490	8630756	West of leachate treatment plant	Receives runoff from leachate treatment plant
GW Sump	709102	8629880	Sump within green waste processing and storage area	Receives surface water runoff from green waste processing and storage area. Possibly also surface runoff from the Stage 3 and 5 landfills.
SWStg1&2	709724	8629982	Surface drain between Stage 1 and Stage 2	Receives surface water runoff from central SBWMF areas
SWStg5	709003	8630206	To the northwest of Stage 5	Receives surface runoff from the Stage 5
GWILP	709771	8630733	To the east of the leachate ponds	Receives surface runoff from the leachate ponds



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ21003 - SBWMF WMP update\01 Project Files\Figure 2-1. SBWMF layout and monitorig site locations.mxd

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

3 SOIL AND DEPOSITIONAL SAMPLING NETWORK

3.1 Sampling locations

Monitoring sites, as identified in EPL 188, include 4 soil sampling sites and 4 depositional sampling locations, both of which in the same place. Table 3-1 and Figure 3-1 describe these locations.

Table 3-1. Soil and depositional sampling locations

Site ID	Easting	Northing	Location
SS01/DS01	709187	8630904	North west of leachate pond and leachate treatment plant
SS02/DS02	709580	8631014	North of leachate ponds
SS03/DS03	709788	8630614	South east of leachate treatment ponds, north east of Stage 2 landfill cells
SS04/DS04	709252	8630601	North of Stage 3/4 cells, directly east of GW15-3



Path: Z:\01 EcOz_Documents\04 EcOz Vantage GIS\EZ21003 - SBWMF WMP update\01 Project Files\Map of new soil sampling locations.mxd

Figure 3-1. Map of SBWMF layout and soil and depositional monitoring site locations

4 ANALYTES AND FREQUENCY OF MONITORING

4.1 Ongoing monitoring

The frequency of water sampling in the Wet season and the Dry season are outlined in Table 4-1, Table 4-2 and Table 4-3, along with details of the standard suite of analytes used across all sites.

Table 4-4 and Table 4-5 state the frequency of soil and depositional sampling and list details of the standard suite of analytes to be measured across all sites.

Table 4-1. Leachate monitoring frequency and analytes (amended from Attachment 6 of EPL188-01)

		Sample Locations									
	Site Code	LP01	LP02	DW2	DW3	DW5	DW6	DW7[1]	DW8[1]	TC Sump	LMP02
Parameter	**Units**	**Frequency**									
Flow	kL/day	-	-	C[2]	C[2]	C[2]	C[2]	C[2]	C[2]	C[2]	C[2]
Water level	Measure	M	M	M	M	M	M	M	M	M	M
pH	pH units	Q	Q	B	B	B	B	B	B	B	B
Electrical Conductivity	µs/cm	Q	Q	B	B	B	B	B	B	B	B
Dissolved Oxygen	%saturation	Q	Q	B	B	B	B	B	B	B	B
Temperature	ºC	Q	Q	B	B	B	B	B	B	B	B
Turbidity	NTU	Q	Q	B	B	B	B	B	B	B	B
Metals/Metalloids (filtered (0.45µm) and unfiltered)											
Aluminium (Al)	µg/L	Q	Q	B	B	B	B	B	B	B	B
Arsenic (As)		Q	Q	B	B	B	B	B	B	B	B
Boron (B)		Q	Q	B	B	B	B	B	B	B	B
Cadmium (Cd)		Q	Q	B	B	B	B	B	B	B	B
Chromium (Cr)		Q	Q	B	B	B	B	B	B	B	B
Cobalt (Co)		Q	Q	B	B	B	B	B	B	B	B
Copper (Cu)		Q	Q	B	B	B	B	B	B	B	B
Iron (Fe)		Q	Q	B	B	B	B	B	B	B	B
Lead (Pb)		Q	Q	B	B	B	B	B	B	B	B
Lithium (Li)		Q	Q	B	B	B	B	B	B	B	B
Manganese (Mn)		Q	Q	B	B	B	B	B	B	B	B
Mercury (Hg)		Q	Q	B	B	B	B	B	B	B	B
Nickel (Ni)		Q	Q	B	B	B	B	B	B	B	B
Selenium (Se)		Q	Q	B	B	B	B	B	B	B	B
Vanadium (V)		Q	Q	B	B	B	B	B	B	B	B
Zinc		Q	Q	B	B	B	B	B	B	B	B

Major Ions											
Carbonate (CO3)	mg/L	Q	Q	B	B	B	B	B	B	B	B
Bicarbonate (HCO3)		Q	Q	B	B	B	B	B	B	B	B
Calcium (Ca)		Q	Q	B	B	B	B	B	B	B	B
Magnesium (Mg)		Q	Q	B	B	B	B	B	B	B	B
Potassium (K)		Q	Q	B	B	B	B	B	B	B	B
Sodium (Na)		Q	Q	B	B	B	B	B	B	B	B
Chloride (Cl)		Q	Q	B	B	B	B	B	B	B	B
Sulphate (SO4)		Q	Q	B	B	B	B	B	B	B	B
Nutrients											
Ammonia (NH3)	µg/L	Q	Q	B	B	B	B	B	B	B	B
Ammonium (NH4)		Q	Q	B	B	B	B	B	B	B	B
Nitrate (NO3)		Q	Q	B	B	B	B	B	B	B	B
Nitrite (NO2)		Q	Q	B	B	B	B	B	B	B	B
Oxides of Nitrogen (NOx)		Q	Q	B	B	B	B	B	B	B	B
Total Nitrogen (TN)		Q	Q	B	B	B	B	B	B	B	B
Total Phosphorous (TP)		Q	Q	B	B	B	B	B	B	B	B
Filterable reactive phosphorous (FRP)		Q	Q	B	B	B	B	B	B	B	B
Hydrocarbons											
Total Recoverable Hydrocarbons (TRH)	µg/L	Q	Q	B	B	B	B	B	B	B	B
Polycyclic Aromatic Hydrocarbons (PAHs)		Q	Q	B	B	B	B	B	B	B	B
Benzene		Q	Q	B	B	B	B	B	B	B	B
Toluene		Q	Q	B	B	B	B	B	B	B	B
Ethylbenzene		Q	Q	B	B	B	B	B	B	B	B
Xylene		Q	Q	B	B	B	B	B	B	B	B
Naphthalene		Q	Q	B	B	B	B	B	B	B	B

PFAS (per-and poly-fluoro alkyl substances) (Analysis on a minimum of 28 PFAS compounds using LC-MS/MS)											
PFOS	µg/L	Q	Q	B	B	B	B	B	B	B	B
PFOA		Q	Q	B	B	B	B	B	B	B	B
Other											
Organophosphate Pesticides	µg/L	A	A	-	-	-	-	-	-	-	-
Organochlorine Pesticides		A	A	-	-	-	-	-	-	-	-
Polychlorinated Biphenyls		A	A	-	-	-	-	-	-	-	-
Tributyltin Oxide		A	A	-	-	-	-	-	-	-	-
Phenols		A	A	-	-	-	-	-	-	-	-
Chemical Oxygen Demand (COD)	mg/L	Q	Q	B	B	B	B	B	B	B	B
Total Suspended Solids (TSS)		Q	Q	B	B	B	B	B	B	B	B
Total Organic Carbon (TOC)		Q	Q	B	B	B	B	B	B	B	B
Total Dissolved Solids (TDS)		Q	Q	B	B	B	B	B	B	B	B
Escherichia Coli	CFU 100ml	A	A	-	-	-	-	-	-	-	-
Enterococci		A	A	-	-	-	-	-	-	-	-

C – Continuous
M – Monthly

Q – Quarterly (January, April, July, October)
B – Biannually (January, July)
A – Annually (July)

[1] - Sampling points for Stage 6 leachate collection only active once Stage 6 begins to accept waste
[2] – Using a flow meter

Table 4-2. Groundwater monitoring frequency and analytes (amended from Attachment 4 of EPL188-01)

Parameter	Units	Frequency (all monitoring bores identified in Table 2-2)
Flow	kL/day	M[1]
Standing water level (SWL)	m (AHD)	M
pH	pH units	Q
Electrical Conductivity (EC)	µS/cm	Q
Dissolved Oxygen (DO)	% saturation	Q
Temperature	ºC	Q
Reduction Oxidation Potential (REDOX)	mV	Q
Metals/Metalloids (filtered (0.45µm))		
Arsenic (As)	µg/L	A
Boron (B)		Q
Cadmium (Cd)		A
Chromium (Cr)		Q
Cobalt (Co)		A
Copper (Cu)		Q
Lead (Pb)		Q
Lithium (Li)		A
Nickel (Ni)		Q
Vanadium (V)		A
Zinc (Zn)		Q
Major Ions		
Carbonate (CO3)	mg/L	Q
Bicarbonate (HCO3)		Q
Calcium (Ca)		Q
Magnesium (Mg)		Q
Potassium (K)		Q
Sodium (Na)		Q
Chloride (Cl)		Q
Sulphate (SO4)		Q
Nutrients		
Ammonia (NH3)	µg/L	Q
Ammonium (NH4)		Q
Nitrate (NO3)		Q
Nitrite (NO2)		Q
Oxides of Nitrogen (NOx)		Q
Total Nitrogen (TN)		Q
Total Phosphorous (TP)		Q
Hydrocarbons		
Total Recoverable Hydrocarbons (TRH)	µg/L	A

Benzene		A
Toluene		A
Ethylbenzene		A
Xylene		A
Naphthalene		A
PFAS (per-and poly-fluoro alkyl substances) (Analysis on a minimum of 28 PFAS compounds using LC-MS/MS)		
PFOS		Q
PFOA		Q
Other		
Chemical Oxygen Demand (COD)	mg/L	Q
Total Organic Carbon (TOC)		Q
Total Dissolved Solids (TDS)		Q
Organophosphate Pesticides	µg/L	A
Organochlorine Pesticides		A
Polychlorinated Biphenyls		A
Tributylin Oxide		A
Phenols		A
Escherichia Coli	CFU/100ml	A
Enterococci		A
M – Monthly Q – Quarterly (January, April, July, October) A – Annually (January) [1] – If the water level is above the top of casing when measuring SWLs then estimate the flow. Bores GW17-3, GW17-12, GW17-30, GW18-3 and GW18-12 will be monitored for the above parameters from April 2021 to March 2022		

Table 4-3. Stormwater and surface water monitoring frequency and analytes (Attachment 3 of EPL188-01 and sites SW15 and SW16 of EPA304-01)

			Sample Locations								
		Site Code	SW12	SW13	SW14	SW15	SW16	GW Sump	SWStg1&2	SWStg5	GWILP
Parameter	**Units**	**Trigger Value**	**Frequency**								
Flow	kL/day	-	-	-	-	-	-	-	M[3]	M[3]	C[4]
Water level	Measure	-	M	M	M	M	M	M[5]	-	-	-
pH	pH units	6.0 – 8.5[1]	M	M	M	M	M	M[5]	M[5]	M[5]	Q
Electrical Conductivity	µs/cm	-	M	M	M	M	M	M[5]	M[5]	M[5]	Q
Dissolved Oxygen	% saturation	80 – 100[1]	M	M	M	M	M	M[5]	M[5]	M[5]	Q
Temperature	ºC	-	M	M	M	M	M	M[5]	M[5]	M[5]	Q
Turbidity	NTU	-	M	M	M	M	M	M[5]	M[5]	M[5]	Q
Metals/Metalloids (filtered (0.45µm) and unfiltered)											
Boron (B)	µg/L	-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Cadmium (Cd)		1.4[2]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A
Chromium (Cr) [7]		20[6]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Cobalt (Co)		14[2]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A
Copper (Cu)		3[2]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Lead (Pb)		6.6[2]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Nickel (Ni)		200[2]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Zinc (Zn)		23[2]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Other											
Chemical Oxygen Demand (COD)	mg/L		M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Total Organic Carbon (TOC)			M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Total Suspended Solids (TSS)		10[1]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Total Dissolved Solids (TDS)			M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Major Ions											

Carbonate (CO3)	mg/L		M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Bicarbonate (HCO3)			M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Calcium (Ca)			M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Magnesium (Mg)			M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Potassium (K)			M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Sodium (Na)			M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Chloride (Cl)			M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Sulphate (SO4)			M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Nutrients											
Ammonia (NH3 as N)	µg/L	20[1]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Nitrate (NO3)		-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Nitrite (NO2)		-	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Oxides of Nitrogen (NOx)		20[1]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Total Nitrogen (TN)		300[1]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Total Phosphorous (TP)		30[1]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Filterable reactive phosphorous (FRP)		10[1]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	M[5]	Q
Hydrocarbons											
Total Recoverable Hydrocarbons (TRH)	µg/L		A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A
Benzene		900[2]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A
Toluene			A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A
Ethylbenzene			A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A
Xylene			A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A
Naphthalene		90[2]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A
PFAS (per-and poly-fluoro alkyl substances) (Analysis on a minimum of 28 PFAS compounds using LC-MS/MS)											
PFOS	µg/L	2[8]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A
PFOA		632[8]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A[5]	A

C – Continuous M – Monthly Q – Quarterly (January, April, July, October) A – Annually (January)	[1] – Based on Darwin Harbour Water Objectives (Shoal Bay upper area marine ambient water quality) [2] – Based on 90% species protection for marine waters ANZECC Water Quality Guidelines 2018 (ANZG 2018) [6] – Based on Hexavalent chromium 90% species protection ANZECC Water Quality Guidelines 2018 (ANZG 2018) [3] – Estimate the flow at the time of sampling [4] – Using a flow meter [5] – Only during months October to April [7] – Analyse for Trivalent and Hexavalent Chromium if total chromium exceeds trigger value [8] – Based on PFAS NEMP 2.0 however, trigger values for the latest NEMP must be used when available

Table 4-4. Depositional monitoring frequency and analytes (amended from Attachment 8 of EPL188-01)

		Sample Locations			
	Site Code	DS01	DS02	DS03	DS04
Parameter	**Units**	**Frequency**			
Metals/Metalloids					
Aluminium (Al)	µg/kg	B	B	B	B
Boron (B)		B	B	B	B
Chromium (Cr)		B	B	B	B
Cobalt (Co)		B	B	B	B
Copper (Cu)		B	B	B	B
Lead (Pb)		B	B	B	B
Mercury (Hg)		B	B	B	B
Nickel (Ni)		B	B	B	B
Zinc (Zn)		B	B	B	B
PFAS (per-and poly-fluoro alkyl substances) (Analysis on a minimum of 28 PFAS compounds using LC-MS/MS)					
PFOS	µg/kg	B	B	B	B
PFOA		B	B	B	B
B – Biannually (January, July)					

Table 4-5. Soil monitoring frequency and analytes (amended from Attachment 9 of EPL188-01)

		Sample Locations			
	Site Code	SS01	SS02	SS03	SS04
Parameter	**Units**	**Frequency**			
Metals/Metalloids					
Aluminium (Al)	µg/L	B	B	B	B
Boron (B)		B	B	B	B
Chromium (Cr)		B	B	B	B
Cobalt (Co)		B	B	B	B
Copper (Cu)		B	B	B	B
Lead (Pb)		B	B	B	B
Mercury (Hg)		B	B	B	B
Nickel (Ni)		B	B	B	B
Zinc (Zn)		B	B	B	B
PFAS (per-and poly-fluoro alkyl substances) (Analysis on a minimum of 28 PFAS compounds using LC-MS/MS)					
PFOS	µg/L	B	B	B	B
PFOA		B	B	B	B
B – Biannually (January, July)					

4.2 EPA304-01 monthly water monitoring

Monthly surface and groundwater samples will be collected from five groundwater bores and two surface water sites, as per the *Shoal Bay Leachate Treatment Sampling and Analysis Quality Plan (SAQP)*, developed by EcOz in July 2020. This monthly monitoring will be implemented for an initial 12 months (April 2021 to March 2022). After this time the sampling frequencies will follow the groundwater and surface water plans as outlined in Tables 3-2 and 3-3.

Table 4-6. Monthly sampling of groundwater and surface water sites as per EPA304-01 for initial 12 months (April 2021 to March 2022)

Groundwater bores (to be installed)	Surface water sites	Sample analysis
GW16-3 GW16-12 GW16-30 GW17-3 GW17-12	SW15 SW16	**Field parameters –** • Temperature, • Dissolved oxygen (DO), • Electrical conductivity (EC), • Total dissolved solids (TDS), • Salinity, • pH, • Oxidation-reduction potential (ORP) and • Turbidity **Laboratory analysis -** • Chemical Oxygen Demand • Total Organic Carbon • Explosives - TNT and RDX • Major cations and anions (alkalinity) • TDS/TSS • PFAS • Glyphosate • Nutrients (nitrogen compounds) • Dissolved heavy metals (NEPM suite 15 metals plus Fe, CrVI) • Faecal coliforms and *E. coli* • Polychlorinated biphenyls (PCBs) • Organochlorine pesticides (OCP) • Organophosphate pesticides (OPP) • Volatile organic compounds (VOCs) • Total recoverable hydrocarbons (TRH) • Benzene, toluene, ethylbenzene, xylenes and naphthalene (BTEXN) • Polycyclic aromatic hydrocarbons (PAHs) • Phenolic compounds • Volatile fatty acids (VFAs) • Absorbable organic halide (AOX)

5 SAMPLING METHODS

All sampling will comply with the Australian/New Zealand Standard on Water Quality Sampling - Part 1: *Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples* (AS/NZS 5667.1:1998).

Samples will be immediately chilled in eskies with ice bricks and delivered to a National Association of Testing Authorities (NATA) accredited laboratory each day.

5.1 Sample collection technique

5.1.1 Groundwater

Groundwater sampling methods comply with the Australian/New Zealand Standard on Water Quality Sampling – Part 11: *Guidance on sampling of groundwater* (AS/NZS 5667.11:1998).

Groundwater sampling involves:

- The measurement of physical parameters (pH, temperature, electrical conductivity (EC), dissolved oxygen (DO), turbidity) in groundwater using hand-held field water quality meters calibrated prior to mobilisation to site, and
- The collection of groundwater into laboratory-supplied sample bottles for sending to the laboratory for analysis.

Samples will be collected from groundwater bodies using a micropurge/low-flow bladder pump in the first instance, or with manual bailers if groundwater yields are insufficient to allow pumping. The micropurge/low-flow sampling set up is proven for minimal effect on water chemistry and obtaining representative samples (Sundaram et al. 2009). If manual bailing is required, disposable Clear-View PVC bailers will be used; a new bailer for each bore.

In order to gain a representative sample of the surrounding groundwater aquifer quality and not stagnant water contained within the bore, the pump is lowered to within the screened interval, and the rate of pumping matched to the groundwater recharge rate; confirmed by constant monitoring of the standing water level (SWL), which must remain stable. Water quality parameters (pH, temperature, EC, DO, oxidation reduction potential (ORP)) are constantly monitored in the groundwater as it is pumped from the bore using water quality meters. Pumping is continued until readings stabilise i.e. until three consecutive readings of all parameters measured at 5 minute intervals stabilise to within 5% of each other. This usually takes at least 30 minutes of pumping. Low dissolved oxygen and negative oxidation reduction potential are also indicators of fresh groundwater, and not water from within the bore casing which is in contact with the air. Once stable readings are achieved, samples for laboratory analysis are collected directly into laboratory-supplied bottles.

When using manual bailers, a dedicated bailer is used for each bore, and the bore is purged until dry and then sampled once the bore has recharged and SWL has returned to its original level. If recharge in the bore means it doesn't completely empty, then three times volumes worth of standing water in the bore must be removed and the original standing water level allowed to return prior to sampling.

Samples for dissolved metals analysis will be field-filtered using a new disposable syringe and filter (0.45 µm) for each sample.

5.1.2 Surface water and leachate

Surface water sampling complies with the following standards:

- Australian Standard on Water Quality Sampling - *Part 4: Guidance on sampling from lakes, natural and man-made* (AS/NZS 5667.4:1998);
- Australian Standard on Water Quality Sampling – *Part 6: Guidance on sampling of rivers and streams* (AS/NZS 5667.6:1998);
- Australian Standard on Water Quality Sampling – *Part 10: Guidance on sampling of waste waters* (AN/NZS 5667.10:1998)

Surface water and leachate sampling involves:

- The measurement of physical parameters (pH, temperature, EC, DO, turbidity) using hand-held field water quality meters calibrated prior to mobilisation to site, and
- The collection of water into laboratory-supplied sample bottles for sending to the laboratory for analysis.

The specific method of sampling differs depending on the water source. The five different types of water sources and corresponding sampling methods are:

- Surface water bodies, ponds, and drains with safe direct access – will be sampled directly by placing field water quality meters into the water body for physical parameters, and collecting water samples for laboratory analysis directly into the laboratory-supplied sample bottles (note for bottles with preservative, sample will be decanted into the bottle from one of the unpreserved laboratory-supplied bottles to prevent loss of preservative).
- Surface water bodies, ponds, and drains without safe direct access – will be sampled using a clean, decontaminated jug on a pole, and the physical parameters measured immediately from within the jug. The jug on a pole will then be rinsed in the sample water several times prior to collecting sample for decanting into the laboratory-supplied sample containers for laboratory analysis.
- Sumps without a pump – will be sampled using a clean, decontaminated jug on a pole (as explained above) or a dedicated bailer. When using a bailer, the sample is decanted into a clean, decontaminated jug for measuring physical parameters and the sample poured directly into laboratory-supplied sample containers for laboratory analysis.
- Sumps with a pump – will be sampled by turning the tap on and the sample going into a clean, decontaminated jug for measuring physical parameters and then poured directly from the tap into laboratory-supplied sample containers for laboratory analysis.
- Leachate risers – will be sampled using a submersible pump lowered into the riser with the sample going from the hose into a clean, decontaminated jug for measuring physical parameters and then directly from the hose into laboratory-supplied sample containers for laboratory analysis.

For surface water bodies and sumps sampled either directly or using a sample pole or bailer, samples will be collected approximately 0.3 m below the water surface. When collecting samples from flowing water bodies, the sample must be collected a reasonable distance from the water's edge and facing into the flow direction, keeping hands and sampler equipment downstream to prevent contamination.

Samples for dissolved metals analysis (both surface water and leachate) will be field-filtered using a new disposable syringe and filter (0.45 µm) for each sample.

Water samples are kept on ice in an insulated container until submission to an accredited laboratory.

5.1.3 Soil sampling

To ensure the quality and accuracy of measurements, this sampling procedure complies with the following standards and guidelines:

- Standards Australia 2005. AS4482.1 – 2005. *Guide to the sampling and investigation of potentially contaminated soil – Part 1: Non-volatile and semi-volatile compounds.*
- NEPC Schedule B (1): *Guideline on the Investigation Levels for Soil and Groundwater.*

Soil sampling is to occur as per the following steps:

- The sampler is to be wearing powder-free gloves.
- The required pre-labelled sample containers are to be labelled with sample date and time.
- Hands are to be kept away from sample container openings and the inside of jar lids. Sampler is to be aware that sources of contamination include permanent markers, insect repellent, sunscreen, deodorant, dust and perspiration.
- For soil sampling a trowel or auger is used (depending on seasonal hardness of soil) and a surface sample is collected from 200 mm.
- Containers are to be filled with the excavated soil. Collection of the sample is to be taken from the centre of the soil mass where minimal interaction with sampling equipment occurred.
- Once all containers are filled and tightly sealed, they are to be placed upright into the insulated cooler or car fridge and stored below 4°C before submission to an accredited laboratory.

5.1.4 Dust depositional sampling

Dust deposition sampling involves the passive collection of deposited particulate matter over a 30 day period providing an estimated deposition rate in g/m²/month.

Dust depositional sampling is carried out in accordance with the following standards:

- Australian Standard 2016. AS/NZS 3580.10.1 *Methods for sampling and analysis of ambient air - Determination of particulate matter – deposited matter – gravimetric method*.
- Australian Standard 2016. AS/NZS 3580.1.1 *Methods for sampling and analysis of ambient air - Guide To Siting Air Monitoring Equipment*.

Sampling methods are as follows:

- Installation of deposition gauge consisting of 150 mm glass funnel with rubber stopper and laboratory supplied 4 L glass collection bottle on top of stand so that height of the top of the funnel is 2 m above ground level.
- Deposition gauges are to be labelled with site name, date and time of installation.
- Following the required 30 day sample period, any deposited matter on the glass funnel is washed into the deposition bottle using minimal demineralised water.
- The funnel and rubber stopper are removed, the bottle sealed with supplied lid and the labelling process completed with the date and time of collection.
- The bottle is sealed tight and submitted to NATA accredited laboratory for analysis.

5.2 Field records

At each sampling location, the field records will include at minimum, the following information:

- Sampling time, date and the name of the sampler;
- Weather conditions;
- Sample collection method;
- Purging records including groundwater and surface water field quality measurements and water level measurements (where applicable);
- Soil sampling and soil extraction method;
- Dates of installation and retrieval of depositional gauges;
- Sample equipment decontamination procedures where non-disposing sampling equipment is utilised.

5.3 Quality Assurance / Quality Control (QA/QC)

5.3.1 Water sampling

QA/QC samples will comprise:

- Field duplicate samples at 1 per 10 water samples per monitoring event, to identify the variation in analyte concentrations between samples collected from the same location and/or the repeatability of laboratory analysis.
- Field triplicate (split) samples at 1 per 20 water samples per monitoring event, analysed by a second laboratory, to verify the analytical proficiency of the primary laboratory.

Samples will be analysed by a NATA accredited laboratory and laboratory certificates will be NATA endorsed reports.

Upon receipt of the laboratory analytical results, the following elements will be assessed to ensure QA/QC of samples;

- Laboratory and field duplicates
- Trip blanks
- Laboratory internal standards and calibration blanks and method blanks
- Matrix spike, matrix spike duplicate and surrogate spikes
- The occurrence of apparent unusual or anomalous results, e.g. laboratory results that appear to be inconsistent with field observations or measurements.

5.3.2 Soil sampling

Rinsate blanks

For every event less than 20 samples, and thereafter every 20 samples, 1 rinsate blank sample is required. The Rinsate blank sample is to test the field methods and quality control of cleaning equipment in the field. Once finished all site samples all equipment is washed with the decon demineralised water solution, in the same manner as between sites.

- Equipment is to be rinsed thoroughly with demineralised water

- Demineralised water is to be poured over field sampling equipment into a clean 2 L receptacle, and then pour the water from the 2 L receptacle into the correct water sampling bottles to cover all required analytes for the soil sampling event.
- Sample bottles are to be labelled as rinsate
- Bottles of rinsate are to be sent to the lab along with the soil sample containers.

Field duplicates

For every event less than 20 samples, and thereafter every 20 samples, 1 field duplicate sample is required. Duplicate samples are required to test the accuracy of methods used for sample collection in the field and also the laboratory analysis.

- Once normal site sampling is complete, an extra sample is collected using the same method.
- It is noted from which site the duplicate sample was collected.

Split samples

For every event less than 20 samples, and thereafter every 20 samples, 1 split sample is required. The split sample is sent separately to a different and independent laboratory. This is to test the laboratory analysis.

- Same procedure as for the duplicate sample
- The site the split sample was collected from is noted on the field sheet. Duplicate and split samples are collected from the same site in order to also compare the split and duplicate samples.
- The split sample container is stored on ice and submitted to the different accredited laboratory.

5.4 Reporting

The Australian and New Zealand Environment Conservation Council (ANZECC 2000; ANZG 2018) *Australian and New Zealand Guidelines for Marine and Freshwater Quality* trigger values for protection of 90 % of marine ecosystems have been adopted for reference when assessing the sample analytical results.

A quarterly water monitoring report will be issued to Council and the NT EPA, consisting of a summary of monitoring undertaken, tabulation of results, trend analysis and interpretation of results. The NT EPA will be notified in writing when licence parameters exceed trigger values as per section 5.4.1.

This report should include as a minimum:

- Summary of results for the monitoring event, presented graphically and/or in tabulated format;
- Comparison of results to historical data (if relevant); and
- Comparison of results with respect to the adopted quality criteria and/or trigger levels.

Annual monitoring reviews presenting the results of all (water, depositional and soil) sampling and analysis for the twelve (12) month monitoring period should also be produced by a suitably qualified hydrogeologist/water scientist/scientist. The report should include:

- Summary of results for the sampling rounds, including graphical and tabulated interpretation;
- Historical analytical data (graphical and tabulated);
- Comparison of results with respect to the adopted quality criteria and/or action levels;
- Discussion of results with respect to historical monitoring data and temporal and spatial trends; and
- Recommendations for future monitoring.

All electronic and hard copy files will be maintained electronically and/or in hardcopy to enable timely access. This includes all reports, laboratory analysis results, sampling documentation, chain of custody records, AutoCAD, GIS and associated correspondence.

5.4.1 Exceedance Notification

The NT EPA will be notified in according with EPL188-01 in writing as soon as practicable (and in any case within 24 hrs) after becoming aware, when the guideline specified trigger values are exceeded;

- on three consecutive sampling occasions; or
- at greater than or equal to two times the trigger value; or
- at a median value for six consecutive monitoring results.

This notification should include as a minimum;

- when the exceedance was detected and by whom;
- the date and time of the exceedance;
- the actual and potential causes and contributing factors to the exceedance;
- the risk of environmental harm arising from the exceedance assessed in accordance with relevant standards as listed in the WQMP;
- the action(s) that have or will be undertaken to address the exceedance and/or environmental harm;
- if no action was taken, why no action was taken; and
- a date when an incident investigation report will be submitted to the NT EPA.

5.4.2 Annual Reporting

A completed Annual Return will be submitted via NT EPA Online within 10 business days after each anniversary date of EPL 188-01, which relates to the preceding 12 month period. A completed Monitoring Report will be provided to the NT EPA, as prescribed by EPL 188-01, within 20 business days after each anniversary date of EPL 188.

This Monitoring Report should;

- be prepared in accordance with the requirements of the NT EPA *'Guideline for Reporting on Environmental Monitoring*';
- reports on all surface water, groundwater, leachate, soil and depositional monitoring undertaken as part of the environmental monitoring;
- include tabulation of all monitoring data required as a condition of EPL 188-02;
- include long term trend analysis of monitoring data to demonstrate any environmental impact associated with the activity over a minimum period of three years (where the data is available);
- report on all environmental monitoring exceedances and investigations; and
- include an assessment of environmental impact from the activity.

6 REFERENCES

ANZECC & AMRCANZ 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), Canberra.

ANZECC & AMRCANZ 2000, *Australian Guidelines for Water Quality Monitoring and Reporting*, National Water Quality Management Strategy Paper No 7, Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), Canberra.

ANZG 2018. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines

Australian/New Zealand Standard on Water Quality Sampling - Part 1: *Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples* (AS/NZS 5667.1:1998), Standards Australia, New South Wales.

Australian/New Zealand Standard on Water Quality Sampling - Part 4: *Guidance on sampling from lakes, natural and man-made* (AS/NZS 5667.4:1998), Standards Australia, New South Wales.

Australian/New Zealand Standard on Water Quality Sampling - Part 6: *Guidance on sampling of rivers and streams* (AS/NZS 5667.6:1998), Standards Australia, New South Wales.

Australian/New Zealand Standard on Water Quality Sampling – Part 10: *Guidance on sampling of waste waters* (AN/NZS 5667.10:1998), Standards Australia, New South Wales.

Australian/New Zealand Standard on Water Quality Sampling – Part 11: *Guidance on sampling of groundwater* (AS/NZS 5667.11:1998), Standards Australia, New South Wales.

Australian Standard 2005. AS4482.1 – 2005. *Guide to the sampling and investigation of potentially contaminated soil – Part 1: Non-volatile and semi-volatile compounds,* Standards Australia, New South Wales.

Australian/New Zealand Standard 2016. AS/NZS 3580.10.*1 Methods for sampling and analysis of ambient air - Determination of Particulate matter – deposited matter – gravimetric method*, Standards Australia, New South Wales.

Australian/New Zealand Standard 2016. AS/NZS 3580.1.1 *Methods for sampling and analysis of ambient air - Guide To Siting Air Monitoring Equipment*, Standards Australia, New South Wales.

NEPC Schedule B (1) 2011: *Guideline on the Investigation Levels for Soil and Groundwater*.

NT EPA 2016, *Draft Environment Protection Licence EPL188-02*, Issued 1 July 2016, Expires 30 June 2021, Northern Territory Environment Protection Authority (NT EPA), Darwin, NT.

NT EPA 2013, *Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites in the Northern Territory*, Northern Territory Environment Protection Authority (NT EPA), Darwin, NT.

Sundaram, B., Feitz, A., Caritat, P. de, Plazinska, A., Brodie, R., Coram, J. and Ransley, T., 2009. *Groundwater Sampling and Analysis – A Field Guide*. Geoscience Australia, Record 2009/27 95 pp.

URS 2016, *Shoal Bay Waste Disposal Site Water Monitoring Plan*, March 2016, Report prepared for John Holland Pty Ltd, URS Australia, Darwin, NT.

Work Health and Safety (National Uniform Legislation) Act, and Work Health and Safety (National Uniform Legislation) Regulations, NT Government.

EcOz Environmental Consultants

EcOz Pty Ltd.
ABN 81 143 989 039

Level 1, 70 Cavenagh St,
GPO Box 381,
Darwin, NT 0801

T: +61 8 8981 1100
E: ecoz@ecoz.com.au

www.ecoz.com.au

APPROVED COMPANY ISO 14001 Environmental Management Systems
QMS Certification Services

APPROVED COMPANY AS/NZS 4801 Occupational Health & Safety Management Systems
QMS Certification Services

APPROVED COMPANY ISO 9001 Quality Management Systems
QMS Certification Services