CLEANAWAY

Making a sustainable future possible

2024

Banksia Road Rehabilitation and Closure Plan

PROPOSED REHABILITATION PLAN

CLEANAWAY SOLID WASTE PTY LTD

Lot 2 Banksia Road, Dardanup WA 6236 Australia | PO Box 214, Dardanup WA 6236

Updated Rehabilitation and Closure Plan (2024).

Document Control

Version (Date)	Author	Reviewed By	Approved By
V1 (07 September 2016)	[redacted]		
V2 (15 September 2020)			
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V1 (07 September 2016)	IW Projects Submitted to Department of Environment Regulation, WA
V2 (15 September 2020)	Sally Carlton
V3 (9 February 2021)	Shire of Dardanup in response to Urbaqua third party review
V4 (19 March 2021)	Minor updates for consistency with other documents
V5 (26 March 2021)	Updated for works approval submission
V6 (28 January 2022)	Updated for amended EPA licence issued on 28/10/2021 and Phytocap Trial completion
V7 (29th August 2022)	Updated for Planting Zone Plant Specification & Cell & Capping Event Timing Update
V8 (5 October 2022)	Updated to provide Cell and Capping Timing for both 128 & 149m AHD Waste Filling
V9 (12 September 2023)	Updated for maximum top of waste RL128m AHD
V10 (February 2025)	DWER - Updated Cell filling and Capping timing and revised capping stage boundaries Shire of Dardanup in response to Tronox 1, Capping Development Application Condition 2

TABLE OF CONTENTS

TABLES

PLATES

1 INTRODUCTION

The Banksia Road Landfill Facility located at Lot 2 Banksia Road, Crooked Brook, WA (**Site**) is licensed under Cleanaway Solid Waste Pty Ltd (**CWY**) by the Western Australian Department of Water and Environment Regulation (**DWER**) as per licence amendment number **L8904/2015/1** amendment dated 22 February 2024. The Class III (putrescible) landfill site currently accepts municipal, commercial and industrial waste under the following categories:

TABLE A: CATEGORY AND THROUGHPUT FOR CURRENT LICENCE

Waste Type	Category	Quantity Limit Tonnes per Annual Period	Specification
Clean Fill	Category 64	350,000 (with no more than 20,000 tonnes of Special Waste Type 1 received in any annual period)	None specified
Inert Waste Type 1			
Inert Waste Type 2			Plastics Only
Special Waste Type 1			ACM/Asbestos Waste
Special Waste Type 2			Biomedical/clinical
Putrescible Waste			
Processed Septage Waste			Semi-dry fibrous residue produced from dewatering septage waste
Contaminated Solid Waste			Must meet the acceptance criteria for Class III landfills.
Liquid Waste	Category 61	3,000	Drill Muds
Tailings	Category 5	350,000	Titanium Dioxide Tailings

1.1 PURPOSE AND SCOPE

The progressive rehabilitation is expected to commence within 12-18 months and be completed within 12-24 months of the completion of disposal in that cell or part of a cell where the final waste heights have been reached. Capping in winter is impractical due to difficulties in geosynthetic installation and soil placement. Capping in summer also allows planting of vegetation to occur following capping and in the optimal time of year, being Autumn. The document "Banksia Road Landfill Rehabilitation and Closure Plan" defines:

- Indicative design for the landfill cap,
- Final waste height contours to be achieved,
- Indicative staging of rehabilitation,
- Post Closure Period and Monitoring Regimes, and
- Potential Post Closure Use of the Site

2 CAPPING DESIGN

The aim of a landfill cap as stated in the Environment Protection Authority Victoria Publication Number 788.3 "Siting, design, operation and rehabilitation of landfills" (VIC Landfill BPEM) released in August 2015, is to:

- Achieve a design seepage rate of the cap that does not exceed 75 per cent of the design seepage rate of the landfill liner,
- Provide a long-term stable barrier between waste and the environment in order to protect human health and the environment,
- Prevent the uncontrolled escape of landfill gas, and
- Providing land suitable for its intended after use.

The following sections provide basic details regarding the capping design, with full details being presented in the Technical Specification in **Appendix A** and Construction Quality Assurance Plan in **Appendix B.**

2.1 SYNTHETIC CAP DESIGN

A synthetic cap profile is proposed for the capping of the landfill at the Site. The design of the proposed synthetic capping system (Plate A) includes the following components from the bottom up:

- Trimmed, lightly compacted and prepared cover soil subgrade
- Geosynthetic Clay Liner (GCL);
- LLDPE liner;
- Geocomposite Drainage layer;
- A minimum of 1.3 m with up to 1.5 m of uncompacted growing medium;
- Rehabilitation with grasses and shallow rooted shrubs;
- Stormwater control drains:
- Access roads over the capped surface.

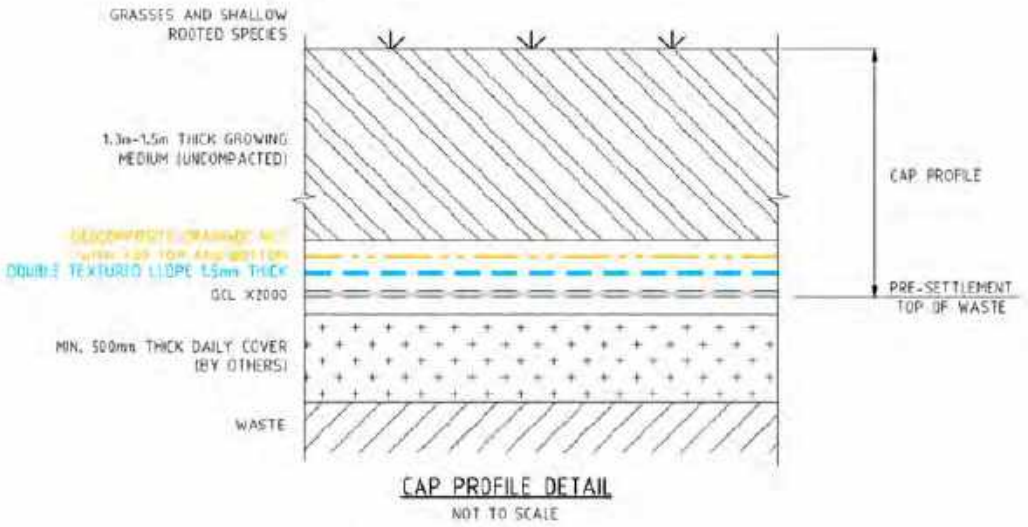


PLATE A: SYNTHETIC CAP PROFILE (IW PROJECTS, 2021)

2.2 PHYTOCAP

Cleanaway undertook an on-site trial to investigate the potential for a phytocap to be used at the Site. Synthetic caps provide a physical barrier to reduce the movement of moisture through the cap and into the waste. For a phytocap, as with a natural system, the control of moisture movement is provided by the hydraulic properties of the soil and the water use requirements of the plants matching the net moisture input from climate.

In 2019, a trial phytocap was constructed on the southern portion of Cell 5 comprising:

- 2m deep Cell 5 overburden *in situ* material over final waste height as this is likely to be representative of the mixed natural profile available in the future, and
- Mulch incorporated into the surface layer to assist plant establishment.

The phytocap trial as defined by Tonkin Consulting were considered to be completed when:

- Plant roots are removing moisture to at least 0.7 m depth. This can be shown by active removal of moisture from deeper layers,
- Fair to good establishment of plants within the lysimeter and vegetated pad, i.e. greater than 40% survival and greater than 70% groundcover has been achieved,
- Self-seeding and succession of native grasses is evident,
- The performance of the cap is known as defined by one or more of the following:
  - a year wetter than the climatic average has been received but resulted in drainage at or below the performance criteria, or;
  - after plants have established (see points above), a year drier than the climatic average has been received but resulted in drainage an order of magnitude above the performance criteria; or
  - a minimum of two years of data once plants have established (see points above) are used to calibrate a water balance model and then predict the water balance performance over a longer time period, and
- DWER has accepted the final monitoring report.

A final report on the performance of the phytocap has been prepared. Two unsuccessful attempts were made to establish vegetation on the trial area; however, neither were successful in establishing coverage over the trial area which would achieve the first three completion requirements listed above. As a result, the performance of the cap is unknown.

The high level of maintenance required to establish the phytocap vegetation combined with the high erodibility of the on-site soil has resulted in Cleanaway determining that a phytocap will not be suitable for their site. Further details on the trial results are presented in **Appendix C**.

3 FINAL CONTOUR PLAN

A landfill top of waste contour plan was developed in January 2024 for the entire potential landfill footprint including the consumed footprint. The contour plan shown in **Figure 2** (Final TOW Contours) refers to the top of waste and bottom of cap and presents the top of waste pre-settlement contours; this is to minimise any risk of overfill with waste. A visual amenity assessment has been completed to assess the visual impacts of the Final TOW Contours.

The final capped landform will be 1.8-2.0 m above top of waste contour. The final top of waste contour was originally submitted in 2016 and has been updated in 2024 to achieve the same objectives as the previous landform. The Final TOW Contours provide the following top of waste gradients:

- Minimum 1V:20H (5%) on the top platform, and
- Maximum 1V:3.5H (approximately 30%) on the batter slopes.

The finished capped contour (TOC Contours) will be maintained by filling and shaping to prevent ponding of stormwater which may occur as the underlying waste settles. The maximum height of the final TOC Contours will be RL 130 (prior to settlement) and aligns with the topography of the adjacent state forest.

4 CAPPING STAGING PLAN

Cleanaway has developed a whole of life model to understand future landfill cell construction and landfill cap staging plan. The Capping Staging Plan shown in **Figure 1** and the timeline presented in **Table B**, are based on the below assumptions:

- The Site, on average, receives 200,000 tonnes of landfill waste per annum (licensed to receive up to 350,000 tonnes),
- On average, a waste density of 1 tonne per m^3 is achieved,
- The available airspace in Cells 12A, 9 and 10 is based on the approved cell baseliner designs (Works Approval W6855/2023/1) and the Final TOW Contours,
- The available airspace in future cells 11, and 13-20 is based on a similar baseliner design to the approved cells and the Final TOW Contours.

The aim of the landfill cap staging plan is to minimise potential environmental impacts, such as leachate generation and LFG emissions by capping completed stages in a timely manner. The objective is to commence capping landfill cells, or part thereof, in the summer immediately following, but no later than 12-18 months and be completed within 12-24 months from reaching final waste contours.

The area deemed as potential landfill footprint including consumed footprint is 48.3ha. The total footprint is estimated to generate approximately 14.3 million m^3 of airspace (to maximum RL128m AHD TOW), of which approximately 10.1 million m^3 is remaining as of November 2023. The landfill, based on the above stated assumptions, is expected to receive waste until approximately 2074.

The landfill is expected to be capped over 13 rehabilitation stages as shown in **Figure 1** and **Table B** below. Estimation of waste volumes received on Site beyond 5 years is uncertain due to increased recycling rates and initiatives in reducing waste disposed to landfill. For this plan, we have used a disposal rate of 200,000 tonnes/annum to estimate the period in which capping is likely to commence for future Rehabilitation Stages. All capping campaigns will be planned to commence in summer to limit wet weather delays and to allow for vegetation planting in autumn or winter.

Stage 1 Cap construction is now complete with vegetation planting planned prior to the upcoming winter. Stage 2 Cap construction is expected to commence in the summer of 2025/26 within 12-18 months and be completed within 12-24 months from reaching the final TOW contours (expected late 2024). Further stages will continue capping the western and north-western batters of the landfill, i.e. Rehabilitation Stages 3 and 4, which will provide a vegetated view sympathetic to the surrounding environment. The remaining landfill operations will be predominantly screened from neighbours and the surrounding roads, improving the visual amenity by approximately 2030.

TABLE B: LANDFILL CAPPING EVENTS

Rehabilitation Stage	Capping Area (Ha)	Corresponding Landfill Cells	Estimated Timeline to Reach Final TOW [1]	Timeline to Commence Capping [2]
1	2.60	Cell 5	Complete	Complete
2	2.35	Cells 5 & 6	Oct-24	Oct-25
3	3.85	Cell 12A to Stage 3 TOW	Aug-27	Oct-28
4	4.15	Cell 12A to Stage 4 TOW	Oct-28	Oct-29
5	3.50	Cells 9 & 10	Aug-35	Oct-36
6	3.00	Cell 15	Apr-39	Oct-40
7	3.40	Cell 16	Dec-43	Oct-44
8	3.35	Cell 17	Aug-48	Oct-49
9	2.85	Cells 11 & 13	Dec-54	Oct-55
10	3.40	Cell 18	Sep-59	Oct-60
11	3.45	Cell 19	Jul-64	Oct-65
12	6.10	Cell 14 and Cell 20 to Stage 12 TOW	Feb-71	Oct-72
13	6.20	Cell 20	Apr-74	Oct-75

Notes:

1. Timeline to reach the final top of waste within each stage of rehabilitation is based on the following assumptions:
    a. Approved cell designs for Cells 12A, 9 and 10.
    b. Indicative cell designs for future Cell 11 and Cells 13-20, based on a similar design to the approved cells.
    c. The Final TOW Contours.
    d. Assumed annual incoming rate of 200,000 tonnes of landfill waste per annum.
2. This timeline presents the latest time when capping is estimated to commence, based on construction works commencing within 12-18 months and be completed within 12-24 months from reaching the final top of waste profile. In practice, all capping campaigns will be planned to commence as soon as practicable the following summer to allow sufficient settlement to avoid unnecessary strain being applied to the lining system due to settlement and also to limit wet weather construction delays and allow for vegetation planting in autumn or winter.

5 POST CLOSURE PERIOD AND MONITORING REGIME

Post closure period refers to environmental performance monitoring duration after placing the final tonne of waste or tailings into the cells, to consume total airspace. Post closure period is expected to be a minimum of 25 years from completion of final capping event and the below aspects will be monitored:

- Groundwater quality,
- Landfill gas migration,
- Landfill settlement due to waste subsidence,
- Landfill cap free drainage capability,
- Leachate pond levels, quality and leachate collection system equipment,
- Stormwater management,
- Vegetation health and coverage, and
- Buffer zones maintenance.

5.1 GROUNDWATER QUALITY

The parameters and frequency of groundwater monitoring will reflect current or future requirements in Table 21 of the DWER operating licence L8904/2015/1 Amendment issued 22 February 2024 Table **C** below shows the current monitoring requirements for the site. If the assessment of groundwater quality over a certain period during post closure reveal stable conditions, then a revised list of parameters and monitoring frequency will be proposed to the DWER for approval. The requirement to submit groundwater quality monitoring results to the DWER continues following closure.

Monitoring of upgradient and downgradient bores from the Tronox Leachate Pond for a period of 10 years post closure of the Leachate Pond to ensure no contamination is present and reported to the Shire on an annual basis. Where contamination is present at any time this must be investigated and addressed and immediately reported to the Shire of Dardanup.

TABLE C: MONITORING REQUIREMENT OF GROUNDWATER QUALITY

Monitoring point reference	Parameter	Units	Sample Type	Frequency
Monitoring wells as shown in Figure 2, Schedule 1 of the Licence	Standing water level[1]	m (AHD)	Spot Sample	Quarterly
	pH[1]	pH unit		
	Electrical conductivity[1]	µS/cm		
	Redox potential[1]	Eh		
	Chemical oxygen demand	mg/L		
	Nitrate-nitrogen			
	Ammonia-nitrogen			
	Total nitrogen			
	Total phosphorus			
	Total dissolved solids			
	Total organic carbon			
	Dissolved oxygen[1]			
	Major cations and anions: calcium, magnesium, potassium, sodium, chloride, bicarbonate and sulphate			
	Heavy Metals: Aluminium, Arsenic, Cadmium, Chromium, Copper, Iron (total) Lead, Manganese, Mercury, Nickel, Selenium and Zinc			
	PFAS: • Perfluorooctane sulfonate; • Perfluorooctanoic acid; • 6:2 Fluorotelomer sulfonate; • 8:2 Fluorotelomer sulfonate, • Perfluoroheptanoic acid; • Perfluorobutane sulfonate; • Perfluorobutanoic acid; • Perfluorohexanoic acid; • Perfluorohexane sulfonate; • Perfluoropentanoic acid; • Perfluorooctane sulfanomide; • Perfluorodecane sulfonate; • Perfluorononanoic acid; • Perfluorodecanoic acid; • Perfluoroundecanoic acid; • Perfluorododecanoic acid; • Perfluorotridecanoic acid; • Perfluorotetradecanoic acid; • N-Methyl-heptadecafluorooctane sulfanomide; • N-Eethyl-heptadecafluorooctane sulfanomide; • N-Methyl-heptadecafluorooctane sulfanomidoethanol; and, • N-Ethyl-heptadecafluorooctane sulfanomidoethanol.	µg/L	Spot Sample	Six monthly
	Organics: Phenols, Polyaromatic hydrocarbons (PAH), Organochlorine pesticides, Organophosphate pesticides (Demeton-S-Methyl, Diazinon, Dimethoate, Fenamiphos, Fenthion, Malathion and Parathion), Polychlorinated biphenyls (PCB), Atrazine, BTEX (benzene, toluene, ethylbenzene, xylens), Total Petroleum Hydrocarbons and Trichloroethylene/ Perchloroethylene	mg/L	Spot Sample	Six monthly

Note 1: In-field non-NATA accredited analysis permitted.

5.2 LANDFILL GAS MIGRATION

In 2013, a LFG extraction system was installed under Works Approval W5301/2012/1. In 2021, expansion of the landfill gas collection system at the landfill was approved by DWER to install gas extraction wells across filled areas of the landfill to provide active landfill gas management. The landfill gas migration detection regime during post closure will reflect the monitoring program stated in the Landfill Gas Management Plan and **Table D** shows the landfill gas monitoring current requirements of the site in accordance with EPA licence L8904/2015/1.

TABLE D LANDFILL GAS MONITORING REQUIREMENTS

Monitoring Point	Parameter	Units	Sample Type	Frequency	Method
Each well, as depicted in Schedule 3, Plan 3 and Plan 4 **Flare, as depicted in Schedule 3, Plan 3**	Volumetric flow rate	m^3/hr	Spot Sample	Monthly	Landtec GEM2000, GEM5000 (or superior field test methods)
	Methane	volume%			
	Carbon dioxide	volume%			
	Oxygen	volume%			
	Nitrogen	volume%			
	Carbon monoxide	Ppm			
	Gas temperature	°C			
	Pressure	Pa			

5.3 LANDFILL SETTLEMENT DUE TO WASTE SUBSIDENCE

Waste subsidence can create internal stress on cap due to differential settlement across the final capped landform. This may lead to zones of stress cracking, allowing escape of landfill gas through the cracks and percolation of stormwater into the landfill. The proposed geosynthetic cap is less prone to this than compacted clay barriers or HDPE liners. Any perforations in the liner, can be detected by virtue of landfill gas surface monitoring regime and visual inspection. Any areas identified will be investigated to determine if improved capping or a repair to the liner is required to minimise LFG emissions to acceptable levels.

5.4 LANDFILL CAP FREE DRAINAGE CAPABILITY

Cleanaway will undertake annual aerial survey of the site during post closure period to determine the settlement areas. The survey will be used to identify the low spots and works required to maintain the cap as free draining.

5.5 LEACHATE POND LEVELS, QUALITY AND LEACHATE COLLECTION SYSTEM EQUIPMENT

Leachate is managed by pumping from the active landfill cells to leachate storage ponds, with the exception of Cell 1 where leachate flows to the ponds via a gravity system. Leachate head within the pumped landfill cells with pumps is measured by bubbler instrumentation. The volume generated is derived from pump data

and/or flow meters. Sprinklers are installed in all leachate ponds to assist evaporation during appropriate weather conditions. Leachate levels are to be managed and a balance between generation and evaporation is to be maintained.

Leachate quality monitoring and frequency is per Licence Condition 54. Should quality testing indicate a capping failure, then this will need to be addressed immediately via investigation for a designer approved repair or alternative solution. This will also be immediately reported to the Shire of Dardanup.

If leachate generation is found to exceed the disposal capacity of the existing infrastructure at the site, Cleanaway will implement additional measures to manage the excess leachate volumes.

Routine monitoring will continually assess the evaporation achieved and staging of capping to closely follow cell completion will assist in minimising leachate generated.

5.6 STORMWATER QUALITY

Stormwater at the site is separated from leachate and is directed to a series of culverts, swales and drains, sedimentation basins and stormwater ponds. Site stormwater ponds, swales, culverts and drains have been designed to comply with the requirements of the Licence and retain all stormwater on site.

Regular inspection and maintenance of the stormwater control structures is undertaken to maintain the function of the stormwater management system. Maintenance includes any necessary repairs to infrastructure and regular silt removal from drainage structures.

5.7 VEGETATION HEALTH AND COVERAGE

A Landscaping Plan **(Appendix D)** has been prepared for the site which identifies several zones, being:

- Zone 1 – an infrastructure zone near the landfill perimeter and includes access roads and tracks and stormwater drains.
- Zone 2 – a grassed area on the upper crest of the landfill and the Tronox ponds area for use as passive recreation. Trees, shrubs and native gardens may be included in this space.
- Zone 3 – The western batter slopes of the landfill will be planted to native shrubs and grasses to provide a visual screen and blend the visual amenity to the eastern & southern boundaries with the Dardanup Conservation Park vegetation and landfill topography.
- Zone 4 – Buffer zone around the landfill comprised of native vegetation, including trees, shrubs and groundcover species to link with adjacent areas.
- Zone 5 - a wetland zone around the stormwater basins and leachate ponds, consisting of native shrubs and groundcovers

The Landscaping Plan also nominates species for use within these zones and methods of sowing, establishment and maintenance. It is noted that weed suppression during vegetation establishment is of critical importance.

Tree and shrub density should achieve a minimum of 1 plant/20 m^2. Where bare patches > 4m^2 or vegetation establishes poorly (refer to **Appendix D**), species shall be replanted with the same or similar species using tubestock for small area or broadscale seeding for larger areas, as advised by a vegetation contractor.

5.8 SEPARATION DISTANCE MAINTENANCE

DWER has prepared *Guidance for the Assessment of Environmental Factors, Separation Distances between Industrial and Sensitive Land Uses,* (WA EPA, 2005) which nominates a 500 m separation distance between a Class III Landfill and any sensitive land use.

6 POTENTIAL POST CLOSURE USE OF THE SITE

Landfills may be used for a variety of final uses from no public access grasslands to commercial uses. Any development on the landfill must consider the capping design used and ensure that the human and environmental health is not compromised by exposing waste or increasing the generation of landfill gas or leachate. The settlement of waste during the early post-closure phase can also limit the location and type of development. The waste settles differentially resulting in cracking and deformation of structures, such as concrete slabs and buildings. Access for maintenance of post-closure infrastructure (landfill gas extraction, leachate collection, stormwater management) and for monitoring of surface integrity, groundwater, leachate and stormwater is required and final land uses must include consideration of these requirements.

The post closure use of the site is expected to be open space utilisable as a natural reserve for passive recreational purposes. The land use surrounding the site is predominantly agricultural and nature reserves, including the Dardanup Conservation Park which abuts the southern boundary. Tourism in the Shire of Dardanup is predominantly related to the natural environment, including the Ferguson Valley and Crooked Brook Forest[1] . The site is also located on the western edge of the Whicher Scarp which is visible from the surrounding areas. Development of the site as a natural reserve for passive recreation will support the adjacent Conservation Park and provide a development sympathetic to the natural character of the Shire of Dardanup.

Other potential alternatives for the site may include:

- agricultural land. The site could be used for grazing, however closed landfills are typically unsuitable for cropping due to potential LFG effects;
- a waste precinct (non-landfill operations) such as use as a waste transfer station or composting facilities subject to appropriate approvals. These works are most likely to occur on the eastern portion of the site as higher rates of waste settlement during the early post closure phase increase the maintenance requirements for hardstands, concrete slabs and structures, such as sheds;
- a renewable energy precinct. Solar farms have been installed on closed landfills elsewhere for the generation of renewable energy without additional land clearing for construction;
- active recreational space (e.g. sporting or other community facilities). Closed landfills can used for active recreation, such as mountain bike trails, sports ovals, etc. Care must be taken to ensure stormwater is carefully controlled to prevent surface erosion from compromising the integrity of the cap. In addition, the increased potential public liability can be a barrier to acceptance;

The development of the site for passive recreation will not preclude the later development of the site for these other uses, subject to the need for the development and gaining appropriate approvals.

7 CLEANAWAY CONTACT DETAILS

Please contact the below person for any clarifications (in order of preference):

[redacted]

8 FIGURES

9 APPENDICES

FIGURE 1: REHABILITATION STAGING PLAN (SENVERSA)

LEGEND

- SURVEY DATED 01.11.2023 CONTOURS AT 1 m INTERVALS
- TOP OF WASTE CONTOURS AT 1 m INTERVALS
- APPROXIMATE CAPPING BOUNDARY
- LOT BOUNDARY
- CELL BOUNDARY

	CAPPING AREA (m²)
REHABILITATION STAGE 1	26,000
REHABILITATION STAGE 2	23,500
REHABILITATION STAGE 3	36,500
REHABILITATION STAGE 4	41,500
REHABILITATION STAGE 5	35,000
REHABILITATION STAGE 6	30,000
REHABILITATION STAGE 7	34,000
REHABILITATION STAGE 8	33,500
REHABILITATION STAGE 9	28,500
REHABILITATION STAGE 10	34,000
REHABILITATION STAGE 11	34,500
REHABILITATION STAGE 12	61,000
REHABILITATION STAGE 13	62,000

REFERENCES:

1. AERIAL PHOTOGRAPH SOURCED FROM METROMAP ON 13.01.2024, IMAGE DATED 08.03.2023,
2. SURVEY PROVIDED BY CLEANAWAY ON 07.12.2023. SURVEY DATED 01.11.2023. FILE REF: Banksia_Rd_2023_11_01_Elevations_reduced.dxf.
3. LOT BOUNDARY AND CELL BOUNDARIES PROVIDED BY CLEANAWAY ON 07.12.2023. FILE REF: CWY_ Excavation Plan 2023.dwg.
4. CAPPING BOUNDARIES PROVIDED BY CLEANAWAY ON 27.05.2024. FILE REF: 20240308 Cappin Stages agreed with BG-AD pdf.
5. STAGE 3 BOUNDARY PROVIDED BY CLEANAWAY ON THE 27.05.2024. FILE REF: Stage 3 Cap_waste_boundry' DXF.
6. STAGE 1 BOUNDARY PROVIDED BY CLEANAWAY ON THE 27.05.2024. FILE REF: Growing Medium with Drains and Roads-01a.DXF.
7. TOP OF WASTE CONTOURS PROVIDED BY CLEANAWAY ON 19.01.2024. FILE REF: Banksia Ultimate Landform TOW 19-01-24.dwg.

PLAN
SCALE 1: 4000

ISSUED FOR
FINAL

THIS DRAWING IS TO BE PRINTED IN COLOUR. IF THIS DRAWING IS NOT PRINTED IN COLOUR THEN YOU DO NOT HAVE THE CORRECT VERSION. THIS NOTE IS RED.

0 40 80 120m
SCALE 1:4000 AT ORIGINAL SIZE

senversa

Client: CLEANAWAY

Designed: [redacted] Drawn: [redacted]
Approved: [redacted] Date: 03.06.2024

Project Title: DARDANUP LANDFILL
BANKSIA ROAD, BANKSIA

Figure Title: REHABILITATION STAGING PLAN

A3 | Height Datum / Projection: AHD / MGA94 ZONE 50 | File No. P21128_004_F001 | Figure No. 1 | Rev 0

Plotted By: Dan Fewtrell
Plot Date: 3 June 2024 - 10:54:47 AM
File location: G:_jobs\6_WA_Jobs\P21128_CWY_BANKSIA_FILL PLANS_CADD\P21128_004_F001.dwg

FIGURE 2: DRAWING BANK-SK90: LANDFILL TOP OF WASTE PROFILE LAYOUT PLAN (IW PROJECTS)

N
W E
S

10m OFFSET BETWEEN CELLS TO ENSURE "T" JOINS AND NOT "+" JOINS.

FUTURE CELL 12A

EXISTING CELL 12

EXISTING CELL 4B

EXISTING CELLS 1 & 2

EXISTING 3 & 4

EXISTING CELL 5

EXISTING CELL 6

EXISTING CELL 7

EXISTING CELL 8

FUTURE CELL 9

FUTURE CELL 10

FUTURE CELL 11

FUTURE CELL 13

FUTURE CELL 14

FUTURE CELL 15

FUTURE CELL 16

FUTURE CELL 17

FUTURE CELL 18

FUTURE CELL 19

FUTURE CELL 20

1 IN 35

1 IN 20

CELL 5 CAP AREA
37,100m²

NOTE:
THE SURFACE SHOWN ON THIS PLAN IS THE TOP OF WASTE PROFILE (UNDERSIDE OF CAP LINER)

NOTES:

1. DESIGN CONTOURS SHOWN ARE AT 2.50m INTERVAL AND ARE TOP OF WASTE SURFACE PROFILE. LANDFILL CAP TO BE PALCED ON TOP OF THIS SURFACE.
2. THE TOP OF WASTE SURFACE SHOWN IN CONCEPTUAL ONLY AND TO BE CONFIRMED DURING DETAILED DESIGN.
3. EXISTING CONTOURS PROVIDED BY CLEANAWAY DATED MARCH 2023.

CONCEPT ONLY
05 SEPTEMBER 2023

40 0 40 80 120 160 200m
SCALE 1:2000 @ A1 SCALE 1:4000 @ A3

REVISIONS							
				DRG. FILE		DATE
				DESIGN		09/23
				DRAWN		09/23
A	S.B.Y.	05/09/23	PRELIMINARY ISSUE FOR REVIEW	DES. CHK.		
No.	BY	DATE	DESCRIPTION	DWG. CHK.		

TECHNICALLY APPROVED:

iw Projects
Email – iwatkins@iwprojects.com.au
Mobile – 0402 909 291
Address – 6 Anemba Close Duncraig 6023

CLEANAWAY SOLID WASTE

BANKSIA ROAD LANDFILL FACILITY, DARDANUP WA
LANDFILL TOP OF WASTE PROFILE
LAYOUT PLAN

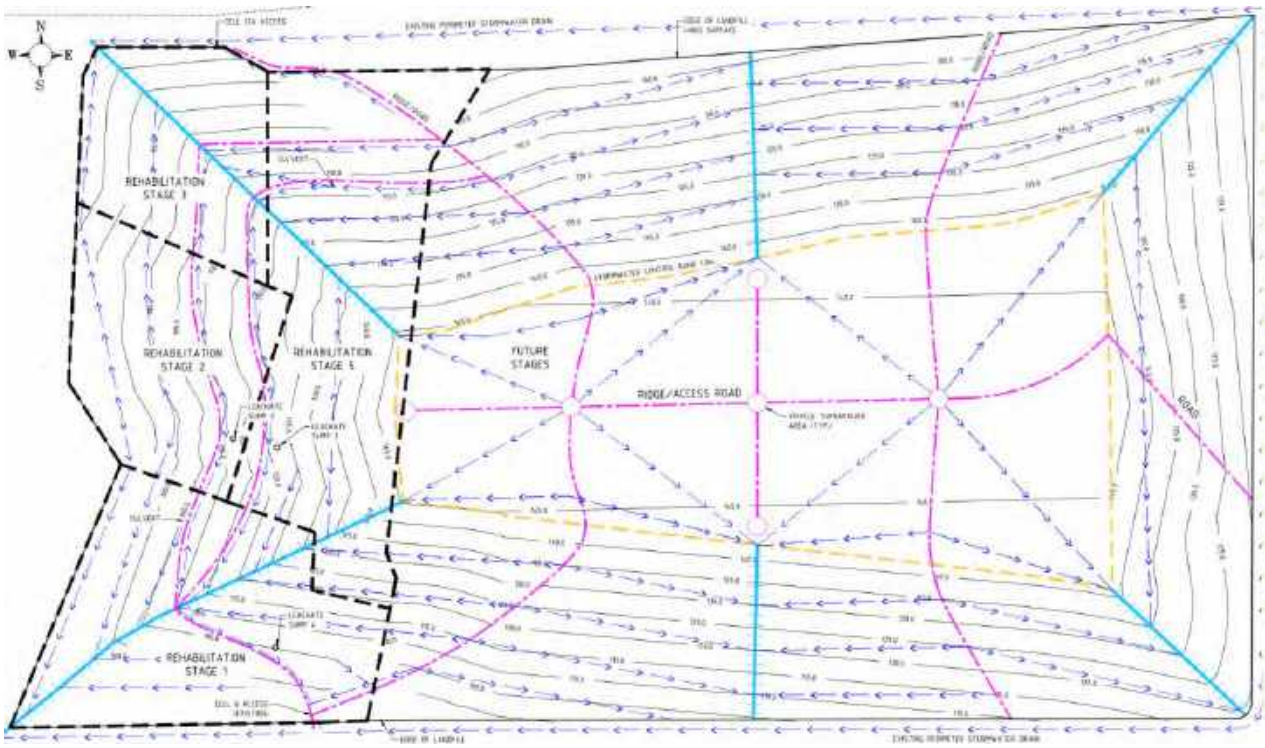
SCALE	AS SHOWN
SHEET	
DRG No.	REVISION A
	Bank–SK90

APPENDIX A: CAPPING STAGE 1 TECHNICAL SPECIFICATION (IW PROJECTS)

BANKSIA ROAD LANDFILL, DARDANUP

LANDFILL STAGE 1 CAPPING CONSTRUCTION

SPECIFICATIONS



Proposed Stage 1, 2 & 5 Capping Areas

Prepared for

CLEANAWAY SOLID WASTE

[redacted]

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Table of Contents

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1 Specifications

1.1 Description of Works

The Contract includes all management, operations, labour, plant, materials, supervision, survey and all else required for the construction and completion of the whole of the Works described in these Specifications and shown on the Drawings, and for complying with the Conditions of Contract, together with any additional Works or variations ordered by the Superintendent. The Contract also includes a Defects Liability Period as stated in the Annexure to the General Conditions of Contract.

The scope of Works includes:

- Survey and setting out;
- Excavation to suit design layout (if required), including stockpiling of the various excavated materials (soft material, clayey material, unsuitable material) as instructed by the Superintendent;
- Fill placement to re-contour the landfill surface (if required);
- Construction of Stage 1 landfill capping;
- Construction of surface water control drainage on the capped surface;
- Construction of access tracks on the capped surface;
- Hydromulching the final capped surface;
- Such other Works as shown on the Drawings or as described in these Specifications;
- Construction Quality Control testing and sampling; and,
- Provision of "As Constructed" information.

1.2 Works Not Included

The scope of the Works does not include:

- Supply of construction water;
- The supply of soil materials;
- Supply of geosynthetic liner materials; and,
- Supply of vegetation seeds for hydromulching the capped surface.

1.3 Principal

The Principal for the project will be Cleanaway Solid Waste Pty Ltd.

1.4 Principal Supply Items

The Principal shall supply the following items:

- Water for construction;
- Soil materials for the capping layer works;
- Geosynthetic liner materials; and,
- Vegetation seeds for hydromulching.

With regards to the supply of the geosynthetic liner materials, the Principal shall supply the GCL (including bentonite paste as required), geomembrane (including welding rods as required) and geocomposite drainage material (excluding the joining cable ties). This material will have been through the necessary quality control process in order to confirm its suitability and acceptability for the Works prior to the Contractor taking position of the liner material. Once handed over to the Contractor, the liner material becomes the responsibility of the Contractor. Any damage to the liner post-handover to the Contractor will be rectified by the Contractor, at no cost to the Principal.

The liner material will either be handed over to the Contractor on site on the back of a flatbed truck, packed within sea containers or appropriately stacked. The Contractor is to fully inspect the liner material and once inspected, sign off on a handover certificate confirming the acceptability of the material and where relevant, documenting any pre-existing damage to the liner material for which the Principal is liable. The Superintendent is to be present during the handover inspection to confirm the state and cause of any pre-existing damaged material.

All handling of the liner material is to be undertaken in accordance with the Specifications and as recommended by the material manufacturer.

Any material damaged after the Contractor has taken responsibility will be replaced with equivalent and compatible material with all associated costs borne by the Contractor. Replacement material will need to go through the necessary quality control process in order to confirm its suitability and acceptability prior to the Contractor installing it in the Works. The Principal may order the additional material and carry out the necessary quality control process prior to providing the Contractor with the replacement material. The Contractor will be liable for all of the Principal's costs associated with the replacement of the damaged liner material, including quality control costs and Superintendent costs. The Contractor is to be aware that there will likely be a significant delay in replacing the damaged material, which could be in excess of eight weeks from the time of order (depending on the material type).

During installation of the liner material, there is the possibility that some of the liner material may be rejected by the Superintendent as being of inferior quality and hence requiring replacement. Where the inferior liner quality is as a result of manufacturing defects, as agreed between the Parties, the Contractor will not be liable for the replacement of the rejected materials, the Principal will replace the rejected material with acceptable material at no cost to the Contractor.

Typically, liner installation has a wastage factor, including overlaps, of between 8% and 15% of the overall area being lined, depending on the complexity of the installation project. The Contractor is to use the liner material in an efficient and professional manner to limit wastage. Should the Superintendent identify that there is excessive material wastage, an independent opinion will be sought to determine if the material wastage is deemed unreasonable. The Contractor will be liable for the cost of any deemed unreasonably excessive wastage.

The Contractor will include in its Works insurance the full replacement value of all Principal supplied liner material. This will include the cost of all necessary quality control testing. Prior to finalising the Works insurance, the Contractor is to obtain the full insurance value of the Principal supplied liner material from the Superintendent. This value is to be included in the Contractor's Works insurance policy.

1.5 Quality Assurance, Inspection and Reporting

The Contractor shall undertake and cover the cost of all Construction Quality Control testing and measurement required in these Specifications to demonstrate that the specified standards of construction have been achieved. The exception being that the Principal shall pay for all Conformance Quality Control testing carried out by the Superintendent as stipulated in these Specifications. Any repeat Conformance Quality Control testing due to material failure (non-conformance) or replacement shall be borne by the Contractor, other than for Principal Supply material defects. For the avoidance of doubt, Conformance Quality Control testing refers to the testing of materials, where the Superintendent receives material samples and obtains independent testing thereof to confirm the materials conform to the Specifications.

The Principal shall supply the GCL, bentonite paste, geomembrane, welding rods, and geocomposite drainage material, including cable ties. This material will have been through the necessary quality control process in order to confirm its suitability and acceptability for the Works prior to the Contractor taking possession of the liner material. Any material damaged after the Contractor has taken responsibility will be replaced with equivalent and compatible material with all associated costs borne by the Contractor. Replacement material will need to go through the necessary quality control process in order to confirm its suitability and acceptability prior to the Contractor installing it in the Works.

The Principal shall appoint and pay for the following:

- Superintendent to manage the project on its behalf; and,
- A CQA Consultant. The duties of the CQA Consultant will include inspections, verifications, audits and evaluation of materials and workmanship, provision of advice on interpretation of the Specifications and issuing a final CQA Validation Report to the Superintendent documenting the quality of the constructed Works.

Within these Specifications, the Superintendent is nominated as the responsible party to undertake all Conformance Quality Control testing, inspections, approvals and reporting as the Superintendent has the management responsibility for these aspects of the Works; however, the Superintendent will allocate some of these activities to the CQA Consultant, depending on the task to be undertaken.

The Contractor is to provide the necessary assistance to the CQA Consultant as if it was dealing with the Superintendent.

If there is any confusion as to which party the Contractor should be dealing with, the Contractor is to always default back to the Superintendent for guidance.

The CQA Consultant is not entitled to provide the Contractor with any advice on construction or design matters. The Contractor is not to rely on any construction or design advice from the CQA Consultant. Any related queries are to be directed to the Superintendent.

1.6 Contract Limits

The Works limits shall be in accordance with the Drawings.

1.7 Areas Available to the Contractor

On written request, the Superintendent will allocate work, storage and laydown areas for use by the Contractor.

1.8 Contractor's Facilities

The Contractor shall be responsible for the supply of its own Site services, including power, potable water, wastewater and communications. The proposed details of the Contractor's power, potable water and sanitation arrangements shall be submitted to the Superintendent for approval and shall be maintained throughout the Works.

The Contractor shall be responsible for the maintenance and watering of the access roads within the Works area as defined by the Drawings and workplaces.

Waste and refuse of all sorts will be regularly and satisfactorily removed. On completion of the Works all sanitary facilities will be removed, the ground thoroughly disinfected and the Site restored to its original condition.

1.9 Pollution and Spillage

Without limiting the Contractor's obligations under the Contract, it shall be the Contractor's responsibility to:

- Investigate and comply with all applicable laws;
- Investigate and comply with Regulations and Rules relating to pollution and contamination with particular regard to the water discharging off the Site; and,
- Limit airborne dust and noise, which could cause a hazard or nuisance to other persons or property. The Superintendent may require the Contractor to take additional steps to reduce the dust hazard and any steps taken shall be at the Contractor's cost.

During construction and commissioning, spillage of any type whatsoever, including fabricating and hydraulic oils, fuel and any other material, shall be immediately removed and disposed of, and the area cleaned as directed by the Superintendent.

1.10 Hours of Site Work

The Superintendent's hours of work on the project will normally be:

- Monday to Friday (inclusive) 0700 to 1700.

Should the Contractor require to work outside these hours, the Contractor shall submit a request in writing to the Superintendent, stating the reason and working hours required, 24 hours in advance and, in any event, not later than noon. The Superintendent will not refuse a reasonable request.

For the purpose of variations and extensions of time to Contract shall consist of 10 hours per working day. The Contract Price shall be deemed to include all additional costs incurred resulting from compliance with industrial awards.

The Contractor will be required to work outside normal working hours to attend to emergency situations or as directed by the Superintendent to attend to items within the scope of Works.

Any variation to the above will be at the discretion of the Superintendent and subject to prior written approval. Refusal to vary or extend the hours of work will not be grounds for an extension of time or a direction to accelerate the Works.

For the purpose of Liquidated Damages assessment, a day will mean any 24 consecutive hour day including Saturdays, Sundays and statutory holidays.

1.11 Site Meetings/Briefings

The Contractor must attend Site meetings/briefings with the Principal and/or Superintendent at times which will be notified to the Contractor. The Contractor must ensure the attendance of all sub-contractors directly concerned with the Works in progress at the time. The Superintendent will keep records of these meetings and these records will form part of the Contract Documentation. No claims for costs borne by the Contractor in attending Site meetings will be accepted.

1.12 Remedial Work During Defects Liability Period

The Contractor shall be responsible to perform work during the Defects Liability Period in accordance with the General Conditions of Contract.

1.13 Water for use in the Works

Water for will be available on Site via a standpipe adjacent to the primary dam, which is approximately 1 km by road from the Works area.

The Principal will provide all necessary water supply and equipment to extract and transfer the water from the source to the Contractor’s collection vehicle.

1.14 Setting Out and Measurement of Quantities

The Contractor shall be responsible for setting out the Works and confirm survey control to the Superintendent to the grades and levels shown on the Drawings.

The Contractor shall be responsible for the measurement of quantities under the Contract. Quantities shall be determined by a competent person by field survey, and outcomes of the survey and quantity calculations shall be forwarded to the Superintendent for verification.

The Contractor is to use a suitably qualified surveyor for all survey work. A suitably qualified surveyor includes:

- A qualified and experienced surveyor able to be a fulltime member of the Institution of Mining and Engineering Surveyors Australia; or,
- A surveyor licensed under the WA Licensing Board.

Quantities to be measured for variations must be measured in accordance with AS 1181.

1.15 Weather

The Contractor takes all risk associated with delays related to bad weather. The Contractor is to allow within its program of Works for anticipated delays as a result of bad weather. There will be no extension of time or cost variation as a result of bad weather.

This Clause does not release the Contractor from any obligation to weatherproof and protect the Works, and to remove water from the Works as soon as is practical during and after inclement weather.

1.16 Protection from Weather

The Contractor must, at the Contractor's own expense, provide all plant, materials and labour necessary to protect the Works from damage by inclement weather.

The Contractor must prevent, insofar as is reasonably possible any materials entering any gully, manhole or pipe, and must remove from the drainage system any materials from any source which may be deposited in the drainage system by any agency up to the date of Practical Completion.

1.17 Dust and Wind-Blown Materials Control

The Contractor shall be responsible for the effective control and suppression of all dust and windborne material emanating from the Site as a result of the Works throughout the period of the Works on Site.

Dust management is a critical environmental emissions aspect on site. The Contractor is to ensure that all construction related activities are carried out in order to minimise dust generation. The Contractor is to adequately wet down all haulage roads to limit dust generation. Should the use of a water cart not be sufficient to adequately manage dust emissions, then the Contractor is to implement other, acceptable dust management measures to decrease dust generation. In the event that the Contractor is unable to adequately control dust during construction, the dust related activities are to be ceased until adequate dust management can be undertaken or the ambient weather conditions improve.

The Contractor is to be aware that the Principal has a comprehensive Dust Management Plan for the overall site. The Contractor is to ensure compliance with this Plan at all times.

1.18 Liaison with Others

During the course of the Works, the Contractor will need to interact with other works being carried out on Site. It shall be the Contractor's responsibility to closely liaise with others on Site to ensure Works are completed in accordance with the requirements of the Specification, Drawings and the Superintendent's directions and instructions.

1.19 Provision for Traffic

When Works are proceeding adjacent to or on any existing access track or haul road, the Contractor shall notify the Superintendent and any other company using that access track or haul road seven days in advance of the date that such Works are due to commence and the proposed duration of such Works and take all steps necessary during the execution of such Works to ensure that disruption to normal traffic is minimised.

1.20 Demobilisation

Prior to the issue of a Certificate of Practical Completion, the Contractor shall, unless otherwise agreed in writing by the Superintendent, have removed all goods and temporary Works from the Site.

All Contractor lay down areas shall be cleaned and graded by the Contractor to the satisfaction of the Superintendent.

1.21 Vegetation and Site Clearing

The Site is an existing waste management facility:

- There is no native vegetation clearing associated with the landfill cap construction; however,
- There is vegetation (weeds) clearing and the removal of mulched and non-mulched greenwaste associated with the preparation of the landfill surface.

1.22 Earthworks

1.22.1 Introduction

The Works covered by this Section include, but are not necessarily limited to, the following:

- The setting out of the Works to the lines and levels shown on the Drawings;
- Removal of unsuitable/excess material and disposal to stockpile;
- Excavation within the Works area to remove or shape existing landfill access roads by spreading on side slopes in vicinity of access roads;
- Excavation of the phytocap soil;
- Excavation to expose the existing landfill liner on perimeter bund;
- Filling, grading and rolling of the landfill cap formation to cover any exposed waste material;
- Surface preparation of completed earthworks prior to liner installation;
- Excavation and haulage of fill, placement and compaction to the required grades and levels for the landfill capping layer Works;
- Excavation and backfill of liner anchor trenches for liner installation;
- Formation of drains and roads on the capped surface, including cross-overs;
- Excavation, haulage of fill and placement to the required grades and levels for the landfill capping growing medium;
- Construction Quality Control testing and sampling; and,
- Control and diversion of surface water and run-off from the Site of the Works.

1.22.2 Earthworks Inspection

The earthworks will be inspected and monitored by the Superintendent and CQA Consultant, which will include the inspection, approval and reporting on all aspects of the earthworks. This is to include:

- Approval of the suitability of the fill material used;
- Approval of the compaction method used;
- Inspection of all fill placement and compaction activities;
- Inspection of all third-party Construction Quality Control testing and sampling (arranged and paid for by the Contractor);
- Assessment of the Construction Quality Control testing results and As-Constructed surveys and drawings;
- Approval of the earthwork's quality and shape; and,
- Any other activities that are deemed necessary to ensure that appropriate earthworks standard of workmanship and quality of Works is achieved.

Where the Specifications refer to inspection, approval or other activities relating to the Superintendent, some of these actions may be carried out by the CQA Consultant, on behalf of the Superintendent.

1.22.3 Applicable Documents

All Works shall be carried out in accordance with the latest editions of all and any specifications, guidelines and standards referenced with the Contract.

1.22.4 Definitions

For all purposes of this Section, the words and phrases listed below shall have the meanings herein ascribed to them:

- "Modified Maximum Dry Density" (MMDD) As determined in accordance with AS 1289.5.2.1-2003.

1.22.5 Handover

On handover of the Site to the Contractor, the Contractor is to undertake a detailed base survey of the Works area. As a minimum, the surface shall be surveyed about the perimeter of the Works area and on a maximum 20 m grid and include all changes in grade within the perimeter. The survey is to identify all necessary details to accurately determine the surface topography for the purposes of measuring construction qualities. The results of the survey shall be provided to the Superintendent prior to any Works commencing. This base survey will be compared to the Principal's base survey (which may have been undertaken prior to Site handover) and the handover base survey profile will be agreed between the Parties.

This agreed handover base survey will then be used for calculating quantities of Works undertaken throughout the project.

No Works shall be undertaken in any area until the handover base survey has been agreed between the Parties and without the written confirmation of the Superintendent.

1.22.6 Excavation

1.22.6.1 General

The Contractor shall carry out all earthworks excavation to the extent shown on the Drawings or directed by the Superintendent. The Contractor is responsible for assessing the soil/rock types on Site and selecting suitable plant and equipment for undertaking excavation Works.

The Contractor is to remove all soft or unsuitable material identified within the existing soil cover material over the waste.

All completed earthworks are to be inspected and approved by the Superintendent.

1.22.6.2 Excavated Material

All suitable excavated material is to be used as fill material.

The Superintendent will determine the suitability of the excavated fill material for use as fill.

All excavated material that is deemed unsuitable to be used as fill by the Superintendent, will be stockpiled within 500 m of the Works area in a location as directed by the Superintendent.

1.22.6.3 Excavation of Phytocap Soil

Excavation to remove Phytocap material for reuse as growing medium, including careful removal of instrumentation and handing over to the Principal, demolition of lysimeter (buried HDPE/timber box) and dispose of to landfill. The excavated soil is to be placed on the adjacent landfill surface, beyond the capping area for subsequent reuse as growing medium.

1.22.6.4 Excavation Around Existing Landfill Base Liner

The facilitate the tie-in to the existing landfill base liner, the Contractor is required to excavate soil and possibly some waste from the vicinity of the existing liner anchor trench. All excavation around the existing liner material is to be carried out with extreme care so as not to damage the liner material. Any damage identified to the liner material, will be repaired by the Contractor, at no cost to the Principal.

1.22.7 Fill Materials

1.22.7.1 General

The Contractor shall carry out all earthworks fill to the extent shown on the Drawings or as directed by the Superintendent. The Contractor is responsible for assessing the fill requirements and selecting suitable plant and equipment for undertaking required Works.

All fill material must be approved for use by the Superintendent, who may reject unsuitable material.

A portion of the earthworks involves the minor re-contouring of the landfill surface to achieve a reasonable surface shape for lining, access track and drain alignment and to control surface water. Between the design phase of the project and the award of the construction contract, there is likely to have been a degree of differential settlement and possibility waste placement which will have changed the shape of the actual waste surface. Consequently, there will be a need to undertake minor excavation Works to improve the final landfill surface.

1.22.7.2 Material

Select fill material and growing medium shall comprise naturally occurring silty/clayey soil sourced on-site from the phytocap demolition and stockpile within 1 km of the Works area (northern stockpile). The material is to be free of debris and deleterious material and with a maximum particle dimension no larger than 40 mm. The suitability of the fill material will be determined by the Superintendent prior to incorporation into the Works.

1.22.7.3 Unsuitable Material

The term "unsuitable material" shall apply to excavated material, which, because of its inherent nature, cannot be satisfactorily reconditioned and is not suitable for use as a fill material. Unsuitable material shall be removed within the limits specified by the Superintendent using whatever equipment is required. All material that is deemed unsuitable by the Superintendent to be used as fill will be stockpiled within 500 m of the Works area in a location as directed by the Superintendent.

1.22.8 Sub-Grade Preparation

All standing water shall be drained or pumped away before surface preparation can commence.

All vegetation (weeds), mulched and un-mulched greenwaste and any other obstructions shall be removed from areas on which synthetic liner is to be installed.

No fill shall be placed in any area without the written approval of the Superintendent.

1.22.9 Fill Placement and Compaction

1.22.9.1 Inspection

Minor filling will be required in order to re-contour the landfill surface.

Before fill is placed in any area, the Superintendent shall be notified in writing 24 hours prior to Works commencing. The Superintendent may inspect the area to confirm the Works conforms to the Specifications. This inspection may include witnessing any proof rolling to detect soft spots on the landfill surface.

1.22.9.2 General Placement and Compaction Standards

Fill below the lined surface, shall be placed, levelled, and if necessary, moisture conditioned to +/- 2 % of optimum and compacted to not less than 90% of the Modified Maximum Dry Density (MMDD) determined in accordance with AS 1289.5.2.1.

Fill to form the access tracks and stormwater drains on top of the growing medium is to be compacted to 95% MMDD. Due to the relatively flexible nature of the substrate (waste and uncompacted growing medium), it is unlikely that this degree of compaction will be achievable in the first or second compaction lift; however, subsequent compaction lifts should be able to achieve the specified degree of compaction. If 95% MMDD compaction is unable to be achieved, the Superintendent is to assess the compactive effort and determine the most suitable solution in order to achieve the maximum compaction on the capped surface.

The Contractor is to determine the fill placement and compaction methodology to the Superintendent for review and acceptance; however, the Contractor is to ensure that any proposed methodology is able to achieve a minimum compaction density of 90% or 95% of the Modified Maximum Dry Density (MMDD) determined in accordance with AS 1289.5.2.1.

The growing medium is to be placed in a single layer and NOT compacted.

The placement of growing medium material on top of the synthetic liner and geocomposite drainage layer is to be carried out in accordance with the following minimum requirements so as not to damage the liner materials and not to negatively impact on the slope stability:

- No pushing down the slope, all material is to be moved up the slope;
- Minimum layer thickness of 1.3 m, the material is not to be placed in numerous layers (to prevent excessive compaction);
- Positrack vehicles can operate anywhere;
- Excavators (maximum 25 tonne) passing the material up the slope must be static when moving material;
- Swamp dozers can push material up the slope; and,
- No dump trucks or any other plant on the slope under any circumstances.

The Contractor is to provide a Work Method Statement (WMS) for the proposed fill placement methodology that needs to consider the dot points above, including measures to prevent damage to the underlying geosynthetics and that won't impact on the slope stability. The superintendent is to have approved the proposed WMS prior to any fill placement.

The Contractor is to be aware that there will be leachate sump access pipes and gas pipe penetrations through the capped surface and that the growing medium will need to be carefully installed around and between the penetrations.

1.22.9.3 Landfill Surface Preparation

The complete surface of the capped area that is to be covered with synthetic liner material (GCL, LLDPE and geocomposite drain) is to be prepared such that there is no exposed waste and no objects on or near the surface that have the potential to damage the synthetic liner.

Following the removal of vegetation and greenwaste from the landfill surface, the Contractor is to track roll the waste surface to flatten and push down any protruding items.

There is an unknown depth of soil over the waste surface. It is not required that this soil be removed, other than in the vicinity of the phytocap and to expose the base liner.

1.22.9.4 Timing of Growing Medium Installation

The growing medium is to be installed within 4 weeks of the geocomposite drainage material having been installed. This is to protect the geotextile on the surface of the geocomposite drainage material from excessive UV decay.

1.22.9.5 Final Surface Preparation

The complete surface of the capped area that is to be covered with synthetic liner material (GCL, LLDPE and Geocomposite drain) is to be steel drum rolled to provide a smooth surface on which to place the liner material. Prior to the deployment of the GCL, the surface is to be inspected to confirm there are no excessive irregularities, depressions or obstructions that may affect the integrity of the synthetic liner.

The Contractor is to be aware that the sloping portions of the landfill surface at relatively steep (maximum 1 vertical in 3.5 horizontal) and extreme care is to be taken when working in these areas. In addition, when placing liner material, the Contractor is to ensure that the prepared surface below the liner is not damaged by the liner installation equipment. Any damage to the surface is to be repaired prior to the liner being installed.

1.22.9.6 Compaction Testing

The Contractor shall arrange for the testing and sampling of compacted fill in the access tracks and drain bunds. Fill operations shall be interrupted as necessary to allow the recovery of samples or to carry out control tests on the fill.

If the fill during recontouring the landfill surface is greater than 1 m thick, then these areas are to be compaction tested. Recontouring fill less than 1 m thick does not require to be compaction tested.

All materials testing and density testing shall be undertaken by a laboratory that is NATA accredited for those tests being undertaken. Testing will be used to confirm specified moisture conditions and standards of compaction are achieved. All testing shall be undertaken in accordance with the appropriate sections of AS 1289 – Methods for Testing Soils for Engineering Purposes.

Testing and sampling will be undertaken at regular intervals by the Contractor or its nominated representatives. The construction programing and Contract Sum shall include allowances for taking and testing samples and time delays while samples are being collected, tested and reported.

No additional payment will be made for any completed Works requiring removal and/or repair as a result of any tests organised by the Superintendent.

Inspection and testing shall be carried out in accordance with the requirements of this Specification.

The frequency of field density testing during these Works shall not be less than the following:

- One test per 500 m^3 distributed evenly throughout the full depth and area;
- One test per layer per material type per 2,500 m^2, distributed evenly over the surface of the layer;
- One test per layer or per 300 mm thickness per 150 m length constructed horizontal layer;
- Three tests per visit when material is placed in horizontal layers; or
- Whichever frequency is greater of the above or alternative frequencies that may be agreed with the Superintendent.

Dry density ratio for each of the field density tests shall be determined from Nuclear Densometer methods (AS1289.5.8.1) in association with modified compaction (AS1289.5.2.1).

Where nuclear densometer methods are used, compaction shall be carried out in accordance with the Assigned Values Method, as defined by AS1289.5.4.2.

If any areas of the Works are found to be non-compliant with the compaction requirements of this Specification, they shall be re-worked (if necessary), re-compacted and re-tested for compliance.

1.22.9.7 Dimensions and Tolerances

The finished levels of fill shall be within -25 mm and +25 mm of the design levels. The fill surface shall be inspected to ensure accuracy and any irregularities and if identified, shall be corrected prior to the surface treatment being applied.

The impact of waste settlement within the landfill is to be considered when assessing dimensions and tolerances.

1.22.9.8 Control of Water

During excavation and construction, all areas of earthworks shall be kept free of water by temporary drains or other means. Excavation and fill areas shall always be graded to facilitate surface drainage and any loose material compacted to prevent erosion and absorption.

1.22.9.9 Surface Confirmation

The completed surface shall be surveyed by the Contractor on a maximum 20 m grid and include all changes in grade to confirm the accuracy of construction. The results of the survey shall be provided to the Superintendent prior to inspecting the completed surface to confirm the Works meets the specified requirements.

No liner installation shall be carried out in any area without the written approval of the Superintendent.

1.22.9.10 Clean-up

On completion of the Works the Site shall be cleared of all materials and debris. Any damage shall be made good and the Site restored to a neat and tidy condition. All Works areas shall be smoothed and graded conforming to the natural appearance of the landscape.

1.23 Supply and Installation of Geosynthetic Clay Liner

1.23.1 General

The capping construction of the landfill incorporates the use of a standard GCL product overlaid by a LLDPE liner and a geocomposite drain.

1.23.1.1 Exposure to Sodium Bentonite

It is noted that sodium bentonite is classified as hazardous for both State and Federal legislation, largely to eliminate any silica and cristobalite risk. Key points are as follows:

- The exposure risk of sodium bentonites and any crystalline silica (quartz and cristobalite) contained within, is based on dust concentrations in the air, and the length of exposure.
- There is no Short-term exposure limit set, it is all 8-hour Time-Weighted Average (TWA). Hence, a maximum average exposure level over an 8 hr/5 day week is considered, the TWA is 0.1 mg/m³ averaged over the 40 hr week.
- This means that exposure levels are considered over a time period, and for GCLs this time period should only apply to people working with GCL's for an extended period.
- The exposure risk for cutting samples or handling onsite is short term, but this fundamentally means that it is easier to analyse the risk, but also easier to adopt full protection controls and not rely on engineering controls.
- **The advice is always to wear suitable PPE as defined in the material manufacturer's Safety Data Sheet (SDS) or in the relevant Australian Standard, wherever the risk of dust generation is observed.**

From a construction point of view, there is an OH&S risk with the exposure of sodium bentonite from the GCL, particularly around the risk of crystalline silica exposure when the GCL is cut for sampling and whilst being installed; consequently, the Contractor is to ensure that the following activities are carried out:

- All parties, including the Contractor's staff, lining sub-contractor and any other relevant sub-contractors, Superintendent, CQA Consultant, the Principal's staff and anyone who may come in contact with the GCL are to be made aware of the risks associated with exposure to sodium bentonite;
- The Contractor (who is accountable for the sampling and installation of the GCL) is to develop a safety plan for the handling, sampling and installation of GCL and bentonite paste/powder, including detailed procedures that will be undertaken to mitigate exposure to dust from the GCL (eg masks or respirators). The safety plan is to be developed in accordance with the manufacturer's SDS and industry best practise.
- The safety plan is to be provided to the Principal, Superintendent and all relevant parties prior to the sampling, installation or testing of the GCL and that procedures mentioned in the plan are being adhered to.
- This risk is to be discussed in toolbox talks at the start and throughout the construction program, when GCL is being handled on site.

1.23.1.2 GCL Sub-Contractor

The Contractor shall only engage the specialist liner sub-contractor, which may also be the main Contractor to install the GCL that was accepted by the Principal at the time of Tendering. Any change to the approved liner sub-contractor must be approved in writing by the Superintendent prior to any lining Works being undertaken on Site.

The various types of GCL shall be installed in all locations as indicated in the Drawings.

The primary function of the lining system is to:

- Limit rainwater from percolating into the waste mass and generating leachate; and,
- Limit the fugitive emission of landfill gas through the cap and into the environment.

Stringent quality assurance standards shall be maintained throughout the Contract to ensure the integrity of the lining system.

The Contractor shall provide all materials, supervision, labour and equipment for the installation of the GCL in accordance with the Specifications and Drawings.

Prior to installation, all GCL to be incorporated in the Works shall be approved in writing by the Superintendent.

1.23.1.3 Submittals

Submittal Documentation

The Contractor is to submit the following to the Superintendent for review and approval, within a reasonable time to expedite installation of the GCL. This is not an all-inclusive list; it is the Contractor's responsibility to ensure that it has been through these Specifications in sufficient detail to identify all submittal requirements:

- If any proposed change in liner sub-contractor from what was approved at Tender, documentation of the liner sub-contractor and installer's qualifications:
  - Submit proposed sub-contractor relevant company experience;
  - Submit resumes or qualifications of the proposed Field Installation Supervisor, Master Installer and Installer to be assigned to this project; and,
- Liner installation Quality Control Program.

Panel Layout Drawings

Submit copies of panel layout drawings for the Superintendent's approval within a reasonable time so as not to delay the start of GCL installation. Panel layout drawings shall show the proposed panel layout. Panels shall generally follow the direction of the slope. Roll-end joins on the side slopes shall clearly be identified.

Placement of GCL will not be allowed to proceed until the Superintendent has received and approved the panel layout drawings.

Additional Submittals (In-Progress and at Completion):

This is not an all-inclusive list; it is the Contractor's responsibility to ensure that it has been through these Specifications in sufficient detail to identify all submittal requirements:

- Daily written acceptance of subgrade surface;
- Daily field installation reports; and,
- Installation record drawing.

1.23.1.4 Quality Control

Installer's Qualifications

Installation and joining of the GCL must be undertaken by GCL installers with extensive experience in installing and joining the same type of GCL being installed and using the same joining procedure to be used on Site.

Installation shall be performed under the direction of a Field Installation Supervisor who shall be responsible throughout the GCL installation, for GCL panel layout, joining, patching, repairs and all other activities of the liner sub-contractor. The Field Installation Supervisor shall have installed or supervised the installation and joining of a minimum of 10 projects involving a total of 500,000 m^2 of GCL of the type specified or similar product.

Joining shall be performed under the direction of a Master Installer (who may also be the Field Installation Supervisor) who has joined a minimum of 300,000 m^2 of GCL of the type specified or similar product, using the same type of joining to be used in the current project. The Field Installation Supervisor and/or Master Installer shall be present whenever installation and joining is performed.

Installation and joining shall be performed by an Installer who has installed and joined a minimum of 100,000 m^2 of GCL of the type specified or similar product, using the same type of joining to be used in the current project.

All joining, patching, other operations shall be performed by qualified installers employed by the GCL sub-contractor.

Third-Party CQA Consultant

The Principal will appoint an independent CQA Consultant with experience and knowledgeable of GCL and joining performance characteristics to verify that the Works have been carried out in accordance with the Specifications.

The duties of the CQA Consultant include inspections, verifications, audits and evaluation of materials and workmanship, provision of advice on installation, repair, and covering of the GCL lining system and issuing a final CQA Validation Report to the Principal documenting the quality of the constructed facility.

The cost associated with the appointment of the CQA Consultant will be covered by the Principal.

The Contractor is to provide the necessary assistance, advanced notification of lining activities and access to all Works area to the CQA Consultant to enable the full inspection of the Works.

1.23.1.5 Delivery, Storage and Handling

Each roll of GCL delivered to the Site will be labeled by the manufacturer. The label will be firmly affixed and shall clearly state the following:

- Manufacturer's name;
- Product identification (material type);
- Date of manufacture;
- Batch number;
- Roll number;
- Roll length;

- Roll weight;
- Roll width; and,
- Label with handling guidelines.

The GCL rolls shall be delivered to the Site by the Principal and handed over to the Contractor. The material will be handled and stored in such manner that no damage occurs to the GCL or its protective wrapping. The GCL rolls shall be wrapped with heavy duty weatherproof wrapping to protect the material from moisture uptake.

Rolls with damaged wrapping shall be pointed out to the Superintendent who will inspect to assess the extent of hydration of the liner. GCL rolls or portions of rolls with moisture content equal or above 40% by weight (ASTM D5993) may be rejected, as instructed by the Superintendent. GCL rolls with damaged wrapping and moisture content lower than 40% shall be re-wrapped and sealed.

A dedicated area shall be used for the storage of all GCL material delivered to Site. The material shall be stored and handled as follows:

- In its original, unopened packaging or resealed following the removal of samples from the roll;
- Away from high traffic areas, but sufficiently close to the active Works area to minimise handling;
- On a level, dry, well-drained and stable area;
- Not more than three (3) rolls high;
- Protected from precipitation, chemicals, excessive heat, ultraviolet (UV) radiation, standing water, vandalism and animals;
- Blocks provided to prevent sliding or rolling of stacks;
- All roll labeling shall be clearly visible;
- Handling of GCL rolls is to be via the use of a spreader stinger bar (a bar protruding from the front end of a forklift or other equipment). The bar must be capable of supporting the full weight of the GCL roll without significant bending; and,
- Under no circumstances may the rolls be dragged, lifted with the forks of a forklift or pushed to the ground from the delivery vehicle.

Any damaged material shall be assessed by the Superintendent and if deemed necessary, rejected and the Contractor advised to immediately remove the material from Site.

1.23.1.6 GCL Pre-Construction Meeting

A GCL Pre-Construction Meeting (and simultaneously the Geomembrane Pre-Construction Meeting) shall be held at the Site prior to installation of the GCL. As a minimum, the meeting shall be attended by the GCL Field Installation Supervisor, the Superintendent, the CQA Consultant and the Contractor.

Topics for this meeting shall include:

- Responsibilities of each party;
- Lines of authority and communication;
- Resolution of any project document ambiguity;
- Project QA/QC plan;
- Methods for documenting, reporting and distributing documents and reports;
- Procedures for packaging and storing archive samples;

- Review of time schedule for all installation and inspection;
- Weather limitations;
- Defining acceptable subgrade, GCL, or ambient moisture and temperature conditions for working during liner installation;
- Subgrade conditions, dewatering responsibilities and subgrade maintenance plan;
- Deployment techniques including allowable subgrade for the liner installation and in particular, working on the landfill side slopes;
- Consideration of how subsequent liner/geocomposite material will be placed on top of the GCL, again, with particular focus on working on the landfill side slopes;
- Covering of the GCL – normal practice and in the event of rain;
- Measurement and payment schedules; and,
- Health and safety, including protection from exposure to sodium bentonite powder.

The Superintendent will take minutes of the meeting and the minutes shall be transmitted to all Parties.

1.23.2 Product

1.23.2.1 General

Although the liner material is a Principal Supply Item, this product information has been provided so that the Contractor is aware of the type of liner material that will be utilised in the Works.

1.23.2.2 Manufacturing Quality Control

The test methods and frequencies used by the manufacturer for quality control/quality assurance of the GCL prior to delivery shall be in accordance with Section 1.23.5 - Table 1.

The manufacturer's GCL quality control certifications, including results of quality control testing of the products, must be supplied to the Superintendent to verify that the materials supplied for the project are in compliance with all product and/or project Specifications. The certification shall be signed by a responsible party employed by the manufacturer, such as the QAIQC Manager, Production Manager or Technical Services Manager. Certifications shall include lot and roll numbers and corresponding shipping information.

1.23.2.3 Minimum Requirements for GCL

The GCL shall be a reinforced, multi-layered system comprising two layers of geotextiles encapsulating a layer of dry bentonite.

The bentonite and GCL will meet the property requirements as shown in Section 1.23.5 - Table 1.

Bentonite used for overlapping shall comply with the same specifications as the bentonite used in the GCL delivered to the Site (same rule applies for sealing penetrations and repairs).

Material Conformance Quality Control testing by the Superintendent will be conducted in accordance with the project Specifications and CQA Plan.

1.23.2.4 Manufacturing Quality Control Documentation

MQC documentation from the manufacturer of the GCL supplied must be submitted for approval by Superintendent. Submissions shall include:

- Location and date of manufacture;
- Lot number, roll number, length and width;
- Bentonite manufacturer quality documentation for the particular lot of clay used in the production of the rolls delivered;
- MSDA or bentonite used during manufacture;
- Geotextile manufacturer quality control documentation for the particular lots of geotextiles used in the production of the rolls delivered;
- Cross-referencing list delineating the corresponding geotextile and bentonite lots for the materials used in the production of the rolls delivered;
- QC program laboratory certified reports in accordance with Section 1.23.5 – Table 1; and
- The manufacturer's approved QA stamp and the technician's signature.

1.23.2.5 Acceptance by Superintendent

No materials will be accepted for delivery to Site or for progress payment unless all necessary manufacturer's quality assurance/quality control certification, including results of quality control testing has been provided to the Superintendent. All such data shall be supplied in sufficient time such that no delay shall be caused to the project program. Failure to provide the required certifications and test data and any resultant delay will not be grounds for an extension of time or removal of any commercial penalties that accompany the Contract.

In addition, no material will be accepted for progress payment until the necessary Conformance Quality Control testing has demonstrated that the material delivered to site is of the acceptable standard.

1.23.3 Installation

1.23.3.1 Project Conditions

GCL shall not be installed in the presence of standing water, while precipitation is occurring or during excessive winds.

1.23.3.2 Surface Preparation

The surface to be lined shall be uniform and free of all sharp or angular objects that may damage the GCL prior to installation of the liner and the quality of the surface maintained until liner has been installed.

The Contractor, liner sub-contractor and Superintendent shall inspect the surface to be covered with the GCL on each day's operations prior to placement of GCL to verify suitability.

The liner sub-contractor shall provide daily written acceptance to the Superintendent for the surface to be covered by the GCL installation, to ensure surface suitability.

All subgrade surface damage caused by construction equipment and deemed unsuitable for GCL deployment shall be repaired by the Contractor prior to placement of the GCL. All repairs require the approval of the Superintendent and the liner sub-contractor.

1.23.3.3 GCL Placement

No GCL shall be deployed until the applicable certifications and quality control certificates are submitted to, and approved by the Superintendent. Should GCL material be deployed prior to approval by the Superintendent it will be at the sole risk of the Contractor. If the material does not meet project Specifications, it shall be removed from the Works area at no cost to the Principal.

The GCL shall be installed such that the panels are continuous down side slopes. The arrangement of the GCL panels shall be according to a predetermined panel layout plan to minimise the amount of end overlaps, in particular on the side slopes.

The panels shall be laid in roof tile effect to allow continuous flow of water in the downward slope direction.

The GCL shall be installed to the limits shown on the Drawings and essentially as shown on approved panel layout drawings.

The GCL shall only be placed on adequately prepared surfaces that have been approved by the Superintendent.

Appropriate lifting equipment is to be used to ensure safe and efficient material placement and any damage to the subbase by lifting equipment shall be repaired prior to the laying of any GCL.

Installation of the GCL shall not result in scratching, scoring, tearing or otherwise damaging of the material.

The GCL sub-contractor and Superintendent shall inspect the surface of each roll of material as it is being deployed or after deployment, to verify that the material is free from visual defects such as tears, punctures, abrasions, thin spots or other faults in the material. If damages are identified, they are to be repaired or replaced according to these Specifications or as directed by the Superintendent.

Roll-end joins on the side slopes are to be anchored as indicated in the Drawings.

NO vehicular traffic shall travel on the liner material.

Prior to installation, the Contractor is to provide a method statement on how it is proposed to install the subsequent LLDPE and geocomposite drainage layers without any driving on the lined surface. This method statement must be provided within a reasonable time so as not to delay the installation of the liner material.

GCL placement shall not be carried out during rainfall events, on a wet subbase, if moisture prevents proper surface preparation, panel placement or panel joining. Moisture limitations shall be defined in the pre-construction meeting.

Damaged panels or portions of the damaged panels, which have been rejected, shall be marked and removal from the Works area recorded.

The GCL shall not be allowed to "bridge over" voids or low areas in the subgrade. In these areas, the GCL shall be placed to allow the GCL to rest in intimate contact with the subbase.

Wrinkles caused by panel placement shall be minimised. In the event that wrinkles occur in the GCL or where wrinkles extend to the edge of the roll due to manufacturing tolerances, they will need to be removed prior to installation of subsequent layers.

Considerations on Site Geometry: In general, joins shall be oriented parallel to the line of the maximum slope. In corners and odd shaped geometric locations, the total length of joins shall be minimised.

Overlap joins between panels shall be formed by overlapping the panels and sealed by manufactured edge treatment, bentonite paste or powder/granules. The overlap zone shall be kept clean and shall not be contaminated with loose soil or other debris. There shall be no folds or wrinkles in the overlap zone and no traffic or walking shall occur on the completed overlap. The minimum longitudinal overlap shall be 300 mm and the minimum roll-end overlap shall be 1.0 m on the top of the landfill and an anchor trench and 1.5 m overlap on the side slopes.

Bentonite used for overlapping shall comply with the same specifications as the bentonite used in the GCL delivered to the Site (same rule applies for sealing penetrations and repairs).

Particular care shall be taken to avoid contaminating the upper surface of the GCL with bentonite powder. The presence of loose bentonite may affect welding of overlying geomembrane and may also influence interface friction.

GCL installed on slopes is to be fixed in anchor trenches or extend a minimum of 5 m up onto the top of the landfill. This is to secure the GCL and prevent it from sloughing or slipping down the side slopes during construction. The front edge of the trench is to be rounded to prevent the development of stress concentrations on the GCL or any other geosynthetics. The GCL shall be laid on the inside wall and base of the anchor trench only and the trench shall be cleared of any debris, gravel or loose material before the GCL is installed. The trench shall be backfilled and compacted with suitable selected fill in layers of maximum 300 mm, by a minimum two passes with a plate compactor per layer.

The GCL shall be covered by the geomembrane liner as soon as practical to prevent water damage, but at least by the end of each working day. No GCL is to be left uncovered overnight.

In the event of any water damage, the Superintendent will inspect the material to assess the extent of hydration of the liner. Areas of GCL with moisture content equal or above 40% by weight (ASTM D5993) may be rejected, as instructed by the Superintendent. Areas suspected of being over hydrated are to be sampled and tested to confirm suitability, with costs borne by the Contractor.

The liner sub-contractor shall surcharge load <u>all</u> lining material during construction with appropriate material (i.e. sandbags or approved equivalent) to ensure the liner is protected from wind uplift and displacement. The frequency and spacing of the sandbag shall be as required based on Site conditions and lining sub-contractor's experience/recommendation. The sandbag material shall be sufficiently close-knit to prevent soil fines from working through the bags and discharging on the liner. The sandbags shall be filled with material that does not pose a risk of damage to the geosynthetics. The sandbags must be removed prior to placement of overlying soils.

1.23.3.4 Joining Procedures

Joining procedures are to be as per the material Manufacture's installation instructions, with the following minimum overlaps:

- Longitudinal joins – 300 mm
- Roll-end joins:
  - On top of landfill – 1.0 m; and,
  - On side slope – anchor trench and 1.5 m.

1.23.3.5 Field Quality Control

Daily Field Installation Reports

At the beginning of each day's Works, the liner sub-contractor shall provide the Superintendent with daily reports for all Works accomplished on the previous Works day. Reports shall include the following:

- Total amount and location of GCL placed; and,
- Drawings of the previous day's installed GCL showing panel numbers.

1.23.3.6 Defects and Damage

The Superintendent shall inspect the GCL as it is rolled out on the surface to be lined. The Superintendent shall be responsible for the acceptance or rejection of GCL being incorporated into the Works and shall make a determination of whether the identified defect or damage is a function of manufacture or installation of the GCL.

Manufacturing defects are areas where the geotextile is not continuous and/or areas where the bentonite in the GCL is missing. If a roll is suspected to be of inferior quality the Superintendent shall take samples to assess its conformance with the Specifications. All testing is to be carried out in accordance with the appropriate standards and by a NATA accredited laboratory. Conformance Quality Assurance testing results will determine the adequacy of the GCL.

Material replacement as a result of identified defects or damage shall be carried out by the Principal, as the material supplier, with the Contractor being liable for all material supply and CQA testing costs as a result of replacing damaged liner material.

1.23.3.7 Repair

If the GCL has been damaged during installation, it can be repaired by patching a new piece of GCL of the same material type and thickness extending a minimum of 500 mm on the top of the landfill and 1.0 m on the side slopes beyond the damaged area in all directions. The patched area must be augmented with bentonite powder or granules/paste as per normal joining requirements.

1.23.3.8 Liner Acceptance

GCL liner will be accepted by the Superintendent when:

- The entire installation is finished, or an agreed-upon subsection of the installation is finished;
- All liner sub-contractor's QC documentation is completed, submitted to and approved by the Superintendent; and,
- All CQA testing on the installed material has been completed and approved by the Superintendent.

1.23.3.9 Disposal of Scrap Materials

On completion of installation, the liner sub-contractor shall dispose of all waste and scrap material in a location approved by the Superintendent, remove equipment used in connection with the Works herein, and shall leave the Site in a neat acceptable manner. No scrap material shall be allowed to remain on the GCL surface.

1.23.4 Materials Properties and Testing Scope

1.23.4.1 General

These Specifications set forth a set of minimum physical, mechanical and chemical properties that must be met, or exceeded by the GCL being manufactured. In a few cases a range is specified.

In the context of quality systems and management, these Specifications represents manufacturing quality control (MQC).

Note: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in this Specification.

1.23.4.2 Definitions

Manufacturing Quality Control (MQC) - a planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and Contract Specifications.

Manufacturing Quality Assurance (MQA) - a planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and Contract Specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organisation to determine if the manufacturer is in compliance with the product certification and Contract Specifications for this project.

1.23.4.3 Manufacturing Specifications and Quality Control

The quality of the GCL shall be in accordance with the requirements of the Geosynthetic Research Institute (GRI) — GCL3. The minimum specifications for quality GCL products are contained in GRI Test Method GCL3 Standard Specification for "*Test Methods, Required Properties, and Testing Frequencies of Geosynthetic Clay Liners (GCL's)*". The GRI specifications set forth a set of minimum physical and mechanical properties that must be met or exceeded by the GCL being manufactured.

In addition to the above, the bentonite Specifications in Section 1.23.5 – Table 1 shall be verified every 50 tonnes of the product.

A statement on the origin of the bentonite must be included, as well as certified copies of the quality control certificates issued by the bentonite supplier and reports on the tests conducted by the manufacturer to verify the quality of the bentonite used to manufacture the GCL rolls assigned to the project.

The geotextile components of the GCL must also have been through a QC program. The manufacturer's geotextile QC program shall be available for auditing.

1.23.4.4 Physical and Mechanical Property Requirements

The GCL shall conform to the test property requirements prescribed in Section 1.23.5 - Table 1.

The properties of the GCL shall be tested at the minimum frequency shown in Section 1.23.5 - Table 1. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

1.23.4.5 Workmanship and Appearance

The GCL shall have good appearance qualities. It shall be free from such defects that would affect the specified properties of the GCL.

General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

1.23.4.6 MQC Sampling

Sampling shall be in accordance with the specific test methods listed in Section 1.23.5 - Table 1. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

The number of tests shall be in accordance with the appropriate test methods listed in Section 1.23.5 - Table 1.

The average of the test results shall be calculated per the particular standard cited and compared to the minimum value listed in these tables; hence, the values listed are the minimum average values and are designated as "min. ave."; the exception being permeability, which is measured against the maximum average.

1.23.4.7 MQC Retest and Rejection

If the results of any test do not conform to the requirements of these Specifications, retesting to determine conformance or rejection shall be carried out in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

1.23.4.8 Packaging and Marketing

The GCL shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery.

The roll cores shall be sufficiently strong to ensure that they do not deflect by more than half their diameter during transit and handling.

1.23.4.9 Certification

A manufacturer's certification that the material was manufactured and tested in accordance with the Specifications, together with a report of the test results shall be furnished at the time of shipment.

1.23.4.10 Conformance Quality Control Testing

The Principal shall provide test results for the rolls delivered to Site to demonstrate that the rolls meet the requirements of the Specifications. The test frequency shall be as set out in Section 1.23.5 - Table 1.

The Superintendent will arrange for independent Conformance Quality Control testing of the material. The Superintendent shall arrange for samples to be recovered from the rolls delivered to Site and tested at an independent NATA accredited laboratory. The results from the independent laboratory shall take precedence over the test results provided by the manufacturer of the material. The Conformance Quality Control testing shall be at the Principal's cost.

The Superintendent will arrange for independent Conformance Quality Control testing of the material. In order to achieve this:

- The Superintendent will determine the location of where the samples are to be received, either at the point of manufacture or on Site;
- The timing of when the sampling will occur is to be coordinated by the Superintendent, between all Parties, to ensure the most efficient sampling process and handover of the samples. This will either be during or immediately after manufacture or as soon as is reasonable following delivery to Site;
- The CQA Consultant will be present at the point of sampling to monitor the sampling procedure and to receive the samples;
- The Principal is responsible for providing all samples, as required, from the rolls of liner material that will or have been delivered to Site and handing the samples to the CQA Consultant; and,
- The CQA Consultant will arrange for the delivery and testing of the samples to be carried out at an independent NATA accredited laboratory.

Any non-conformance in the delivered materials as identified by the Conformance Quality Control testing shall be addressed by the Principal and thereafter, if the Superintendent rejects the material, the Principal shall replace the non-conforming material with conforming material. Again, the new delivery of material will be subject to Conformance Quality Control testing to demonstrate its conformance with the Specifications. Any replacement of non-conforming material and subsequent Conformance Quality Control testing carried out by the Superintendent will be at the Principal's cost.

The material delivered to Site shall meet the Specifications relative to the independent laboratory test results, for the material to be considered for incorporation into the Works.

Section 1.23.6 - Table 2 sets out the minimum Conformance Quality Control testing that will be carried out by the Superintendent. The Contractor is to allow at least six weeks in its construction program for the Conformance Quality Control testing to be completed.

1.23.5 GCL Material Specification

All GCL material use shall be reinforced and comprised of both woven and non-woven geotextile fully needle punch and heat bonded together to contain the bentonite powder.

The GCL shall have the minimum material Specifications as set out in Table 1:

Table 1 - GCL Material Specification

Property	Test	Frequency	Value
Montmorillonite content	XRD (X-ray diffraction) Quantitative Mineralogy Analysis	50 tonnes of GCL	> 70 wt%
Carbonate content (*1*)		50 tonnes of GCL	< 2 wt%
Bentonite form		50 tonnes of GCL	Natural Na-bentonite or >80 wt% Sodium as activated bentonite
Particle size	AS 1289-3.6.2	50 tonnes of GCL	Powdered (e.g. 80% passing 75 micron sieve) or Granulated (e.g. < 1% passing 75 micron)
Cation exchange capacity	Methylene Blue Method	50 tonnes of GCL	≥ 70 meq/100 g (or cmol/kg)
Swell Index (bentonite) (min. ave)	ASTM D5890	50 tonnes of GCL	≥ 24 mL/2g
Moisture Content (bentonite) (*2*)	ASTM D5993	4,000 m^2	≤ 25% at Manufacture ≤ 35% Site Samples
Fluid Loss (bentonite) (*2*)	ASTM D5891	50 tonnes of GCL	≤ 18 ml max.

Property	Test	Frequency	Value
Top Geotextile Mass (min. ave) (*3*)	ASTM D5261	20,000 m^2	≥ 220 g/m^2 non-woven
Mass of GCL (min. ave) (*4*)	ASTM D5993	4,000 m^2	≥ 4,240 g/m^2
Mass of Bentonite (min. ave) (*4*)	ASTM D5993	4,000 m^2	≥ 3,700 g/m^2
Bottom Geotextile Mass (min. ave)	ASTM D5261	20,000 m^2	≥ 320 g/m^2
Elongation (MD) (min. ave)	ASTM D6768	20,000 m^2	≥ 10%
Tensile Strength (min. ave)	ASTM D6768	20,000 m^2	≥ 8 kN/m
Peel Strength (min. ave)	ASTM D6496	4,000 m^2	≥ 360 N/m
Permeability (2)	ASTM D5887	25,000 m^2	≤ 5 x 10^{-11} m/s

(1) Carbonate here implies calcite, calcium carbonate or other soluble or partially soluble carbonate minerals
(2) These values are maximum (all others are minimum).
(3) For both cap and carrier fabrics for non-woven reinforced GCL's; one, or the other, must contain a scrim component of mass ≥ 100 g/m^2 for dimensional stability. This only applies to GM/GCL composites, which are exposed to the atmosphere for several months or longer so as to mitigate panel separation.
(4) Mass of the GCL and bentonite is measured after oven drying per the stated test method.

The GCL rolls shall include edge treatment on both longitudinal sides of the GCL with 250 dry grams added bentonite per metre length of overlap included in the outer 300 mm strip of the roll. The rolls shall also include edge markings to indicate a minimum 300 mm overlap for panels.

1.23.6 GCL CQA Testing

The GCL shall undergo the minimum CQA testing as set out in Table 2:

Table 2 - GCL CQA Testing

Item	Property	Standard	Frequency
Conformance Quality Control testing (sampled at the point of manufacture or on Site, as determined by the Superintendent)	Mass per unit area of bentonite component of GCL	ASTM D5993	1 sample per 2,500 m^2
	Mass per unit area of GCL	ASTM D5993	1 sample per 1,000 m^2
	Montmorillonite content	XRD (X-ray diffraction) Quantitative Mineralogy Analysis	1 sample per 10,000 m^2
	Cation exchange capacity of bentonite	Methylene blue method	1 sample per 1,500 m^2
	Mass/unit length of bentonite in overlaps	ASTM D5993	1 sample per 1,000 m^2
	Moisture content of bentonite	ASTM D5993	1 sample per 2,500 m^2
	Swell index/free swell of clay	ASTM D5890	1 sample per 1,500 m^2
	Water absorption	ASTM D5891	1 sample per 1,500 m^2
	Peel strength (for needle-punched products only)	ASTM D6496	1 sample per 1,000 m^2
	Tensile strength	ASTM D6768	1 sample per 10,000 m^2
	Index flux	ASTM 5887	1 sample per 10,000 m^2
Visual inspection of GCL	Colour, needle punching, presence of needles or broken needles, and sewing density or other faults in the material.		Every roll during placement
Thickness of GCL (i.e. uniformity of bentonite distribution) and apparent variations in	On-Site		Each roll during placement. If thickness appears to be variable a check of the variability of

[redacted]

Item	Property	Standard	Frequency
the as placed moisture distribution.			the mass per unit area shall be conducted

Note:

1. All Conformance Quality Control tests must be reviewed, accepted, and reported by the Superintendent before deployment of the GCL.
2. All testing must be performed on samples taken from the GCL delivered to Site or at the supplier's/manufacturer's premises under the Superintendent's inspection or delegated authority.
3. All laboratory tests must be performed in a third-party independent NATA accredited laboratory.
4. The required testing frequencies may be revised by the Superintendent to conform with improvements in testing methods and/or in the state-of-the-art practice and/or to account for the criticality of the application (i.e to account for the importance of the GCL for the stability of Works).

1.24 Installation of LLDPE Geomembrane

1.24.1 General

1.24.1.1 Geomembrane Sub-Contractor

The Contractor shall only engage the specialist liner sub-contractor, which may be the main Contractor to install the geomembrane that was accepted by the Principal at the time of award of the Contract. Any change to the liner sub-contractor must be approved in writing by the Superintendent prior to any lining Works being undertaken on Site.

Geomembrane shall be installed in all locations as indicated in the Drawings.

The primary function of the lining system is to:

- Limit rainwater from percolating into the waste mass and generating leachate; and,
- Limit the fugitive emission of landfill gas through the cap and into the environment.

Stringent quality assurance standards shall be maintained throughout the Contract to ensure the integrity of the lining system.

The Contractor shall provide all supervision, labour and equipment for the installation of the geomembrane in accordance with the Specifications and Drawings.

Prior to installation, all geomembrane to be incorporated in the Works shall be approved in writing by the Superintendent.

1.24.1.2 Submittals

Submittal Documentation

The Principal is to submit the following to the Superintendent for review and approval, within a reasonable time to expedite shipment or installation of the geomembrane. This is not an all-inclusive list; it is the Principal's responsibility to ensure that it has been through these Specifications in sufficient detail to identify all submittal requirements:

- Documentation of manufacturer's qualifications;
- Manufacturer's Quality Control program manual or descriptive documentation;
- A material properties sheet, including at a minimum all properties specified, including test methods used;
- Typically, 0.5 m of roll length of material that will or has been delivered to Site to be used by the Superintendent for Conformance Quality Control testing as required in Section 1.24.7 - Table 5; and,
- Resin Supplier's name, resin production plant identification, resin brand name and number, production date of the resin, resin Manufacturer's quality control certificates, and certification that the properties of the resin meet the requirements for the project.

The Contractor is to submit the following to the Superintendent for review and approval, within a reasonable time to expedite installation of the geomembrane. This is not an all-inclusive list; it is the Contractor's responsibility to ensure that it has been through these Specifications in sufficient detail to identify all submittal requirements:

- If any proposed change in liner sub-contractor from what was approved at Contract award, documentation of the liner sub-contractor and installer's qualifications:

- Submit proposed sub-contractor relevant company experience;
- Submit resumes or qualifications of the proposed Field Installation Supervisor, Master Installer, and Installer to be assigned to this project; and,

- Liner sub-contractor Quality Control Program.

Panel Layout Drawings

Submit copies of panel layout drawings for the Superintendent's approval within a reasonable time so as not to delay the start of geomembrane installation. Panel layout drawings shall show the proposed panel layout identifying seams and details. Seams shall generally follow the direction of the slope. The connecting seam between geomembranes shall be located a distance of at least 1 m from any join in the GCL below.

All primary welds used to connect panel end to sheets shall form T-joins (tees). These T-connections must be a distance of at least 0.5 m apart. The welding seams of the geomembrane cannot cross (no cruciform connections).

Placement of geomembrane will not be allowed to proceed until the Superintendent has received and approved the panel layout drawings.

Additional Submittals (In-Progress and at Completion):

For convenience, the relevant Sections have been highlighted; however, these may not necessarily be the only references to submittal documentation required. This is not an all-inclusive list; it is the Contractor's responsibility to ensure that it has been through these Specifications in sufficient detail to identify all submittal requirements:

- Geomembrane installation warranty;
- Daily written acceptance of substrate surface;
- Prequalification test seam samples;
- Field seam non-destructive test results;
- Field seam destructive test results;
- Daily field installation reports; and,
- Installation record drawing.

1.24.1.3 Quality Control

Manufacturer's Qualifications

The manufacturer of geomembrane of the type specified or similar product shall have at least five years' experience in the manufacture of such geomembrane. In addition, the geomembrane manufacturer shall have manufactured at least 1,000,000 m^2 of the specified type of geomembrane or similar product during the last five years.

Installer's Qualifications

Installation and seaming of the geomembrane must be undertaken by geomembrane installers with extensive experience in seaming the same type of geomembrane being installed and using the same seaming procedure to be used on Site.

Installation shall be performed under the direction of a Field Installation Supervisor who shall be responsible throughout the geomembrane installation, for geomembrane panel layout, seaming, patching, testing, repairs and all other activities of geomembrane installation. The Field Installation Supervisor shall have installed or supervised the installation and seaming of a minimum of 10 projects involving a total of 500,000 m^2 of geomembrane of the type specified or similar product.

Seaming shall be performed under the direction of a Master Seamer (who may also be the Field Installation Supervisor) who has seamed a minimum of 300,000 m^2 of geomembrane of the type specified or similar product, using the same type of seaming apparatus to be used in the current project. The Field Installation Supervisor and/or Master Seamer shall be present whenever seaming is performed.

Seaming shall be performed by an Installer who has seamed a minimum of 100,000 m^2 of geomembrane of the type specified or similar product, using the same type of seaming apparatus to be used in the current project.

All seaming, patching, other welding operations and testing shall be performed by qualified technicians employed by the geomembrane liner sub-contractor.

Third-Party CQA Consultant

The Principal will appoint an independent CQA Consultant with experience with geomembranes and knowledgeable of geomembrane and seam performance characteristics to verify that the Works have been carried out in accordance with the Specifications.

The duties of the CQA Consultant include inspections, verifications, audits and evaluation of materials and workmanship, provision of advice on installation, testing, repair, and covering of the geomembrane lining system and issuing a final CQA Validation Report to the Principal documenting the quality of the constructed facility.

The cost associated with the appointment of the CQA Consultant will be covered by the Principal.

The Contractor is to provide the necessary assistance, advanced notification of lining activities and access to all Works area to the CQA Consultant to enable the full inspection of the Works.

1.24.1.4 Delivery, Storage and Handling

Each roll of geomembrane delivered to the Site will be labeled by the manufacturer. The label shall be firmly affixed and shall clearly state the following:

- Manufacturer's name;
- Product identification (material type);
- Material thickness;
- Roll number;
- Roll length;
- Roll weight;
- Roll width;
- Reference number to raw material batch and laboratory certified reports; and,

- Manufacturer's approved QA stamp and the technician's signature. The technician's signature may be omitted from each roll label, but then must be included on each of the manufacturer's test certificates associated with each roll.

A dedicated area shall be used for the storage of all geomembrane material delivered to Site. The material shall be stored as follows:

- The geomembrane shall be protected from mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions;
- All rolls shall be covered and secured using tarp material resistant to moisture;
- Away from high traffic areas, but sufficiently close to the active Works area to minimise handling;
- Elevated aboveground on a level, dry, well-drained and stable area. Should timber pallets be used, they must be inspected and free of nails/pins prior to roll placement;
- Not more than three rolls high;
- Protected from precipitation, stormwater runoff, standing water, chemicals, excessive heat, ultraviolet (UV) radiation, standing water, vandalism and animals;
- Blocks provided to prevent sliding or rolling of stacks;
- All roll labeling shall be clearly visible;
- Handling of geomembrane rolls is to be via the use of a spreader or stinger bar (a bar protruding from the front end of a forklift or other equipment). The bar must be capable of supporting the full weight of the geomembrane roll without significant bending; and,
- Under no circumstances may the rolls be dragged, lifted with the forks of a forklift or pushed to the ground from the delivery vehicle.

Any damaged material shall be assessed by the Superintendent and if deemed necessary, rejected and the Contractor advised to immediately remove the material from the Works area.

1.24.1.5 Geomembrane Installation Warranty

The geomembrane liner sub-contractor shall guarantee the geomembrane installation against defects in the installation and workmanship for one year commencing with the date of final acceptance by the Superintendent.

1.24.1.6 Geomembrane Pre-Construction Meeting

A Geomembrane Pre-Construction Meeting (and simultaneously the GCL Pre-Construction Meeting) shall be held at the Site prior to installation of the geomembrane. As a minimum, the meeting shall be attended by the geomembrane Field Installation Supervisor, the Superintendent, the CQA Consultant and the Contractor.

Topics for this meeting shall include:

- Responsibilities of each party;
- Lines of authority and communication;
- Resolution of any project document ambiguity;
- Project QA/QC plan;
- Methods for documenting, reporting and distributing documents and reports;
- Procedures for packaging and storing archive samples;
- Review of time schedule for all installation and testing;
- Review of panel layout and numbering systems for panels and seams including details for marking on geomembrane;
- Procedures and responsibilities for preparation and submission of As-Constructed panel and seam drawings;
- Temperature and weather limitations. Installation procedures for adverse weather conditions and temperature conditions for working during liner installation;
- Defining acceptable GCL moisture content prior to over-laying with geomembrane;
- GCL/subgrade conditions, dewatering responsibilities and GCL/subgrade maintenance plan;
- Deployment techniques, especially placement of geomembrane on top of GCL with the geomembrane textured side down;
- Plan for controlling expansion/contraction and wrinkling of the geomembrane;
- Covering of the geomembrane and subsequent material placement;
- Measurement and payment schedules; and,
- Health and safety.

The Superintendent will take minutes of the meeting and the minutes shall be transmitted to all Parties.

1.24.2 Products

1.24.2.1 General

Although the liner material is a Principal Supply Item, this product information has been provided so that the Contractor is aware of the type of liner material that will be utilised in the Works.

1.24.2.2 Manufacturing Quality Control Documentation

The test methods and frequencies used by the manufacturer for quality control/quality assurance of the above geomembrane prior to delivery shall be in accordance with Section 1.24.5 - Table 3.

The manufacturer's geomembrane quality control certifications, including results of quality control testing of the products, must be supplied to the Superintendent to verify that the materials supplied for the project are in compliance with all product and/or project Specifications. The certification shall be signed by a responsible party employed by the manufacturer, such as the QA\QC Manager, Production Manager or Technical Services Manager. Certifications shall include lot and roll numbers and corresponding shipping information.

The Manufacturer will provide Certification that the geomembrane and welding rod supplied for the project have the same base resin and material properties.

1.24.2.3 Geomembrane

The geomembrane shall consist of new, first quality products designed and manufactured specifically for the purpose of this Works which shall have been satisfactorily demonstrated by prior testing to be suitable and durable for such purposes. The geomembrane rolls shall be seamless, Linear Low Density Polyethylene (LLDPE resins of density ≥0.915 g/ml and ≤ 0.926 g/ml, sheet density ≤ 0.939 g/ml) containing no plasticizers, fillers or extenders and shall be free of holes, blisters or contaminants, and leak free verified by 100% in-line spark or equivalent testing. The geomembrane shall be supplied as a continuous sheet with no factory seams in rolls. The geomembrane will meet the property requirements as shown in Section 1.24.5 - Table 3.

Material Conformance Quality Control testing by the Superintendent will be conducted in accordance with the project Specifications and CQA Plan.

1.24.2.4 Acceptance by Superintendent

No materials will be accepted for delivery to Site or for progress payment unless all necessary manufacturer's quality assurance/quality control certification, including results of quality control testing has been provided to the Superintendent. All such data shall be supplied in sufficient time such that no delay shall be caused to the project program. Failure to provide the required certifications and test data and any resultant delay will not be grounds for an extension of time or removal of any commercial penalties that accompany the Contract.

In addition, no material will be accepted for progress payment until the necessary Conformance Quality Control testing has demonstrated that the material delivered to site is of the acceptable standard.

1.24.3 Installation

1.24.3.1 Project Conditions

Geomembrane shall not be installed in the presence of standing water, while precipitation is occurring, during excessive winds or when material temperatures are outside the limits specified in these Specifications.

1.24.3.2 Surface Preparation

The surface to be lined shall be uniform and free of all sharp or angular objects that may damage the geomembrane prior to installation of the geomembrane.

The Contractor, liner sub-contractor and Superintendent shall inspect the surface to be covered with the geomembrane on each day's operations prior to placement of geomembrane to verify suitability.

The liner sub-contractor shall provide daily written acceptance for the surface to be covered by the geomembrane installation, to ensure surface suitability.

All subgrade and GCL surface damage caused by construction equipment and deemed unsuitable for geomembrane deployment shall be repaired by the Contractor prior to placement of the geomembrane. All repairs require the approval of the Superintendent and the liner sub-contractor.

1.24.3.3 Geomembrane Placement

No geomembrane shall be deployed until the applicable certifications and quality control certificates as specified are submitted to and approved by the Superintendent. Should geomembrane material be deployed prior to approval by the Superintendent it will be at the sole risk of the Contractor. If the material does not meet project Specifications, it shall be removed from the Works area at no cost to the Principal.

The geomembrane shall be installed to the limits shown on the Drawings and essentially as shown on approved panel layout drawings.

The panels shall be laid in roof tile effect to allow continuous flow of water in the downward slope direction.

No geomembrane material shall be unrolled and deployed if the material temperatures are lower than 10°C unless otherwise approved by the Superintendent. The specified minimum temperature for material deployment may be adjusted by the Superintendent based on recommendations by the manufacturer and the Superintendent. Temperature limitations shall be defined in the pre-construction meeting. Only the quantity of geomembrane that will be anchored and seamed together in one day shall be deployed.

Installation of the geomembrane shall not result in scratching, scoring or crimping of the material.

The liner sub-contractor and Superintendent shall inspect the surface of each roll of material as it is being deployed or after deployment, but before welding, to verify that the material is free from visual defects such as tears, punctures, abrasions, indentations, cracks, thin spots or other faults in the material. If damages are identified, they are to be repaired or replaced according to these Specifications or as directed by the Superintendent.

NO vehicular traffic shall travel on the liner material.

The liner sub-contractor shall surcharge load all lining material during construction with appropriate material (i.e. sandbags or approved equivalent) to ensure the liner is protected from wind uplift and displacement. The frequency and spacing of the sandbag shall be as required based on Site conditions and lining sub-contractor's experience/recommendation. The sandbag material shall be sufficiently close-knit to prevent soil fines from working through the bags and discharging on the liner.

Geomembrane placement shall not be carried out if moisture prevents proper surface preparation, panel placement or panel seaming. Moisture limitations shall be defined in the pre-construction meeting.

Damaged panels or portions of the damaged panels, which have been rejected, shall be marked and its removal from the Works area recorded.

The geomembrane shall not be allowed to "bridge over" voids or low areas in the subgrade. In these areas, the geomembrane shall be placed to allow the geomembrane to rest in intimate contact with the GCL.

Wrinkles caused by panel placement or thermal expansion shall be minimised in accordance with these Specifications.

Considerations on Site Geometry: In general, seams shall be oriented parallel to the line of the maximum slope. In corners and odd shaped geometric locations, the total length of field seams shall be minimised.

Overlapping: The panels shall be overlapped prior to seaming to whatever extent is necessary to affect a good weld and allow for proper testing. In no case shall this overlap be less than 75mm.

1.24.3.4 Defects and Damage

The Superintendent shall inspect the geomembrane as it is rolled out on the surface to be lined. The Superintendent shall be responsible for the acceptance or rejection of geomembrane being incorporated into the Works and shall make a determination of whether the identified defect or damage is a function of manufacture or installation of the geomembrane.

Manufacturing defects are areas where the geomembrane surface and/or texturing is not consistent and uniform. If a roll is suspected to be of inferior quality the Superintendent shall take samples to assess its conformance with the Specifications. All testing is to be carried out in accordance with the appropriate standards and by a NATA accredited laboratory. Conformance Quality Assurance testing results will determine the adequacy of the geomembrane.

Material replacement as a result of identified defects or damage shall be carried out by the Principal, as the material supplier, with the Contractor being liable for all material supply and CQA testing costs as a result of replacing damaged liner material.

1.24.3.5 Seaming Procedures

Cold weather installations shall follow guidelines as outlined in GRI GM 9.

No geomembrane material shall be seamed when liner temperatures are less than 10°C unless the following conditions are complied with:

- Seaming of the geomembrane at material temperatures below 10°C is allowed if the liner sub-contractor can demonstrate to the Superintendent, using prequalification test seams, that field seams comply with the project Specifications, the safety of the crew is ensured and geomembrane material can be repaired at temperatures less than 10°C;
- The liner sub-contractor shall submit to the Superintendent for approval, detailed procedures for seaming at low temperatures, possibly including the following:
  - Preheating of the geomembrane;
  - The provision of a tent or other device if necessary to prevent heat losses during seaming and rapid heat losses subsequent to seaming; and,
  - Number of test welds to determine appropriate seaming parameters.

No geomembrane material shall be seamed when the sheet temperature is above 75°C as measured by an infrared thermometer or surface thermocouple unless otherwise approved by the Superintendent. This approval will be based on recommendations by the manufacturer and on a field demonstration by the liner sub-contractor using prequalification test seams to demonstrate that seams comply with the Specifications.

Seaming shall primarily be performed using automatic fusion welding equipment and techniques. Extrusion welding shall be used where fusion welding is not possible such as at, patches, repairs and short (less than a roll width) runs of seams.

The weld surfaces shall be cleaned prior to welding. The weld area shall be free of moisture, dust, debris, markings and foreign materials. In the case of extrusion welding, oxidation by-products shall be removed from the surface to be welded by grinding/buffing. Grind marks shall not be deeper than 10 % of the geomembrane thickness. Welding shall be performed shortly after grinding (within 30 minutes) so that surface oxide formation does not reform.

The Contractor shall be responsible for regularly checking, calibrating and recording the following items:

- Preheat air flow and temperature at the nozzle;
- Extrudate flow and temperature at the barrel outlet; and,
- Split copper wedge temperature on both contact points.

The Contractor shall utilise the machine mounted temperature readout (calibrated in accordance with the manufacturer's recommendation) or have an independently calibrated hand-held temperature measuring device to confirm temperatures of each and every welding machine prior to the commencement of any test or field welds. All information regarding the results gained from the temperature device shall be recorded for each welding machine.

Welding of all main joins between adjacent geomembrane panels (primary welds) shall be conducted using hot-wedge welding, producing two parallel seams with an air channel in between (dual track fusion welding). The hot-wedge welding shall be conducted using the split head wedge fusion weld method which will fuse the upper and lower overlapped geomembrane sheets.

The welding equipment shall be a fully automated device comprising of a heated copper wedge, pressure rollers and electronic controls. The copper wedge shall be controlled and constantly monitored by a programmable controller with an audible off temperature alarm and a variable speed drive unit. The copper wedge shall create two contact fusion areas of a minimum width of 15 mm and a 5 mm minimum wide void between each of the separate parallel weld zones. This void shall be created over the entire seam length to allow for field weld pressure testing.

The extrusion process is used primarily for detailed work and repair work (secondary weld) or where approved in areas that would be inaccessible to the dual track fusion weld (such as around structures, pipes and other penetrations). The extrusion welding shall be conducted using surface extrusion hand welders.

The minimum width of the surface extruded bead shall be 30 mm. The surface extrusion welder shall be semi-automated and equipped with electronic controls, which constantly monitor outputs for both preheat and extradite. The unit shall be capable of pre-heating the sheet just prior to the casting of the extradite over the upper and lower section of the weld zone.

The extruded granulate or rod for surface extrusion welding shall be manufactured from the same resin type used in the manufacture of the geomembrane. All physical properties shall be identical to those possessed by the geomembrane raw material. The manufacturer shall provide certified test data with each batch of welding granulate or rod. All granulate or rod supplied shall be packed to prevent the ingress of moisture and other contaminants. If necessary, the Contractor shall also employ an apparatus specifically built for drying granulate to ensure weld quality.

All geomembrane panels subject to hot wedge welding shall be overlapped by a minimum of 125 mm and a minimum of 75 mm for extrusion welding to allow for proper Conformance Quality Control testing.

The Contractor shall ensure prior to any primary or secondary welding that weld zones be clean, free from moisture, dust and any other foreign matter. All weld zone surfaces shall be either cleaned or abraded no more than 30 minutes prior to the commencement of welding any seam. In extremely bad conditions it may be necessary for the liner Installer to clean and/or abrade the weld zone areas only minutes prior to the required weld.

Fishmouths or excessive wrinkles at the seam overlaps, shall be minimised and when necessary, cut along the ridge of the wrinkles back into the panel to affect a flat overlap. The cut shall be terminated with a keyhole cut (nominal 10 mm diameter hole) to minimise crack/tear propagation. The overlay shall subsequently be seamed. The keyhole cut shall be patched with an oval or round patch of the same base geomembrane material extending a minimum of 150 mm beyond the cut in all directions.

1.24.3.6 Field Quality Control

The Superintendent shall be notified prior to all prequalification and production welding and testing, or as agreed upon in the pre-construction meeting.

Pre-qualification Test Seams

Test seams shall be prepared and tested by the liner sub-contractor to verify that seaming parameters (speed, temperature and pressure of welding equipment) are adequate.

Test seams shall be made by each welding technician and tested in accordance with ASTM D 5820 at the beginning of each seaming period. Test seaming shall be performed under the same conditions and with the same equipment and operator combination as production seaming. The test seam shall be approximately 3.5 m long for fusion welding and 1 m long for extrusion welding with the seam centered lengthwise. As a minimum, test seams shall be made by each technician once every 4-6 hours or if any welding stoppage exceeds one hour; additional tests may be required with changes in environmental conditions.

Two 25 mm wide specimens shall be die-cut using calibrated equipment by the liner sub-contractor from each end of the test seam (total of four specimens). These specimens shall be tested by the liner sub-contractor using a calibrated field tensiometer, testing both tracks for peel strength and also for shear strength. Each specimen shall fail in the parent material and not in the weld, "Film Tear Bond" (FTD) failure. Seam separation equal to or greater than 25% weld area of the track width shall be considered a failing test.

The minimum acceptable seam strength values to be obtained for all specimens tested are listed in Section 1.24.6 - Table 4. All four specimens shall pass for the test seam to be a passing seam.

If a test seam fails, an additional test seam shall be immediately conducted. If the additional test seam fails, the seaming apparatus shall be rejected and not used for production seaming until the deficiencies are corrected and a successful test seam can be produced.

A sample from each test seam shall be labelled. The label shall indicate the date, geomembrane temperature, number of the seaming unit, technician performing the test seam and pass or fail description. The sample shall then be given to the Superintendent for archiving.

Field Seam Non-destructive Testing

All field seams shall be non-destructively tested by the liner sub-contractor over the full seam length before the seams are covered. Each seam shall be numbered or otherwise designated. The location, date, test unit, name of tester and outcome of all non-destructive testing shall be recorded and submitted to the Superintendent.

Section 1.24.7 - Table 5 sets out the minimum non-destructive weld testing that will be carried out by the liner sub-contractor.

Testing shall be carried out as the seaming Works progresses, not at the completion of all field seaming. All defects found during testing shall be numbered and marked immediately after detection. All defects found shall be repaired, retested and remarked to indicate acceptable completion of the repair.

Non-destructive testing shall be performed using vacuum box, air pressure or spark testing equipment.

Non-destructive testing shall be performed by experienced technicians familiar with the specified test methods. The liner sub-contractor shall demonstrate to the Superintendent all test methods to verify the test procedures are valid.

Extrusion seams shall be vacuum box tested by the liner sub-contractor in accordance with ASTM D 5820 and ASTM D 5641 with the following equipment and procedures:

- Testing is to begin no earlier than one (1) hour after welding;
- Equipment for testing extrusion seams shall be comprised of but not limited to: a vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft rubber gasket attached to the base, porthole or valve assembly and a vacuum gauge; a vacuum pump assembly equipped with a pressure controller and pipe connections; a rubber pressure/vacuum hose with fittings and connections; a plastic bucket; wide brush or mop; and a soapy solution;
- The vacuum pump shall be charged, and the tank pressure adjusted to approximately 35 kPa (5 psig);
- The liner sub-contractor shall create a leak tight seal between the gasket and geomembrane interface by wetting a strip of geomembrane approximately 0.3 m by 1.2 m (length and width of box) with a soapy solution, placing the box over the wetted area, and then compressing the box against the geomembrane. The liner sub-contractor shall then close the bleed valve, open the vacuum valve, maintain initial pressure of approximately 35 kPa (5 psig) for approximately five seconds. The geomembrane shall be continuously examined through the viewing window for the presence of soap bubbles, indicating a leak. If no bubbles appear after five seconds, the area shall be considered leak free. The box shall be depressurised and moved over the next adjoining area with an appropriate overlap and the process repeated;
- All areas where soap bubbles appear shall be marked, repaired and then retested;
- At locations where seams cannot be non-destructively tested alternate non-destructive spark testing or equivalent shall be substituted; and,
- All seams that are vacuum tested shall be marked with the date tested, the name of the technician performing the test and the results of the test.

Double fusion seams with an enclosed channel shall be air pressure tested by the liner sub-contractor in accordance with ASTM D 5820 and the following equipment and procedures:

- Equipment for testing double fusion seams shall be comprised of, but not limited to: an air pump equipped with a pressure gauge capable of generating and sustaining a pressure of 210 kPa (30 psig), mounted on a cushion to protect the geomembrane; and a manometer equipped with a sharp hollow needle or other approved pressure feed device;
- The testing activities shall be performed by the liner sub-contractor. Both ends of the seam to be tested shall be sealed and a needle or other approved pressure feed device inserted into the tunnel created by the double wedge fusion weld;
- The air pump shall be adjusted to a pressure of 210 kPa, and the valve closed. Allow two minutes for the air to come to equilibrium in the channel, and sustain pressure for five minutes;

- If pressure loss does not exceed 28 kPa after this five-minute period, the seam shall be considered leak tight. Release pressure from the opposite end verifying pressure drop on needle to ensure testing of the entire seam. The needle or other approved pressure feed device shall be removed, and the feed hole sealed; and,
- If loss of pressure exceeds 28 kPa during the testing period or pressure does not stabilise, the faulty area shall be located, repaired and retested by the liner sub-contractor.

Results of the pressure testing shall be recorded on the liner at the seam tested and on a pressure testing record.

In addition to the above tests, the welds are to be visually inspected to assess the quality of the workmanship and the appearance of the welded seam. For wedge welds there needs to be a consistent “squeeze out” on the weld edge which is an indicator that the correct temperature and pressure were used during installation. In the case of extrusion fillet welds, the weld appearance shall be smooth, uniform and free of streaks and lumps. In addition, there shall be no obvious scoring, notches or deep scratches introduced by the surface grinding.

Destructive Field Seam Testing

One destructive test sample per 150 linear metre seam length of fusion/wedge weld and 120 linear metre of extrusion weld shall be taken by the liner sub-contractor from a random location specified by the Superintendent. The liner sub-contractor shall not be informed in advance of the sample location. In order to obtain test results prior to completion of geomembrane installation, samples shall be cut by the liner sub-contractor as directed by the Superintendent as seaming progresses.

Section 1.24.7 - Table 5 sets out the minimum destructive weld testing that will be carried out by the liner sub-contractor.

All field samples shall be marked with its sample number and seam number. The sample number, date, time, location and seam number shall be recorded. The liner sub-contractor shall repair all holes in the geomembrane resulting from obtaining the seam samples. All patches shall be vacuum box tested or spark tested. If a patch cannot be permanently installed over the test location the same day of sample collection, a temporary patch shall be tack welded or hot air welded over the opening until a permanent patch can be affixed.

The destructive sample size shall be 300 mm wide by 1m long with the seam centered lengthwise. The sample shall be cut into three equal sections and distributed as follows: one section given to the Superintendent as an archive sample; one section given to the Superintendent for laboratory testing as specified below; and one section retained by the liner sub-contractor for field testing as specified below.

For field testing, the liner sub-contractor shall cut, using a calibrated die cutter, 10 identical 25 mm wide replicate specimens from its sample. The liner sub-contractor shall test five specimens for seam shear strength and five for peel strength. Peel tests will be performed on both inside and outside weld tracks. To be acceptable, all five test specimens must pass the stated criteria in Section 1.24.6 - Table 4 with less than 25% weld area separation. If the field test weld is acceptable, the sample qualifies for testing by the testing laboratory. If the field test weld is unacceptable in accordance with the above, then the weld is deemed failed and is to be treated accordingly.

Independent seam testing arranged by the Superintendent it shall be conducted in accordance with ASTM D 6392. Laboratory testing is the ultimate confirmation of the acceptability of the weld quality. To be acceptable, all five test specimens must pass the stated criteria in Section 1.24.6 - Table 4 with less than 25% weld area separation.

Reports of the results of examinations and testing shall be prepared and submitted to the Superintendent.

For field seams, if a laboratory test fails, that shall be considered as an indicator of the possible inadequacy of the entire seamed length corresponding to the test sample. Additional destructive test portions shall then be taken by the liner sub-contractor, typically 3 m on either side of the failed sample and laboratory seam tests shall be performed. Passing tests shall be an indicator of adequate seams. Failing tests shall be an indicator of inadequate seams and the testing process repeated. All seams represented by the destructive test location shall be repaired with a cap-strip, extrusion welded to all sides of the capped area. All cap-strip seams shall be non-destructively vacuum box tested until adequacy of the seams is achieved. Cap-strip seams exceeding 50 m in length shall be destructively tested. All costs associated with additional sampling and testing, including laboratory testing, shall be at the Contractor's expense.

Identification of Defects

Panels and seams shall be inspected by the liner sub-contractor and Superintendent during and after panel deployment to identify all defects, including holes, blisters, undispersed raw materials and signs of contamination by foreign matter.

Evaluation of Defects

Each suspect location on the liner (both in geomembrane seam and non-seam areas) shall be non-destructively tested using one of the methods described in this Section. Each location which fails non-destructive testing shall be marked, numbered, measured and posted on the daily "installation" drawings and subsequently repaired.

If a destructive sample fails the field or laboratory test, the liner sub-contractor shall repair the seam between the two nearest passed locations on both sides of the failed destructive sample location.

Defective seams, tears or holes shall be repaired by re-seaming or applying an extrusion welded cap-strip.

Re-seaming may consist of either:

- Removing the defective weld area and re-welding the parent material using the original welding equipment; or,
- Re-seaming by extrusion welding along the overlap at the outside seam edge left by the fusion welding process.

Blisters, larger holes and contamination by foreign matter shall be repaired by patches and/or extrusion weld beads as required. Each patch shall extend a minimum of 150 mm beyond all edges of the defects.

All repairs shall be measured, located and recorded.

Verification of Repairs on Seams

Each repair shall be non-destructively tested using either vacuum box or spark testing methods. Tests which pass the non-destructive test shall be taken as an indication of a successful repair. Failed tests shall be re-seamed and re-tested until a passing test results. The number, date, location, technician and test outcome of each patch shall be recorded.

Daily Field Installation Reports

At the beginning of each day's Works, the liner sub-contractor shall provide the Superintendent with daily reports for all Works accomplished on the previous Works day. Reports shall include the following:

- Total amount and location of geomembrane placed;
- Total length and location of seams completed, name of technicians doing seaming and welding unit numbers;
- Drawings of the previous day's installed geomembrane showing panel numbers, seam numbers and locations of non-destructive and destructive testing;
- Results of prequalification test seams;
- Results of non-destructive testing; and,
- Results of vacuum testing of repairs.

Destructive test results shall be reported prior to covering of liner or within 48 hours whichever is the soonest.

1.24.3.7 Liner Acceptance

Geomembrane liner will be accepted by the Superintendent when:

- The entire installation is finished, or an agreed-upon subsection of the installation is finished;
- All liner sub-contractor's QC documentation is completed, submitted and approved by the Superintendent;
- Verification of the adequacy of all field seams and repairs and associated geomembrane testing is complete; and,
- All CQA testing on the installed material has been completed and approved by the Superintendent.

1.24.3.8 Disposal of Scrap Materials

On completion of installation, the liner sub-contractor shall dispose of all waste and scrap material in a location approved by the Superintendent, remove equipment used in connection with the Works herein, and shall leave the Site in a neat acceptable manner. No scrap material shall be allowed to remain on the geomembrane surface.

1.24.4 Materials Properties and Testing Scope

1.24.4.1 General

These Specifications set forth a set of minimum physical, mechanical and chemical properties that must be met, or exceeded by the geomembrane being manufactured. In a few cases a range is specified.

In the context of quality systems and management, these Specifications represent manufacturing quality control (MQC).

Note: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in these Specifications.

1.24.4.2 Definitions

Manufacturing Quality Control (MQC) - a planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and Contract Specifications.

Manufacturing Quality Assurance (MQA) - a planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and Contract Specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organisation to determine if the manufacturer is in compliance with the product certification and Contract Specifications for this project.

1.24.4.3 Manufacturing Specifications and Quality Control

LLDPE

The quality of the geomembranes shall be in accordance with the requirements of the Geosynthetic Research Institute (GRI) – GM17. The minimum Specifications for a quality LLDPE geomembrane product is contained in GRI Test Method GM-17 Standard Specification "*Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes*".

In addition to the above, the Principal is to provide a statement on the origin of the resin, its identification (type and lot number), its production date and the maximum amount of recycled polymer material added to the raw resin must be included as well as certified copies of the quality control certificates issued by the resin supplier and reports on the tests conducted by the manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to this project.

1.24.4.4 Material Classification and Formulation

These Specifications cover Linear Low Density Polyethylene (LLDPE) with a formulated sheet density of ≤ 0.939 g/ml as measured in accordance with ASTM D 1505 and D 792.

The base resin from which the geomembrane is made will generally be in the density range of ≥0.915 g/ml and ≤ 0.926 g/ml and have a melt flow index value per ASTM D 1238 of less than 1.0 g/10 min. Base resin density is measured without carbon black and additives added.

Resin for the geomembrane shall be virgin, first quality LLDPE resin and shall not be intermixed with other resin types. Furthermore, it shall not contain more than 2% clean recycled polymer by weight of the resin and with no more than 10% rework. If rework is used, it must be a similar LLDPE as the parent material.

No post-consumer resin (PCR) of any type shall be added to the formulation.

1.24.4.5 Physical, Mechanical and Chemical Property Requirements

The geomembrane shall conform to the test property requirements prescribed in Section 1.24.5 - Table 3.

The properties of the geomembrane shall be tested at the minimum frequency shown in Section 1.24.5 - Table 3. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

1.24.4.6 Workmanship and Appearance

The geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties of the geomembrane.

General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

1.24.4.7 MQC Sampling

Sampling shall be in accordance with the specific test methods listed in Section 1.24.5 - Table 3. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

The number of tests shall be in accordance with the appropriate test methods listed in Section 1.24.5 - Table 3.

The average of the test results shall be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave."

1.24.4.8 MQC Retest and Rejection

If the results of any test do not conform to the requirements of these Specifications, retesting to determine conformance or rejection shall be carried out in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

1.24.4.9 Packaging and Marketing

The geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery.

1.24.4.10 Certification

A manufacturer's certification that the material was manufactured and tested in accordance with the Specifications, together with a report of the test results shall be furnished at the time of shipment.

1.24.4.11 Conformance Quality Control Testing

The Principal shall provide manufacturer's test results for the rolls delivered to Site to demonstrate that the rolls meet the requirements of the Specifications. The test frequency shall be as set out in Section 1.24.5 - Table 3.

The Superintendent will arrange for independent Conformance Quality Control testing of the material. In order to achieve this:

- The Superintendent will determine the location of where the samples are to be received, either at the point of manufacture or on Site;
- The timing of when the sampling will occur is to be coordinated by the Superintendent, between all Parties, to ensure the most efficient sampling process and handover of the samples. This will either be during or immediately after manufacture or as soon as is reasonable following delivery to Site;
- The CQA Consultant will be present at the point of sampling to monitor the sampling procedure and to receive the samples;
- The Principal is responsible for providing all samples, as required, from the rolls of liner material that will or have been delivered to Site and handing the samples to the CQA Consultant; and,
- The CQA Consultant will arrange for the delivery and testing of the samples to be carried out at an independent NATA accredited laboratory.

The CQA results from the independent laboratory shall take precedence over the test results provided by the manufacturer of the material. The Conformance Quality Control testing shall be at the Principal's cost.

Any non-conformance in the delivered materials as identified by the Conformance Quality Control testing shall be addressed by the Principal and thereafter, if the Superintendent rejects the material, the Principal shall replace the non-conforming material with conforming material. Again, the new delivery of material will be subject to Conformance Quality Control testing to demonstrate its conformance with the Specifications. Any replacement of non-conforming material and subsequent Conformance Quality Control testing carried out by the Superintendent will be at the Principal's cost.

The material delivered to Site shall meet the Specifications relative to the independent laboratory test results, for the material to be considered for incorporation into the Works.

Section 1.24.7 - Table 5 sets out the minimum Conformance Quality Control testing that will be carried out by the Superintendent.

The Contractor is to allow at least six weeks in its construction program for the Conformance Quality Control testing to be completed.

1.24.5 LLDPE Geomembrane Material Specifications

The LLDPE geomembrane shall have the minimum material Specifications as set out in Table 3:

Table 3 - LLDPE Geomembrane Material Specifications

Property	Test Method	LLDPE Test Value – 1.50 mm Textured/Textured	Testing Frequency (minimum)
Thickness (min. ave.) • Lowest individual for 8 out of 10 values • Lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	Per roll
Asperity Height (min. ave.)	D 7466	0.40 mm	Every 2nd roll (1)
Sheet Density (max);	D 1505/ D 792	0.939 g/cc	90,000 kg
Tensile Properties (min. ave.) (2) • break strength • break elongation	D 6693 Type IV	 ≥ 16 kN/m ≥ 250%	9,000 kg
2% Modulus (max)	D 5323	≥ 630 kN/m	Per formulation
Tear Resistance (min. ave.)	D 1004	≥ 150 N	20,000 kg
Puncture Resistance (min. ave.)	D 4833	≥ 300 N	20,000 kg
Axi-Symmetric Break Resistance Strain (min)	D 5617	≥ 30%	Per formulation
Carbon Black Content - Particle size ~20 nm (range)	D 4218 (3)	2.0-3.0%	20,000 kg
Carbon Black Dispersion	D 5596	note (4)	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) (6) (a) Standard OIT, or (b) High Pressure OIT	 D 3895 D 5885	 ≥ 100 min. ≥ 400 min.	90,000 kg
Oven Aging at 85ºC (5), (6) (a) Standard OIT (min. ave.) - % retained after 90 days, or (b) High Pressure OIT (min. ave.) -	D 5721 D 3895 D 5885	 ≥ 35% ≥ 60%	Per each formulation

Property	Test Method	LLDPE Test Value – 1.50 mm Textured/Textured	Testing Frequency (minimum)
% retained after 90 days			
UV Resistance (7) (a) Standard OIT (min. ave.) or (b) High Pressure OIT (min. ave.) - % retained after 1,600 hrs (9)	D 7238 D 3895 D 5885	N.R. (8) ≥ 35%	Per each formulation

(1) Alternate the measurement side for double sided texture sheet.

(2) Machine direction (MD) and cross machine direction (XMD) average values shall be on the basis of 5 test specimens each direction: Break elongation is calculated using a gauge length of 50 mm at 50 mm/min.

(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views: 9 in Categories 1 or 2 and 1 in Category 3.

(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(7) The condition of the test shall be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60° C.

(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(9) UV resistance is based on percentage retained value regardless of the original HP-OIT value.

For Notes, refer to GRI Test Method GM17.

Minimum Average Roll Value (min. ave.) is defined as the Mean value less 2 standard deviations. Mathematically, this implies that 97.5% of the results of the tested specimens will exceed the min. ave.

1.24.6 LLDPE Geomembrane Weld Properties

The geomembrane shall have the minimum average weld properties as set out in Table 4, with the Sample Strength being applicable to a 25 mm wide, 1.5 mm thick sample. Weld properties are determined in accordance with GRI GM19a Standard Specification:

Table 4 - Minimum Average Weld Properties

Property	Test Method	Sample Strength (N/25 mm)
Fusion/Wedge Weld - Shear strength	ASTM D 6392	394
Fusion/Wedge Weld - Peel strength	ASTM D 6392	328
Extrusion Weld – Shear Strength	ASTM D 6392	394
Extrusion Weld – Peel Strength	ASTM D 6392	290

1.24.7 Geomembrane CQA Testing

The geomembrane shall undergo the minimum Conformance Quality Control testing as set out in Table 5:

Table 5 - Geomembrane CQA Testing

Item	Property	Standard	Frequency
Conformance Quality Control testing (sampled at the point of manufacture or on Site, as determined by the Superintendent)	Thickness	ASTM D5994	Each roll
	Density	ASTM D1505, ASTM D792	One sample per 5,000 m^2, or every five rolls delivered to Site whichever is the greatest number of tests
	Tensile properties (break stress and break elongation)	ASTM D6693 type IV	
	Puncture resistance	ASTM D4833	
	Tear resistance	ASTM D1004	
	Carbon black content	ASTM D4218	
	Carbon black dispersion	ASTM D5596	
	Axi-Symmetric Break Resistance Strain (min.)	ASTM D5617	Per formulation
	Oxidative induction time	ASTM D3895, ASTM D5885	One sample every 10,000 m^2, or resin type or manufacturing run
Start-up test weld	Welding equipment		Checked daily at

Item	Property	Standard	Frequency
			start of Works, and whenever the welding equipment is shut-off for more than one hour. Also after significant changes in weather conditions
	Weld conditions		Test weld strips will be required whenever personnel or equipment are changed and/or wide temperature fluctuations are experienced. Minimum 1.5 m continuous seam
Destructive weld testing	On-Site, hand tensiometer in peel and shear	ASTM D6392	Every 150 m (if fusion weld), every 120 m (if extrusion weld)
	Off-Site — weld seam strength in peel and shear	ASTM D6392	Every 150 m (if fusion weld), every 120 m (if extrusion weld)
Non-destructive weld testing		Air pressure test, ASTM D5820 Vacuum box test, ASTM D5641	All seams over full length
Visual inspection of geomembrane	Tears, punctures, abrasions, cracks, indentations, thin spots, or other faults in the material.		Every roll

Note:

1. All Conformance Quality Control tests must be reviewed, accepted, and reported by the CQA Consultant before deployment of the geomembrane.
2. All testing must be performed on samples taken from the geomembrane delivered to Site or at the supplier's/manufacturer's premises under the Superintendent's inspection or delegated authority.
3. All laboratory tests must be performed in a third-party independent NATA accredited laboratory.
4. The required testing frequencies may be revised by the Superintendent to conform with improvements in testing methods and/or in the state of the art practice and/or to account for the criticality of the application (i.e. to account for the importance of the geomembrane for the stability of Works).

1.25 Installation of Geocomposite Drainage Material

1.25.1 Scope of Work

The scope of Works incorporates the installation of geocomposite drainage material as specified and to the extent shown in the Drawings.

The Contractor shall provide all supervision, labour, cable ties (for joins) and equipment for the installation of the geocomposite drainage material in accordance with these Specifications and Drawings.

Prior to installation, all geocomposite drainage material to be incorporated in the Works shall be approved in writing by the Superintendent.

1.25.2 General

Although the geocomposite drainage material is a Principal Supply Item, product information has been provided so that the Contractor is aware of the type of material that will be utilised in the Works.

1.25.3 Geocomposite Drainage Material Requirements

The geocomposite drainage material shall consist of a HDPE resin geonet with non-woven 100% polyester or polypropylene (with the exception of inhibitors and/or carbon black added for UV resistance), non-woven needle-punched geotextile fabric heat bonded on both sides. The geocomposite drainage material shall not be made from recycled materials.

The geotextile filaments shall be rot proof, chemically stable and shall have low water absorbency. It shall resist de-lamination and maintain its relative position in the geotextile.

Geocomposite drainage material shall be free of flaws that may have an adverse effect on the physical and mechanical properties of the material.

Geotextiles shall be free of any manufacturing broken-off needles. Should any needles be found either by visual inspection or the Superintendent using a metal detector, the Principal is to thereafter arrange for the continuous inspection of both sides of each and every roll of geocomposite drainage material prior to installation. Inspection is to be via a Superintendent approved method of metal detection. Should more than 1 manufacturing needle or part thereof be detected per 200 m^2 of material, the Superintendent may reject the complete roll. Should more that 10 rolls, each with more than 1 needle per 200 m^2 be detected, the Superintendent may reject that complete batch of geocomposite drainage material.

The costs in replacing any rejected material will be covered by the Principal, including all necessary Conformance Quality Control testing undertaken by the CQA Consultant, including the CQA Consultant's time related costs.

Geotextiles shall be stabilised against ultraviolet radiation to the degree that one (1) month exposure of the geotextile to sunlight shall not reduce its strength to less than 90% of the specified values.

The geocomposite drainage material shall have the minimum material Specifications as set out in Table 6:

Table 6 - Geocomposite Drainage Material Specifications

Property	Value	Test Method & Frequency
Geonet		
Thickness (min. ave)	≥ 5.6 mm	ASTM D 5199, 1 sample per 5,000 m^2
Carbon Black (min. ave)	2-3%	ASTM D 4218, 1 sample per 5,000 m^2
Tensile Strength (min. ave)	≥ 8.7 kN/m	ASTM D 7179, 1 sample per 5,000 m^2
Density (min. ave)	0.94 g/cm^3	ASTM D 1505, 1 sample per 5,000 m^2
Compressive Strength (min. ave)	800 kPa	ASTM D 6364, 1 sample per 5,000 m^2
Composite		
Ply Adhesion (min. ave)	≥ 170 g/m	ASTM D 7005, 1 sample per 5,000 m^2
Transmissivity(1) (min. ave)	≥ 2 x 10^{-3} m^2/sec	ASTM D 4716, 1 sample per 5,000 m^2
Geotextile – non-woven material only - Demonstrated by Geotextile Manufacturer's MQA Documentation		
Grab Tensile (min. ave)	≥ 1,590 N	ASTM D 4632, as per MQA Frequency
Trapezoid Tear (min. ave)	≥ 530 N	ASTM D 4533, as per MQA Frequency
CBR Puncture (min. ave)	≥ 3,950 N	ASTM D 6241, as per MQA Frequency
Water Flow (min. ave)	≥ 60 L/s/m^2	ASTM D 4491, as per MQA Frequency

(1) Transmissivity measured using water at 21 + 2 ^{O}C with a gradient of 0.1 and a confining pressure of 480 kPa between HDPE plates after 15 minutes. Values may vary with individual labs.

The geotextile is to be bonded onto the geonet such that there is no single area greater than 2,500 cm^2 (50 cm x 50 cm) where the geotextile has either delaminated or is unbonded. A minimum of 95% of the roll material surface area is to be securely bonded to the geonet. A maximum of 0.3 m of unbonded material is permissible on the roll edges. This unbonded portion is excluded from the above calculations.

1.25.4 Geocomposite Drainage Material CQA Testing

The geocomposite drainage material shall undergo the minimum CQA testing as set out in Table 7:

Table 7 - Geocomposite Drainage Material CQA Testing

Item	Property	Standard	Frequency
Conformance Quality Control testing (sampled at the point of manufacture or on Site, as determined by the Superintendent)	Thickness	ASTM D5199	1 sample per 2,500 m^2
	Tensile Strength	ASTM D7179	1 sample per 5,000 m^2
	Compressive Strength	ASTM D6364	1 sample per 5,000 m^2
	Ply Adhesion	ASTM D7005	1 sample per 5,000 m^2
Visual inspection of geocomposite drainage material	Colour, non-adhered or delaminated portions, tears, holes, presence of needles or broken needles, and other faults in the material.		Each roll during placement.

Note:

1. All Conformance Quality Control tests must be reviewed, accepted, and reported by the Superintendent before deployment of the geocomposite drainage material.
2. All testing must be performed on samples taken from the geocomposite drainage material delivered to Site or at the supplier's/manufacturer's premises under the Superintendent's inspection or delegated authority.
3. All laboratory tests must be performed in a third-party independent NATA accredited laboratory.
4. The required testing frequencies may be revised by the Superintendent to conform with improvements in testing methods and/or in the state-of-the-art practice and/or to account for the criticality of the application (i.e to account for the importance of the geocomposite drainage material for the stability of Works).

1.25.5 Manufacturing Specifications and Quality Control

The test methods and frequencies used by the manufacturer for quality control/quality assurance of the above geocomposite drainage material prior to delivery shall be in accordance with Section 1.25.3 - Table 6.

The manufacturer's material quality control certifications, including results of quality control testing of the products, must be supplied to the Superintendent to verify that the materials supplied for the project are in compliance with all product and/or project Specifications. The certification shall be signed by a responsible party employed by the manufacturer, such as the QAIQC Manager, Production Manager or Technical Services Manager. Certifications shall include lot and roll numbers and corresponding shipping information.

The manufacturer's QC program shall be available for auditing. The manufacturer shall also provide a written certification that the geocomposite drainage material conforms to the material requirements for this project.

1.25.6 Quality Assurance

Manufacturer quality control (MQC) documentation from the manufacturer of the geocomposite drainage material supplied must be submitted by the Contractor to the Superintendent for approval. Submissions shall include:

- Date of manufacture;
- Lot number, roll number, length and width;
- Polymer quality documentation used in the production of the rolls delivered;
- Fibre quality documentation used in the production of the rolls delivered;
- Manufacturer quality control documentation for the particular lots of geocomposite drainage material used in the production of the rolls delivered;
- QC program laboratory-certified reports; and,
- The manufacturer's approved QA stamp and the technician's signature. The technician's signature may be omitted from each roll label, but then must be included on each of the manufacturer's test certificates associated with each roll.

Prior to delivery to Site, the Principal is to have provided the relevant certification documents to the Superintendent to substantiate that the material conforms to the required Specifications.

1.25.7 Conformance Quality Control Testing

The Principal shall provide test results for the rolls delivered to Site to demonstrate that the rolls meet the requirements of these Specifications. The test frequency shall be as set out in Section 1.25.3 - Table 6.

The Superintendent will arrange for independent Conformance Quality Control testing of the material. The Superintendent shall arrange for the Principal to provide samples to be recovered from the delivered rolls to Site, and tested at a NATA accredited laboratory. The results from the laboratory shall take precedence over the test results provided by the manufacturer of the material. The Conformance Quality Control testing shall be at the Principal's cost.

The Superintendent will arrange for independent Conformance Quality Control testing of the material. In order to achieve this:

- The Superintendent will determine the location of where the samples are to be received, either at the supplier's depot or on Site;
- The timing of when the sampling will occur is to be coordinated by the Superintendent, between all Parties, to ensure the most efficient sampling process and handover of the samples. This will either be at the supplier's depot or as soon as is reasonable following delivery to Site;
- The CQA Consultant will be present at the point of sampling to monitor the sampling procedure and to receive the samples;
- The Principal is responsible for providing all samples, as required, from the rolls of liner material that will or have been delivered to Site and handing the samples to the CQA Consultant; and,
- The CQA Consultant will arrange for the delivery and testing of the samples to be carried out at an independent NATA accredited laboratory.

Any non-conformance in the delivered materials as identified by the Conformance Quality Control testing shall be addressed by the Principal and thereafter, if the Superintendent rejects the material, the Principal shall replace the non-conforming material with conforming material. Again, the new delivery of material will be subject to Conformance Quality Control testing to demonstrate its conformance with these Specifications. Any replacement of non-conforming material and subsequent Conformance Quality Control testing carried out by the Superintendent will be at the Principal's cost.

The material delivered to Site shall meet these Specifications relative to the independent laboratory test results, for the material to be considered for incorporation into the Works.

Section 1.25.4 - Table 7 sets out the minimum Conformance Quality Control testing that will be carried out by the Superintendent.

1.25.8 Delivery, Storage and Handling

Each roll of geocomposite drainage material delivered to the Site shall be labeled by the manufacturer. The label shall be firmly affixed and shall clearly state the following:

- Manufacturer's name;
- Product identification (material type);
- Date of manufacture, batch number, polymer type;
- Roll number;
- Roll length;
- Roll weight; and,
- Roll width.

The geocomposite drainage material rolls shall be delivered to the Site, handled and stored in such manner that no damage occurs to the geocomposite drainage material or its protective wrapping. The geocomposite drainage material rolls shall be wrapped with weatherproof wrapping to protect material from ultraviolet degradation and moisture uptake. In the event that rolls are damaged, the Superintendent shall assess the extent of the damage and consider possible rejection of the damaged rolls.

A dedicated area shall be used for the storage of all geocomposite drainage material delivered to Site. The material shall be stored and handled as follows:

- In its original, unopened packaging or resealed following the removal of samples from the roll;
- All rolls shall be covered and secured using trap material resistant to moisture;
- Away from high traffic areas, but sufficiently close to the active Works area to minimise handling;
- Elevated aboveground, on a level, dry, well-drained and stable area. Should timber pallets be used, they must be inspected and free of nails/pins prior to roll placement;
- Not more than three rolls high;
- Protected from precipitation, stormwater runoff, standing water, chemicals, excessive heat, ultraviolet (UV) radiation, vandalism and animals;
- Blocks provided to prevent sliding or rolling of stacks;
- All roll labeling shall be clearly visible;
- Appropriate slings used when lifting to prevent damage to any material; and,
- Under no circumstances may the rolls be dragged, lifted with the forks of a forklift or pushed to the ground from the delivery vehicle.

Any damaged material shall be assessed by the Superintendent and if deemed necessary, rejected and the Contractor advised to immediately remove the material from Site.

1.25.9 Placement

Geocomposite drainage material placement shall be as follows:

- The Contractor is to provide a panel layout drawing to the Superintendent for approval a minimum of one week prior to any geocomposite drainage material installation. Once approved by the Superintendent, the geocomposite drainage material is to be installed in accordance with the approved panel layout;
- There is to be no driving on any liner material. Prior to installation, the Contractor is to provide a method statement on how it is proposed to install the geocomposite drainage layers without any driving on the LLDPE lined surface;
- No installation of geocomposite drainage material is to occur until the Superintendent has approved all manufacturer's QA/QC documentation and all Conformance Quality Control testing has been concluded and the material approved by the Superintendent, including the method of geocomposite drainage layer installation over the LLDPE;
- Installation shall be performed by an Installer who has installed a minimum of 50,000 m^2 of geocomposite drainage material of the type specified or similar product, using the same type of installation apparatus to be used in the current project;
- No placement shall occur during heavy rain events or during excessively windy conditions;
- Appropriate lifting equipment is to be used to ensure safe and efficient material placement;

- The Contractor shall ensure that the underlying LLDPE has been approved by the Superintendent prior to the installation of the geocomposite drainage material. The LLDPE surface upon which the geocomposite drainage material will be deployed shall be free of any sharp objects, stones, debris, standing water, or other potentially damaging objects;
- The geocomposite drainage material shall not be installed until inspection of the LLDPE has been undertaken and deemed suitable and in accordance with these Specifications by the Superintendent;
- The geocomposite drainage material shall be installed such that the sheets are free of wrinkles and folds. The arrangement of the geocomposite drainage material sheets shall be according to a predetermined layout plan;
- The panels shall be laid in close contact and in accordance with the manufacturer's recommendations to allow continuous flow of water within the geocomposite drainage material;
- NO vehicular traffic shall travel on any liner material.
- The entire surface area of each and every roll shall be inspected by the Superintendent (for example, during unrolling/installation) to ensure that there is no damage or other faults in the material (such as significant and obvious variability in thickness/mass per unit area, tears, holes or presence of broken needles). If damage is identified, it will need to be repaired according to these Specifications or as instructed by the Superintendent;
- During installation, adequate sandbags are to be left in place to prevent material being blown around by wind; and,
- The material is to be covered by subsequent layers within 4 weeks of installation to protect the geotextile from excessive UV decay.

Installation shall comply with the manufacturer's requirements, details of which shall be provided to the Superintendent prior to installation. Installation shall only occur once the Superintendent has accepted the material as being in accordance with the required Specifications.

1.26 Cap Penetrations

There are landfill gas and leachate extraction system penetrations through the capped surface.

All penetrations through the cap liner system are to be sealed in accordance with detail contained within the Drawings and where appropriate, the manufacturer's installation recommendations or as agreed with the Superintendent.

The Contractor may propose alternative penetration details based on previous experience or manufacturer recommendations. The Design and CQA Consultants are to be satisfied that any proposed alternative is able to meet the intent of the Specifications and are likely to achieve the maximum leakage rate through the liner. Alternative penetration details are to be approved in writing by the Superintendent prior to installation.

1.27 Interaction with Landfill Gas and Leachate Extraction Network

The Contractor is to be aware that there are a number of existing landfill gas and leachate extraction pipes within the Works area. The Contractor is required to install penetrations through the capped surface. As part of the process, the Contractor is to work closely with the landfill gas and leachate extraction contractors and the Principal to ensure that all Works are carried out with due consideration of the landfill gas and leachate extraction networks. The gas and leachate extraction networks are active networks that will be partially interrupted during the capping Works. The landfill gas and leachate contractor will need to disconnect and connect/reconnect various components of the networks during construction to ensure that landfill gas and leachate continues to be extracted from the waste mass with minimal down-time. There will be a need for close coordination and programing of the Works to ensure minimal delays to the Works.

All Works associated with the landfill gas and leachate infrastructure is to be coordinated with the related contractors.

1.28 Capping Stability Requirements

The designer has undertaken a stability assessment of the proposed capping system. The sloping side portions of the cap have the potential to fail if there is insufficient interface friction between the layers of synthetic materials.

In assessing the stability of the capped side slope, the designer undertook shear box testing of the various interfaces between the soil and synthetic liner materials. The materials and products used for the shear box testing included:

- Insitu silty clay soil;
- GCL – ELCOSEAL X2000;
- LLDPE – Solmax 1.5 mm double textured; and,
- Geocomposite Drainage Material – Interdrain geonet with top and bottom A39.

In the event that the Principal supplies different types of materials, then, as part of the CQA process, the Principal is to provide samples of the synthetic liner material to the Superintendent, which will be used to undertake additional shear box testing to confirm that the actual liner materials used during construction provide equivalent or greater slope stability.

1.29 Access Tracks and Stormwater Drains

The Contractor is to construct access tracks and stormwater drains on top of the growing medium, in the typical locations indicated in the Drawings. On completion of the installation of the growing medium, the Superintendent will determine the actual location of the access tracks and stormwater drains, which will typically be in the locations indicated; however, will be adjusted to suit the top of cap profile, while achieving access to specific infrastructure and adequate stormwater control of the capped surface.

The growing medium is to be installed to ensure minimal compaction; however, the access track and stormwater drain earthworks are to be constructed to minimum 95% MMDD compaction. Due to the relatively flexible nature of the substrate (waste and uncompacted growing medium), it is unlikely that this degree of compaction will be achievable in the first or second compaction lift; however, subsequent compaction lifts should be able to achieve the specified degree of compaction. If 95% MMDD compaction is unable to be achieved, the Superintendent is to assess the compactive effort and determine the most suitable solution in order to achieve the maximum compaction on the capped surface.

1.30 Quality Assurance and Testing

1.30.1 General

The Contractor shall at all times be responsible for achieving the specified standards and demonstrating such achievement through testing and measurement and the provision of documentation which shall cover all Works under the Contract, both on-site and off-site and shall include the activities of all sub-contractors and suppliers. The exception being, that the Principal will be responsible for the quality of all Principal Supply Items.

1.30.2 Traceability

Traceability is required for all materials as stipulated in these Specifications or if not stipulated, as per the relevant Standard, Code of industry norm. The trace shall start at the specified or nominated source point and finish at the location where the material is incorporated into the Works.

Traceability shall apply to:

- Geosynthetic Clay Liner;
- Geomembrane Liner; and,
- Geocomposite drainage material.

1.30.3 Inspection

The Superintendent or its nominated representative shall at all times be provided access to any facility where Works associated with the Contract is being performed, including the facilities of sub-contractors or suppliers either on-site, and any laboratory used for testing.

1.30.4 Testing Personnel

All quality control testing unless specified otherwise shall be carried out by a laboratory holding current NATA accreditation for all test methods referred to or required by these Specifications. NATA accreditation for all test methods shall be held at the time of tendering and be maintained until completion of the Contract. All test reports shall be NATA endorsed by a current NATA signatory approved for the laboratory conducting the testing.

Surveying processes to verify conformance shall be conducted by suitably qualified personnel, which includes:

- A qualified and experienced surveyor able to be a fulltime member of the Institution of Mining and Engineering Surveyors Australia; or,
- A surveyor licensed under the WA Licensing Board.

1.30.5 Sampling and Test Frequency

Sampling methods shall be unbiased and either random or systematic in concept or as specified. The minimum frequency of tests shall be as stipulated in these Specifications or if not stipulated, as per the relevant Standard, Code of industry norm.

1.30.6 Testing

1.30.6.1 Limits of Work to be Tested

The minimum frequency of tests shall be as stipulated in these Specifications.

1.30.6.2 Test Methods

The tests methods shall be as stipulated in these Specifications or equivalent alternative test methods approved by the Superintendent.

1.30.7 Measurement and Test Equipment

Measurement and test equipment shall include all equipment necessary for the proper setting out and for production and Construction and Conformance Quality Control testing of the Works. Calibration and certification of test equipment shall comply with NATA stipulations.

1.30.8 Records and Reporting

The Contractor shall complete all As-Constructed and quality verification documentation and submit all records to the Superintendent at regular intervals during the Contract period as agreed with the Superintendent.

Manufacturers' and suppliers' certificates provided by the Principal shall enable a clear trace of items from source to the location within the Works.

1.30.9 Payment for Quality Control and Testing

The cost of Construction Quality Control testing to the extent required by these Specifications shall be borne by the Contractor.

The Principal shall pay for all Conformance Quality Control testing as stipulated in these Specifications.

1.31 As-Constructed Drawings

The Contractor is to provide a set of As-Constructed drawings in AutoCAD format and A3 size hard copy. The As-Constructed drawings are to show the following minimum detail:

- Top of surface of re-contoured landfill;
- Top of GCL position, including anchor trench position;
- Location of all penetrations through the liner;
- Top of growing medium;
- Location of all access tracks and stormwater drains;
- Other miscellaneous items as required; and,
- Any changes to the Approved For Construction Drawings that occurred during construction.

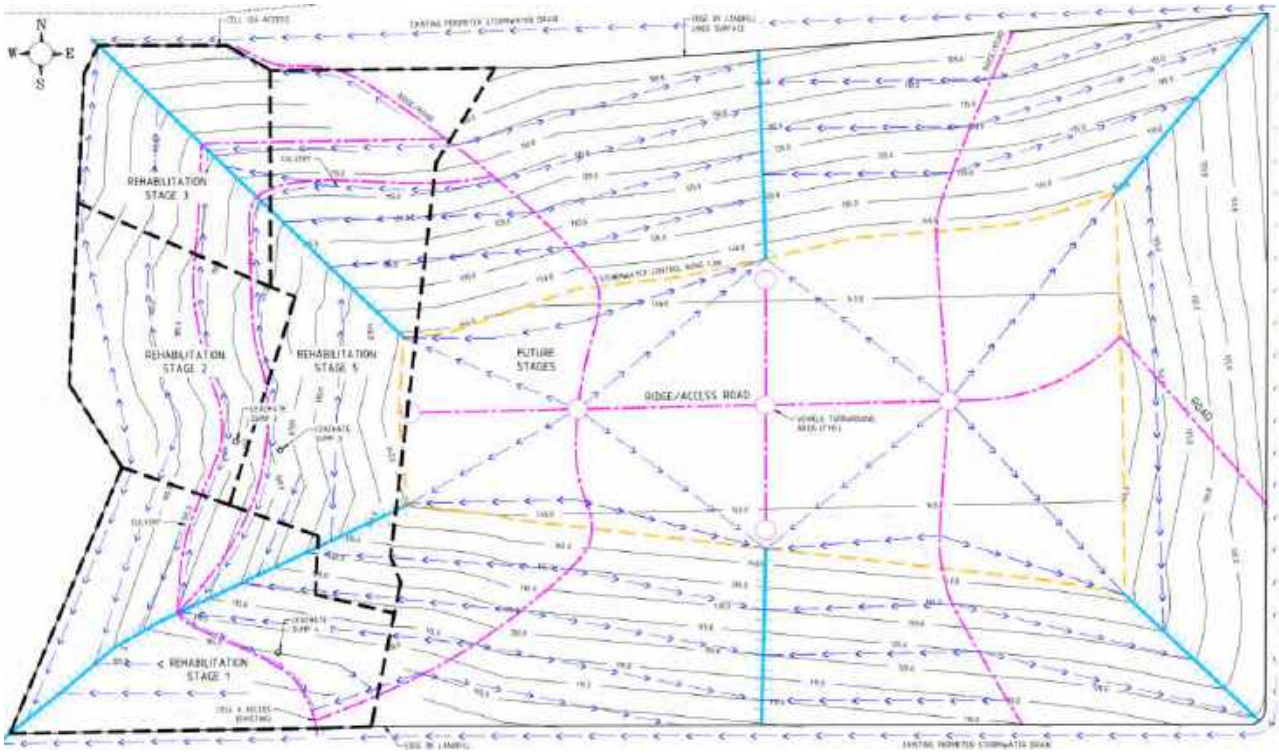
The Contractor will be provided with an electronic copy of the Approved For Construction Drawings. These original Drawings are to be modified to include all As-Constructed details. In addition, the Contractor is to remove the Design Consultant's Logo and contact details and replace the information with the Contractor's logo and contact details.

APPENDIX B: CAPPING STAGE 1 CONSTRUCTION QUALITY ASSURANCE PLAN (IW PROJECTS)

BANKSIA ROAD LANDFILL, DARDANUP

LANDFILL STAGE 1 CAPPING CONSTRUCTION

CONSTRUCTION QUALITY ASSURANCE PLAN



Proposed Stage 1, 2 & 5 Capping Areas

Prepared for

CLEANAWAY SOILD WASTE PTY LTD

[redacted]

Revision: Final
Date of Issue: 26 Mar 2022

Table of Contents

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1 Introduction

The Construction Quality Assurance (CQA) is defined as a planned system of activities that provide assurance that the landfill capping and associated Works were constructed as specified in the design and documentation. It is an important factor in ensuring that design and installation of the Works is done in accordance with the standards, Drawings and Specifications agreed with the Department of Water and Environment Regulation (DWER).

For this purpose, an independent third-party CQA Consultant(s) with experience in earthworks and landfill capping construction and more specifically synthetic liner performance characteristics will be appointed to verify that the Works have been carried out to the agreed standards. The duties of the third-party CQA Consultant(s) will include:

- Inspections;
- Verification;
- Audits and evaluation of materials and workmanship;
- Provision of advice on the interpretation of the Drawings and Specifications, including; installation, testing, repair and covering of the critical aspects of construction (not design or contractual advice); and,
- Issuing a final CQA Validation Report documenting the quality of the constructed facility.

The CQA Plan will verify that:

- Materials used comply with Specifications; and,
- Method of construction/installation is appropriate and, as a result the design requirements have been met.

The CQA Plan including reference to the construction Drawings and Specifications contains the material/construction Specifications, testing methods, testing frequency, corrective action and provides for appropriate documentation procedures.

The final CQA Validation Report will be prepared by the CQA Consultant in accordance with the requirements of the facility operating Licence, to demonstrate that all requirements of the project Drawings and Specifications and CQA Plan have been complied with.

2 Related Activities

This CQA Plan covers the following landfill capping related construction activities:

- Earthworks;
- GCL, LLDPE, geocomposite drainage material installation;
- Cap penetrations; and,
- Access tracks and stormwater drains.

3 Critical Aspects of Construction

The critical aspects of construction relating to this particular project include the following:

- Confirmation of the actual material properties in comparison to the design assumption material properties used during the design stability assessment (shear box testing of on-site materials) if the material supplied differs from the materials that were used for design stability shear box testing;
- Extent of fill during landfill surface recontouring;
- Sub-Grade preparation;
- Fill placement;
    - Growing medium;
    - Access tracks and stormwater drains;
- Geosynthetic Clay Layer (GCL) installation;
- Geomembrane installation;
- Geocomposite drainage material installation; and,
- Landfill cap penetrations.

4 Construction Drawings and Specifications

The construction Drawings and Specifications forming part of the construction Works set out the following requirements:

- Location, lines and levels of all Works;
- Material and construction Specifications;
- Applicable Standards;
- Testing methods and procedures;
- Inspections;
- Testing Frequencies;
- Corrective actions; and,
- Documentation Procedures.

The construction Drawings and Specifications are to be read in conjunction with this CQA Plan. The CQA Consultant is to confirm that the Works are carried out in accordance with the construction Drawings and Specifications. The construction Drawings and Specifications are not repeated within this CQA Plan.

5 Confirmation of Material Properties

In assessing the stability of the capped side slope, the Design Consultant undertook shear box testing of the various interfaces between the soil and synthetic liner materials. The materials and products used for the shear box testing included:

- Insitu silty clay soil;
- GCL – ELCOSEAL X2000;
- LLDPE – Solmax 1.5 mm double textured; and,
- Geocomposite Drainage Material – Interdrain geonet with top and bottom A39.

In the event that the Principal supplies different types of materials, then, as part of the CQA process, the Principal is to provide samples of the synthetic liner material to the CQA Consultant, which will be used to undertake additional shear box testing to confirm that the actual liner materials used during construction provide equivalent or greater slope stability.

If additional shear box testing is required, the CQA Consultant is to liaise with WML to determine which materials need to be sourced in order for WML to undertake the necessary site-specific materials testing to confirm the design assessment assumptions.

The CQA Consultant is to:

- Liaise with Design Consultant (IW Projects) and the Superintendent on the type and quantity of site-specific materials required for testing;
- Source the necessary materials and deliver them to the Design Consultant;
- Obtain testing outcome results from the Design Consultant, including an interpretation of the suitability thereof in comparison to the original project assumptions;
- If the results are acceptable to the Design Consultant, include the results and the Design Consultant's conclusion in the CQA Validation Report;
- If the results are not acceptable, liaise with the Design Consultant and the Superintendent to identify the preferred way forward; and,
- Document the ultimate outcome in the CQA Validation Report.

6 Earthworks Construction

The earthwork's associated with the landfill cap construction must be accompanied by Level 2 (part-time) geotechnical inspection and testing as set out in the Specifications and AS 3798-2007, *Guidelines of Earthworks for Commercial and Residential Development*. This entails, among other requirements, testing and part-time inspection of all earthworks by the geotechnical testing authority, a geotechnical engineer independent of the construction Contractor and its sub-contractors. The geotechnical testing authority must provide a report of all testing and, prior to the liner being accepted as appropriately constructed, must express the opinion that the works comply with the requirements of the Drawings and Specifications.

For further details refer to the construction Drawings and Specifications under the Earthworks section.

Material Specifications and Quality Control

The material Specifications and quality control is to be in accordance with the requirements of the construction Specifications.

Non-Conformances

If there are any non-conformances identified or any changes to the construction Drawings or Specifications that have a material effect on the outcome of the Works, the CQA Consultant is to determine:

1. The nature of the non-conformance or change and its level of effect on the project;
2. If the non-conformance is an isolated incident or a recurring problem;
3. How amendments to procedures to prevent future occurrences of the non-conformance can be implemented;
4. The nature of corrective action(s) to be applied to rectify the specific non-conformance;
5. The procedures and persons to be notified of the non-conformance and corrective measures; and,
6. Procedures for reporting to the DWER major exceptions/variations to the approved Drawings or Specifications.

Inspection Activities

The CQA Consultant is to confirm that the following information and procedures are available, and the relevant activities have been carried out in accordance with the construction Drawings and Specifications:

1. Definitions to be used throughout the project to avoid confusion on acronyms and wording;
2. Descriptions of responsibilities, qualifications, and obligations for each party involved in the CQA Plan;
3. The lines of communication and authority for the project;
4. Identify and define the process for addressing request for information, design modifications or changes in the project Drawings and Specifications;
5. A formal process on handling deficiencies which defines responsibilities and the minimum documentation required to correct deficiencies;

6. A project meeting schedule;
7. The proposed level of supervision and quality control;
8. Details of the Conformance Quality Control tests the CQA Consultant will undertake on the earthworks. Any laboratory tests must be performed at a third-party independent accredited laboratory;
9. Details of actions to take if Works fail a Conformance Quality Control tests;
10. Approval procedure for the completed Works;
11. Measures to take to protect the Works if inclement weather occurs during construction;
12. Frequency of testing and evaluation;
13. Procedures for inspecting the Works including the details of the nominated accredited laboratory for offsite testing;
14. Verification process of testing equipment calibration;
15. Details of actions to take in the event of defective Works, including retesting procedures;
16. Rejection criteria of the Works if test results indicated failure;
17. Details of actions to take in case of defective Works and corrective measures;
18. Details of actions to take if Works have been damaged by adverse weather conditions;
19. Details of actions to take to protect the Works following installation;
20. CQA Consultant daily recordkeeping. The daily log should contain the following:
    - Weather and site conditions;
    - Description of any material received at the site, including quality control data provided by Contractor (if applicable);
    - Recording of construction and testing activities;
    - Location of daily construction activities and progress;
    - Photographs of construction Works and any items of specific interest. The captions of all photographs should contain the name of the project, the date on which the photograph was taken and the identity of the feature being photographed;
    - Type of equipment used in each work task (e.g. handling equipment, construction equipment, on-site testing equipment);
    - Calibrations or recalibration of test equipment;
    - Testing conducted and test methods used;
    - Record of any material or workmanship that does not meet specified designs and corrective actions taken to remediate the problem;
    - Details of site visits;
    - Summaries of any meetings held, and action taken; and,
    - Signature of CQA Consultant.
21. As required, periodic acceptance reports summarising daily reports.

The Contractor shall provide the CQA Consultant with the necessary documentation and within an agreed timeline to enable the above CQA activities to be adequately undertaken.

Any major deviations from the approved CQA Plan must be noted and explained and approved by the DWER.

7 GCL Installation

Manufacturing Specifications and Quality Control

The manufacturing Specifications and quality control is to be in accordance with the requirements of the construction Specifications.

Non-Conformances

If there are any non-conformances identified or any changes to the construction Drawings and Specifications that have a material effect on the outcome of the Works, the CQA Consultant is to determine:

- The nature of the non-conformance or change and its level of effect on the project;
- If the non-conformance is an isolated incident or a recurring problem;
- How amendments to procedures to prevent future occurrences of the non-conformance can be implemented;
- The nature of corrective action(s) to be applied to rectify the specific non-conformance;
- The procedures and persons to be notified of the non-conformance and corrective measures; and,
- Procedures for reporting to the DWER major exceptions/variations to the approved technical Drawings and Specifications.

Inspection Activities

The CQA Consultant is to confirm that the following information and procedures are available, and the relevant activities have been carried out in accordance with the construction Drawings and Specifications:

1. Definitions to be used throughout the project to avoid confusion on acronyms and wording;
2. Descriptions of responsibilities, qualifications, and obligations for each party involved in the CQA Plan;
3. The lines of communication and authority for the project;
4. Identify and define the process for addressing request for information, design modifications or changes in the project Drawings and Specifications;
5. A formal process on handling deficiencies which defines responsibilities and the minimum documentation required to correct deficiencies;
6. A project meeting schedule;
7. The proposed level of supervision and quality control;
8. Verification process and review of the quality control certificates of the manufacturers of the GCL, the bentonite and the geotextile;
9. Verification process and review of the property values certified by the GCL manufacturer;
10. Verification process that the measurements of properties by the manufacturer are properly documented, test methods are acceptable, sampling procedure detailed and verification that the geosynthetic clay liner, the geotextile and the bentonite meet the project Specifications;
11. Verification process and review of the quality control certificates of the geosynthetic clay liner rolls assigned to the project (note: this includes a need to agree with the manufacturer on the frequency of the tests);

12. Details of the delivery, handling and storage of the geosynthetic clay liner on site prior to installation;
13. Verification process of the geosynthetic clay liner handling equipment and restraining methods used on the site;
14. Rejection criteria of the geosynthetic clay liner rolls;
15. Details of the installation staff's accreditations and verification of their experience;
16. Details of the Conformance Quality Control tests the CQA Consultant will undertake on the geosynthetic clay liner rolls delivered to site. Any laboratory tests must be performed at an accredited, independent third-party laboratory;
17. Details of actions to take if geosynthetic clay liner fails Conformance Quality Control tests;
18. Approval procedure of the subgrade and anchor trench including details of testing;
19. Establishment of a field geosynthetic clay liner panel identification;
20. Details of actions to take to ensure that field panels and overlap orientation are as indicated in the layout plan;
21. Measures to take to protect the liner if inclement weather occurs during installation;
22. Procedure for sampling and evaluation;
23. Procedures for inspecting overlaps preparation;
24. Details of actions to take in case of defects and or damages to the surface of the laid geosynthetic clay liner are identified and corrective measures;
25. Details of actions to take to minimise geosynthetic clay liner wrinkles and bridging;
26. Verification process of the geosynthetic clay liner installation around areas of protrusions and penetrations is made according to the Drawings and Specifications;
27. Details of actions and procedure to take to protect and to confine the geosynthetic clay liners following installation;
28. Procedure for ensuring that the GCL does not exceed the manufactured moisture content;
29. CQA Consultant daily recordkeeping. The daily log should contain the following:
    - Weather and site conditions;
    - Quality of subgrade;
    - Description of any material received at the site, including quality control data provided by suppliers;
    - Location of daily construction activities and progress;
    - Conformance to panel layout design;
    - Recording of installation activities consisting of panel placement, roll numbers, overlap locations, repairs and testing results for all Works;
    - Records (including photos) of the geosynthetic clay liner at the time that geomembrane is placed over the geosynthetic clay liner;
    - Photographs of construction Works and any items of specific interest. The captions of all photographs should contain the name of the project, the date on which the photograph was taken and the identity of the feature being photographed;
    - Type of equipment used in each work task (e.g. handling equipment);
    - Testing conducted and test methods used for remedial action on GCL defects or overlap defects;
    - Placement of temporary protection to installed GCL;

- Record of any material or workmanship that does not meet specified designs and corrective actions taken to remediate the problem;
- Details of site visits;
- Summaries of any meetings held, and action taken;
- Signature of CQA Consultant; and,

30. Periodic acceptance reports summarising daily reports.

The Principal and the Contractor shall provide the CQA Consultant with the following listed test certificates and records prior to, during and at the completion of the Works as each report and record is required:

- Principal:
  - Certification and test results of bentonite used in the production of the rolls from bentonite material supplier;
  - Certification and test results of geotextiles, fibres used in the production of the rolls;
  - Roll test data reports, for each roll of material;
  - Accessory bentonite test reports; and,
  - Any other documentation as required by the Specifications.
- Contractor:
  - Completed As-Constructed drawing, including roll numbers, panel layout, overlap locations and repair locations; and,
  - Any other documentation as required by the Specifications.

Any major deviations from the approved CQA Plan must be noted and explained and approved by the DWER.

CQA Testing

Table 1 – GCL CQA Testing provides the test properties and minimum testing frequencies. Higher testing frequencies might be required in certain applications (i.e. need to identify the importance of the GCL for the safety of the Works, construction and stability included). The onus is on the CQA Consultant and/or design engineer to establish if higher requirements are more appropriate.

Table 1 - GCL CQA Testing

Item	Property	Standard	Frequency
Conformance Quality Control testing (sampled at the point of manufacture or on Site, as determined by the Superintendent)	Mass per unit area of bentonite component of GCL	ASTM D5993	1 sample per 2,500 m^2
	Mass per unit area of GCL	ASTM D5993	1 sample per 1,000 m^2
	Montmorillonite content	XRD (X-ray diffraction) Quantitative Mineralogy Analysis	1 sample per 10,000 m^2
	Cation exchange capacity of bentonite	Methylene blue method	1 sample per 1,500 m^2
	Mass/unit length of bentonite in overlaps	ASTM D5993	1 sample per 1,000 m^2
	Moisture content of bentonite	ASTM D5993	1 sample per 2,500 m^2
	Swell index/free swell of clay	ASTM D5890	1 sample per 1,500 m^2
	Water absorption	ASTM D5891	1 sample per 1,500 m^2
	Peel strength (for needle-punched products only)	ASTM D6496	1 sample per 1,000 m^2
	Tensile strength	ASTM D6768	1 sample per 10,000 m^2
	Index flux	ASTM 5887	1 sample per 10,000 m^2
Visual inspection of GCL	Colour, needle punching, presence of needles or broken needles, and sewing density or other faults in the material.		Every roll
Thickness of GCL (i.e. uniformity of bentonite distribution) and apparent variations in the as placed moisture distribution.	On-Site		Each roll during placement. If thickness appears to be variable a check of the variability of the mass per unit area shall be conducted

Note:

1. All Conformance Quality Control tests must be reviewed, accepted, and reported by the CQA Consultant before deployment of the GCL.
2. All testing must be performed on samples taken from the GCL delivered to Site or at the supplier's/manufacturer's premises under the CQA Consultant's inspection or delegated authority.
3. All laboratory tests must be performed in a third-party independent NATA accredited laboratory.

4. The required testing frequencies may be revised by the Superintendent to conform with improvements in testing methods and/or in the state-of-the-art practice and/or to account for the criticality of the application (i.e to account for the importance of the GCL for the stability of Works).

8 Geomembrane Installation

Manufacturing Specifications and Quality Control

The manufacturing Specifications and quality control is to be in accordance with the requirements of the construction Drawings and Specifications.

Non-Conformances

If there are any non-conformances identified or any changes to the construction Drawings and Specifications that have a material effect on the outcome of the Works, the CQA Consultant is to determine:

- The nature of the non-conformance or change and its level of effect on the project;
- If the non-conformance is an isolated incident or a recurring problem;
- How amendments to procedures to prevent future occurrences of the non-conformance can be implemented;
- The nature of corrective action(s) to be applied to rectify the specific non-conformance;
- The procedures and persons to be notified of the non-conformance and corrective measures; and,
- Procedures for reporting to the DWER major exceptions/variations to the approved technical Drawings and Specifications.

Inspection Activities

The CQA Consultant is to confirm that the following information and procedures are available, and the relevant activities have been carried out in accordance with the construction Drawings and Specifications:

1. Definitions to be used throughout the project to avoid confusion on acronyms and wording;
2. Descriptions of responsibilities, qualifications, and obligations for each party involved in the CQA Plan;
3. The lines of communication and authority for the project;
4. Identify and define the process for addressing request for information, design modifications or changes in the project Drawings and Specifications;
5. A formal process on handling deficiencies which defines responsibilities and the minimum documentation required to correct deficiencies;
6. A project meeting schedule;
7. The proposed level of supervision and quality control;
8. Verification process and review of the quality control certificates of the resin and the quality of the resin used to manufacture the geomembrane rolls assigned to the project. The same applies to the extrudate rod;
9. Verification process and review of the property values certified by the manufacturer. The same applies to the extrudate rod;

10. Verification process that the measurements of properties by the manufacturer are properly documented, test methods are acceptable, sampling procedure detailed and verification that the geomembrane meets the project Specifications. The same applies to the extrudate rod;
11. Verification process and review of the quality control certificates of the geomembranes rolls assigned to the project (note: need to agree with manufacturer on the frequency of the tests);
12. Details of the planned geomembrane storage on site prior to installation;
13. Verification process of the geomembrane handling equipment used on the site;
14. Rejection criteria of the geomembrane sheets;
15. Details of the installation staff's accreditations and verification of their experience;
16. Details of the Conformance Quality Control tests the CQA Consultant will undertake on the geomembrane delivered to site. Any laboratory tests must be performed at a third-party independent accredited geosynthetics laboratory;
17. Details of actions to take if geomembrane fails a Conformance Quality Control tests;
18. Approval procedure of the underlying geomembrane, including details of testing;
19. Establishment of a field geomembrane panel identification;
20. Details of actions to take to ensure that field panels and seam orientation are as indicated in the layout plan;
21. Measures to take to protect the liner if inclement weather occurs during installation.
22. Frequency of trial welds and procedure for sampling and evaluation;
23. Procedures for inspecting seam preparation, trial welds, welds, testing and sampling welds; including the details of the nominated geosynthetic accredited laboratory for offsite testing;
24. Verification process of welding equipment, calibration and welding conditions;
25. Details of actions to take after cutting of each destructive test sample from the production seam;
26. Details of actions to take in the event of a defective weld, including retesting procedures;
27. Rejection criteria of the laid geomembrane if test results indicated failure;
28. Details of actions to take in case of defects and or damages to the surface of the laid geomembrane are identified and corrective measures;
29. Details of actions to take if geomembranes have been damaged due to shifting by wind;
30. Details of actions to take to minimise geomembrane wrinkles and bridging;
31. Verification process of the geomembrane installation around areas of protrusions and penetrations is made according to Drawings and Specifications;
32. Details of actions to take to protect the geomembrane following installation;
33. CQA Consultant daily recordkeeping. The daily log should contain the following:
    - Weather and site conditions;
    - Quality of underlying GCL;
    - Description of any material received at the site, including quality control data provided by suppliers;
    - Location of daily construction activities and progress;
    - Conformance to panel layout design;
    - Recording of installation activities consisting of panel placement, roll numbers, seam/weld locations, repairs and testing results for all Works;

- Records (including photos) of the wrinkling in the geomembrane at the time that geocomposite drainage material is placed over the geomembrane;

- Photographs of construction Works and any items of specific interest. The captions of all photographs should contain the name of the project, the date on which the photograph was taken and the identity of the feature being photographed;
- Type of equipment used in each work task (e.g. handling equipment, welding equipment, on-site testing equipment);
- Calibrations or recalibration of test equipment and weld equipment;
- Testing conducted and test methods used;
- Record of any material or workmanship that does not meet specified designs and corrective actions taken to remediate the problem;
- Details of site visits;
- Summaries of any meetings held, and action taken; and,
- Signature of CQA Consultant.

34. Periodic acceptance reports summarising daily reports.

The Principal and the Contractor shall provide the CQA Consultant with the following listed test certificates and records prior, during and at the completion of the Works as each report and record is required:

- Principal:
    - Certification and test results of raw materials from raw material supplier;
    - Certification and test results of raw materials from membrane manufacturer;
    - Roll test data reports, for each roll of material;
    - HDPE welding granulate test reports; and,
    - Any other documentation as required by the Specifications.
- Contractor:
    - Daily installation reports for each welder and technician:
        - Trial test weld record;
        - Wedge weld records;
        - Surface extrusion weld records;
        - Weld peel and tensile test records;
        - Wedge air-tunnel pressure test records;
        - Vacuum box test records; and,
        - Repair records.
    - Completed As-Constructed drawing, including roll numbers, panel layout, seam locations and repair locations; and,
    - Any other documentation as required by the Specifications.

Any major deviations from the approved CQA Plan must be noted and explained and approved by the DWER.

CQA Testing

Table 2 – Geomembrane CQA Testing provides the test properties and minimum testing frequencies. Higher testing frequencies might be required in certain applications (i.e. need to identify the importance of the geomembrane for the safety of the Works, construction and

stability included). The onus is on the CQA Consultant and/or design engineer to establish if higher requirements are more appropriate.

Table 2 - Geomembrane CQA Testing

Item	Property	Standard	Frequency
Conformance Quality Control testing (sampled at the point of manufacture or on Site, as determined by the Superintendent)	Thickness	ASTM D5994	Each roll
	Density	ASTM D1505, ASTM D792	One sample per 5,000 m^2, or every five rolls delivered to Site whichever is the greatest number of tests
	Tensile properties (break stress and break elongation)	ASTM D6693 type IV	
	Puncture resistance	ASTM D4833	
	Tear resistance	ASTM D1004	
	Carbon black content	ASTM D4218	
	Carbon black dispersion	ASTM D5596	
	Axi-Symmetric Break Resistance Strain (min.)	ASTM D5617	Per formulation
	Oxidative induction time	ASTM D3895, ASTM D5885	One sample every 10,000 m^2, or resin type or manufacturing run
Start-up test weld	Welding equipment		Checked daily at start of Works, and whenever the welding equipment is shut-off for more than one hour. Also after significant changes in weather conditions
	Weld conditions		Test weld strips will be required whenever personnel or equipment are changed and/or wide temperature fluctuations are experienced. Minimum 1.5 m continuous seam
Destructive weld testing	On-Site, hand tensiometer in peel and shear	ASTM D6392	Every 150 m (if fusion weld), every 120 m (if

Item	Property	Standard	Frequency
			extrusion weld)
	Off-Site — weld seam strength in peel and shear	ASTM D6392	Every 150 m (if fusion weld), every 120 m (if extrusion weld)
Non-destructive weld testing		Air pressure test, ASTM D5820 Vacuum box test, ASTM D5641	All seams over full length
Visual inspection of geomembrane	Tears, punctures, abrasions, cracks, indentations, thin spots, or other faults in the material.		Every roll

Note:

1. All Conformance Quality Control tests must be reviewed, accepted, and reported by the CQA Consultant before deployment of the geomembrane.
2. All testing must be performed on samples taken from the geomembrane delivered to Site or at the supplier's/manufacturer's premises under the CQA Consultant's inspection or delegated authority.
3. All laboratory tests must be performed in a third-party independent NATA accredited laboratory.
4. The required testing frequencies may be revised by the Superintendent to conform with improvements in testing methods and/or in the state of the art practice and/or to account for the criticality of the application (i.e. to account for the importance of the geomembrane for the stability of Works).

9 Geocomposite Drainage Material Installation

Manufacturing Specifications and Quality Control

The manufacturing Specifications and quality control is to be in accordance with the requirements of the construction Specifications.

Non-Conformances

If there are any non-conformances identified or any changes to the construction Drawings and Specifications that have a material effect on the outcome of the Works, the CQA Consultant is to determine:

- The nature of the non-conformance or change and its level of effect on the project;
- If the non-conformance is an isolated incident or a recurring problem;
- How amendments to procedures to prevent future occurrences of the non-conformance can be implemented;
- The nature of corrective action(s) to be applied to rectify that specific non-conformance;
- The procedures and persons to be notified of the non-conformance and corrective measures; and,
- Procedures for reporting to the DWER major exceptions/variations to the approved technical Drawings and Specifications.

Inspection Activities

The CQA Consultant is to confirm that the following information and procedures are available, and the relevant activities have been carried out in accordance with the construction Drawings and Specifications:

1. Definitions to be used throughout the project to avoid confusion on acronyms and wording;
2. Descriptions of responsibilities, qualifications and obligations for each party involved in the CQA Plan;
3. The lines of communication and authority for the project;
4. Identify and define the process for addressing request for information, design modifications or changes in the project Drawings and Specifications;
5. A formal process on handling deficiencies that defines responsibilities and the minimum documentation required to correct deficiencies;
6. A project meeting schedule;
7. The proposed level of supervision and quality control;
8. Verification process and review of the quality control certificates of the geocomposite drainage material manufacturers, the fibre suppliers and the polymer manufacturers, with a list of characteristics of the material;
9. Verification process and review of the property values certified by the geocomposite drainage material manufacturer;
10. Verification process that the measurements of properties by the manufacturer are properly documented, test methods are acceptable and sampling procedure detailed, and verification that the polymer, fibres, geotextile, geonet and geocomposite drainage material meet the project Specifications;

11. Verification process and review of the quality control certificates of the geocomposite drainage material rolls assigned to the project (note: need to agree with manufacturer on the frequency of the tests);
12. Details of the delivery, handling and storage of the geocomposite drainage material on site prior to installation;
13. Verification process of the geocomposite drainage material handling equipment and restraining methods used on the site;
14. Rejection criteria for the geocomposite drainage material rolls;
15. Details of the installation staff's accreditations and verification of their experience;
16. Details of the Conformance Quality Control tests the CQA Consultant will undertake on the geocomposite drainage material rolls delivered to site. Any laboratory tests must be performed at an accredited, independent, third-party laboratory;
17. Details of actions to take if geocomposite drainage material fails Conformance Quality Control tests;
18. Approval procedure of the underlying geomembrane, including details of testing;
19. Establishment of a field geocomposite drainage material panel identification;
20. Details of installation and jointing techniques;
21. Details of actions to take to ensure that field panels and jointing orientation are as indicated in the layout plan;
22. Procedure for inspecting, testing and sampling joints, if appropriate;
23. Measures to take to protect the geocomposite drainage material if inclement weather occurs during installation;
24. Procedure for sampling and evaluation;
25. Procedures for inspecting jointing preparation;
26. Details of actions to take in case defects and/or damage to the surface of the laid geocomposite drainage material are identified, and corrective measures;
27. Details of actions to take to minimise geocomposite drainage material wrinkles and bridging;
28. CQA Consultant daily recordkeeping. The daily log should contain the following:
    - Weather and site conditions;
    - Quality of underlying geomembrane;
    - Description of any material received at the site, including quality control data provided by suppliers;
    - Location of daily construction activities and progress;
    - Conformance to panel layout design;
    - Recording of installation activities, consisting of panel placement, roll numbers, overlap locations, repairs and testing results for all Works;
    - Records (including photos) of the geocomposite drainage material at the time that cover material is placed over the geocomposite drainage material;
    - Photographs of construction Works and any items of specific interest. The captions of all photographs should contain the name of the project, the date on which the photograph was taken and the identity of the feature being photographed;
    - Type of equipment used in each work task (e.g. handling equipment);
    - Testing conducted and test methods used;
    - Remedial action on geocomposite drainage material defects or jointing defects;
    - Placement of temporary protection to installed geocomposite drainage material;

- Record of any material or workmanship that does not meet specified designs and corrective actions taken to remediate the problem;
- Details of site visits;
- Summaries of any meetings held, and action taken; and,
- Signature of CQA Consultant.

29. Periodic acceptance reports summarising daily reports.

The Principal and Contractor shall provide the CQA Consultant the following listed test certificates and records prior to, during and at the completion of the Works as each report and record is required:

- Principal:
  - Certification and test results of the fibres, polymer, geotextiles, geonet and geocomposite drainage material used in the production of the rolls;
  - Roll test data reports, for each roll of material, and,
  - Any other documentation as required by the Drawings and Specifications.
- Contractor:
  - Completed As-Constructed drawing, including roll numbers, panel layout, overlap locations and repair locations; and,
  - Any other documentation as required by the Drawings and Specifications.

Any major deviations from the approved CQA Plan must be noted and explained and approved by the DWER.

CQA Testing

Table 3 – Geocomposite Drainage Material CQA Testing provides the test properties and minimum testing frequencies. Higher testing frequencies might be required in certain applications (need to identify the importance of the geocomposite drainage material for the safety of the Works, construction and stability included). The onus is on the CQA Consultant and/or Design Consultant to establish whether higher requirements are more appropriate.

Table 3 - Geocomposite Drainage Material CQA Testing

Item	Property	Standard	Frequency
Conformance Quality Control testing (sampled at the point of manufacture or on Site, as determined by the Superintendent)	Thickness	ASTM D5199	1 sample per 2,500 m^2
	Tensile Strength	ASTM D7179	1 sample per 5,000 m^2
	Compressive Strength	ASTM D6364	1 sample per 5,000 m^2
	Ply Adhesion	ASTM D7005	1 sample per 5,000 m^2
Visual inspection of geocomposite drainage material	Colour, non-adhered or delaminated portions, tears, holes, presence of needles or broken needles, and other faults in the material.		Each roll during placement.

Note:

1. All Conformance Quality Control tests must be reviewed, accepted, and reported by the CQA Consultant before deployment of the geocomposite drainage material.
2. All testing must be performed on samples taken from the geocomposite drainage material delivered to Site or at the supplier's/manufacturer's premises under the CQA Consultant's inspection or delegated authority.
3. All laboratory tests must be performed in a third-party independent NATA accredited laboratory.
4. The required testing frequencies may be revised by the Superintendent to conform with improvements in testing methods and/or in the state of the art practice and/or to account for the criticality of the application (i.e. to account for the importance of the geocomposite drainage material for the stability of Works).

10 CQA Validation Report

On completion of the above CQA activities, a CQA Validation Report is to be prepared by the CQA Consultant in accordance with the requirements of the facility operating Licence, to demonstrate that all requirements of the project Drawings and Specifications and CQA Plan have been complied with.

The report is to include any variations from the construction Drawings and Specifications or the above CQA Plan and contain explanations of why the variations occurred and the potential impact on the construction Works.

The CQA Validation Report is to be provided to the DWER as part of the Compliance Certificate at the end of the landfill capping construction Works.

APPENDIX C: PHYTOCAP PERFORMANCE TRIAL FINAL REPORT (TONKIN)

20171422L02RevA_ Phytocap Final Report

21 January 2022

[redacted]

PHYTOCAP PERFORMANCE TRIAL FINAL REPORT

Background

Cleanaway operates the Banksia Road Landfill (the Site) at Lot 2 DP65861, Banksia Road, Crooked Brook, which is approximately 3 km south-east of Dardanup and 15 km south-east from Bunbury Western Australia. The landfill has been operational since 2000 and is currently licenced to accept Class 3 putrescible waste and liquid waste as per Department of Water and Environmental Regulation (DWER) licence number L8904/2015/1 (the Licence).

In 2015, Cleanaway contracted Tonkin Consulting to design a final cap for the western batter slope of the Site with consideration of a phytocap, which could use materials available on-site, some of which were already placed over Cell 5. Following intrusive field investigations and concept design, including water balance modelling and risk assessment, Tonkin Consulting recommended that a 2 m thick phytocap planted to native trees, shrubs and grasses as potentially suitable for the Banksia Road Landfill; however the design was highly sensitive to plant growth and water use and hence a trial was recommended to be undertaken as part of the final capping[1].

A trial plan[2] and detailed design[3] were prepared in 2016 to facilitate monitoring and construction of the phytocap trial. The trial objectives were stated as:

- Measure the water balance using a field-scale lysimeter. Measurements of rainfall, runoff, soil moisture storage and drainage are required to enable calculation of evapotranspiration (by difference);
- Compare the water balance and vegetative growth between the lysimeter and an adjacent area without the lysimeter (referred to as the vegetated pad), to ensure the results from the lysimeter are representative of the full-scale cap;
- Calibrate the water balance model to more accurately assess cap performance.

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[1] Tonkin. 2016. *Banksia Road Dardanup Landfill Capping Design Report*. Ref No 20155261R001 Rev A Dated 18 March 2016.
[2] Tonkin. 2016. *Banksia Road Dardanup Landfill Phytocap Trial Monitoring Plan*. Ref No 20155261R002 Rev B Dated 22 July 2016.
[3] Tonkin. 2016. *Banksia Road Dardanup Landfill*. Stage A and B Phytocap Technical Specification Ref No 2015526125001B Dated 29 August 2016.

The phytocap trial commenced construction in Spring 2018, with earthworks finished in October 2019, monitoring instruments installed from 19-22 March 2019 with planting following; further details are provided below. In 2021, Cleanaway advised Tonkin that they wished to terminate the phytocap trial. DWER has also updated the site licence following a recent review of on-site activities. "Section 20 Final Capping" of the Licence requires Cleanaway to prepare and submit an updated Rehabilitation and Closure Plan which includes (amongst other things):

(a) Details of the design and operation of the phytocap performance trial on Cell 5
(b) Results and recommendations from the phytocap performance trial on Cell 5

This letter report is prepared to provide the information requested on the phytocap trial performance. Dr Melissa Salt, Principal Scientist, visited the Site on 21/09/21 to view the trial site.

Trial Establishment

The trial area was location on the south facing batter of the completed Cell 5 . The trial consisted of a 20 m by 10 m, non-weighing lysimeter constructed of HDPE within a larger trial area with an upper surface area of 55 m by 70 m. The lysimeter pad details, as shown in Sheet 06 Lysimeter Details and Typical Sections (extracted from the detailed design), and an installation report are attached. Figure 1 presents photographs taken during installation.

Figure 1 Installation Photos showing Weather Station (top left), SM150T sensor installed at 0.4 m depth (top centre), runoff collection gutter (top right), location of sensors with lysimeter to the left (bottom left), downslope installation of runoff (left) and drainage (right) gauges (bottom right)

Monitoring sensors included:

- Weather station recording rainfall (gauge placed upslope of the weather station to prevent interference), temperature, wind speed and direction, relative humidity and solar radiation every 15 minutes
- 5 locations, 3 within the lysimeter and 2 outside the lysimeter, with SM150T capacitance probes, measuring the soil moisture content at 0.2 m, 0.4 m, 0.7 m, 1.0 m and 1.4 m below the surface. Sensors at 0.7 m, 1.0 m and 1.4 m depth were installed in adjacent auger holes whilst the 0.4 and 0.2 m sensors were installed in a trench (as shown below)
- Tipping bucket gauges for runoff (1 L resolution) and drainage (0.2 mm resolution) placed on a level concrete pad within a lockable, enclosed box

The trial area was initially hydroseeded (timber hydromulch) with native seed at a rate of 3 kg/ha using the species shown in Table 1. Plants were pre-treated where required to facilitate germination. Planting was planned to be completed in May 2019 but was delayed until July/August 2019. Rain from August to October was approximately 180 mm which is likely to have been sufficient to germinating plants but was not followed up with the necessary supplementary irrigation to establish the plants over the hot, dry summer and autumn. In May 2020, Cleanaway proposed to again hydromulch native seeds using a lighter polymer base to prevent damage to the timber hydromulch which had assisted in limited erosion of the soil surface. Due to availability of species in 2020, the ratio of species was varied and Wallaby Grass was also included in the seed mix.

Table 1 Native Plants Sown to Trial Area

Form	Scientific name	Common Name	Seed supplied (g)	
			2019	2020
Tree	*Allocasuarina fraseriana*	Sheoak	40	40
Tree	*Corymbia haematoxylon*	Mountain Marri	40	22
Tree	*Eucalyptus decipiens*	Redheart Moit	50	50
Tree	*Eucalyptus drummondii*	Drummond's Gum	40	40
Tree	*Eucalyptus patens*	Yarri	60	80
Shrub	*Acacia lasiocarpa var lasiocarpa*	Panjang	20	20
Shrub	*Acacia pulchella var glaberrima*	Prickly Moses	20	20
Shrub	*Acacia saligna*	Orange Wattle	350	364
Shrub	*Kunzea ericifolia (glabrescens)*	Spearwood	50	50
Shrub	*Kunzea micrantha*		250	250
Shrub	*Melaleuca preissiana*	Moonah	60	60
Shrub	*Melaleuca viminea*	Mohan	60	60
Shrub	*Pultenaea reticulata*		50	50
Forb	*Patersonia occidentalis*	Purple Flag	80	100

Form	Scientific name	Common Name	Seed supplied (g)	
			2019	2020
Grass-like	*Ficinia nodosa*	Knotted Club Rush	10	10
Grass-like	*Mesomelaena tetragona*	Semaphore Sedge	40	40
Grass	*Austrostipa compressa*	Compact Needlegrass	50	9
Grass	*Microlaena stipoides var stipoides*	Weeping Grass	50	50
Grass	*Rytidosperma caespitosum*	Wallaby Grass		5

Figure 2 Trial Area Lysimeter Pad in May 2020. Timber mulch has protected soil surface from erosion but no plants are evident. [Source: S, Carlton]

The seeds were supplied in June 2020 and applied to the site in July 2020. From August to September 2020 over 300 mm of rainfall was received providing good soil moisture for germination. During summer plants were irrigated using a hose from the water cart but records of volumes were not kept. During the site inspection in September 2021, some germination and growth of select species was observed (Figure 3); however coverage was patchy with increased growth in areas where water ponding was likely, e.g. above the top bund of the lysimeter. Noted

species were Prickly Moses, Mountain Marri, Redheart, Moonah and Kunzea along with some unidentified grass species. A number of weeds were also observed growing on the site.

Figure 3 Trial Area Lysimeter in September 2021 showing some germination of planted species.

Monitoring Data - Weather

The site weather station recorded data on 80% of days from 1/4/2019 until 30/4/2021. Comparison of the site recorded temperature with the long-term monthly minima and maxima used in the concept design water balance modelling shows the maximum temperature was similar to the long-term average whist the minimum temperatures were slightly higher on average (Figure 4). The rainfall reported on-site was similar to the nearby BOM station in 2019 but lack of maintenance resulted in reduced data accuracy in 2020 and 2021. Compared with the long-term average, the annual rainfall was lower than the long-term mean which appears to be mainly related to lower spring rainfall.

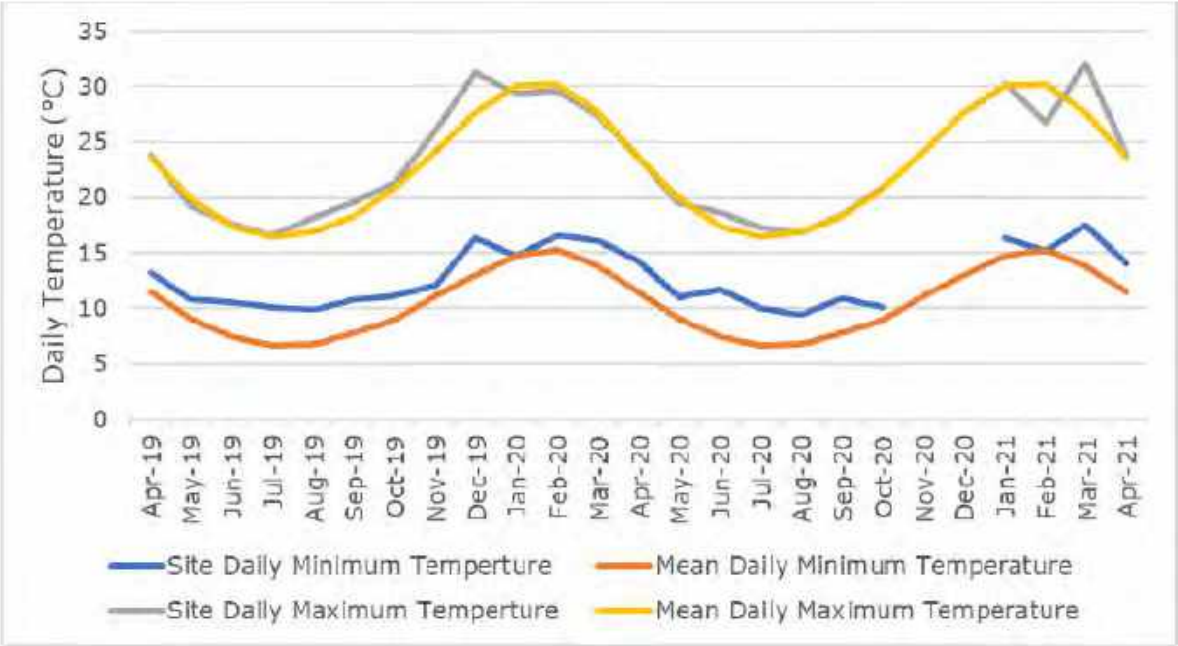


Figure 4 Daily Minimum and Maximum Temperatures over Recorded Period

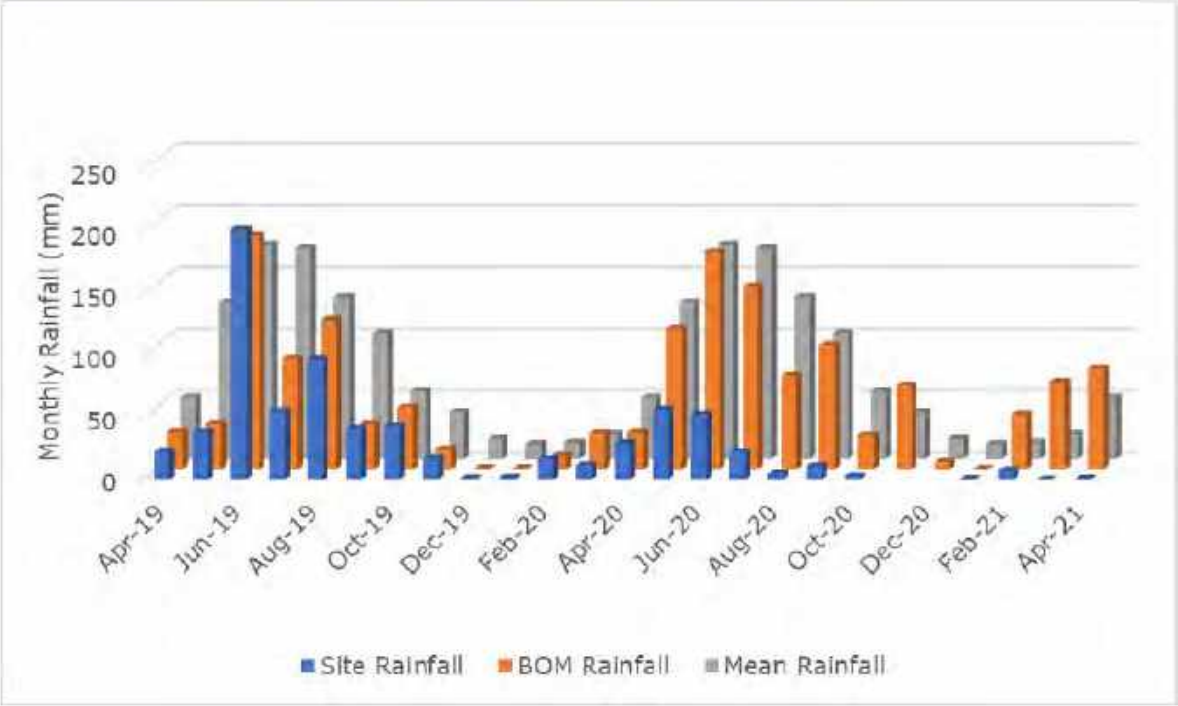


Figure 5 Monthly Rainfall Recorded at the Site Weather Station, Nearby BOM Station and Long-Term Mean

Overall, the temperature is unlikely to have impacted plant germination and establishment but the lower rainfall and lack of supplementary irrigation are likely to be the main cause for the failure of vegetation to establish on-site.

Monitoring Data – Soil Moisture

Soil moisture monitoring data were recorded from 25th March 2019 until 19 October 2020, with sensors beginning to fail at this time and only limited data available through to 1 May 2021 (Figure 6). The data show that moisture moves through the profile to over 1.4 m depth which is likely to result in drainage in both 2019 and 2020. The lack of plant growth is evident as the moisture content increases during winter but then only slowly decreases into summer with no transpiration occurring to reduce the surface moisture content. In summer, the lack of roots at depth in the profile to remove moisture and return the profile to full moisture storage capacity results in an increased potential for drainage in subsequent years.

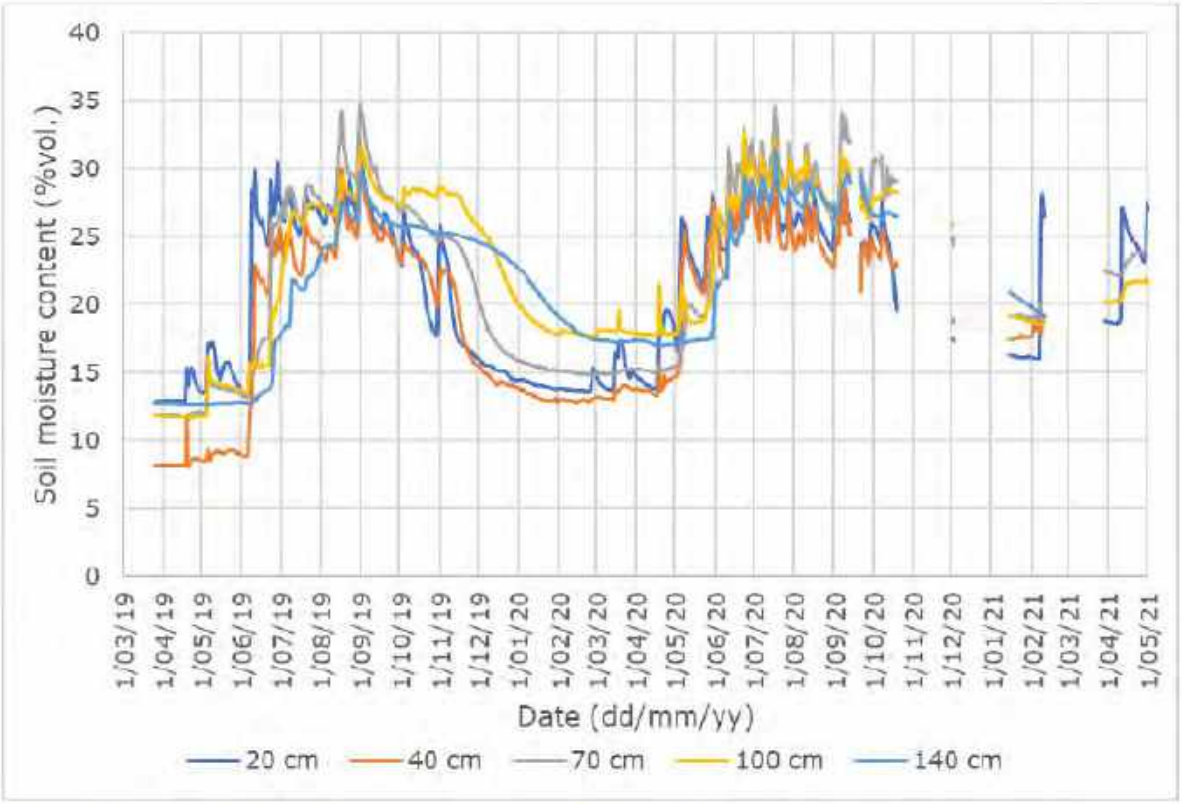


Figure 6 Average Daily Moisture Content for each Sensor Depth over Time

Monitoring Data – Runoff and Drainage

Runoff and drainage data were measured on site; however, it is noted there were a number of issues which result in these data being questionable, including:

- the cover which prevents rainfall entering the gauges was missing for a number of months;
- sediment accumulation in the gauge funnels blocked flow from being registered;
- interference from insects and frogs noted to be living in the housing.

Based on the soil moisture and the drainage data available, the drainage from this unvegetated site is greater than 50 mm/yr and unlikely to provide adequate performance. This demonstrates the importance of successful vegetation establishment.

Conclusions and Recommendations

The phytocap trial at Banksia Road was constructed in accordance with the technical specification but the establishment of plants did not occur. Native plants are slow to establish and require intensive maintenance to ensure their establishment. As a result of the highly erodible site-won soil which requires vegetation to be established quickly alternative approaches to revegetation would be required and would require a higher level of management and maintenance. It is understood that this does not meet Cleanaway's requirements for capping and hence phytocap is unlikely to provide a suitable capping solution for the Banksia Road Landfill.

To establish native vegetation successfully on this site the following will need to be undertaken:

- planting vegetation in late Autumn to maximise the time when adequate rainfall occurs;
- prepare the site prior to planting to maximise the potential for plants to establish, which may include ripping, ameliorants, fertiliser and cover crops;
- provide supplementary irrigation using standard irrigation equipment and not using spray carts;
- prepare a revegetation plan to detail the timing, type of planting maintenance and other important details over the first 3 years of the establishment;
- maintain the site in accordance with the plan or engage a contractor to undertake the maintenance.

Although a phytocap may not be suitable for Cleanaway's purposes, many mining projects in the region have demonstrated that with management and persistence, native vegetation can be established on highly disturbed sites.

If you have any queries, please contact the undersigned.

Yours sincerely,

Dr Melissa Salt

Principal Scientist

Tonkin

Enc

1. Tonkin. 2019. *Banksia Road Landfill As Constructed Reporting – Monitoring Equipment Installation Addendum*. Ref 20171422L01A Dated 12/04/19. Tonkin Consulting, Adelaide SA.
2. Tonkin. 2016. *Banksia Road Landfill Capping Stage A&B Capping Design Lysimeter Details and Typical Sections*. *Sheet 06.* Revision 2 Dated 22/08/16. Tonkin Consulting, Adelaide SA.

20171422L01A_Instrument Install Addendum

12 April 2019

Cleanaway
Banksia Road
Dardanup, WA, 6236

[redacted]

[redacted]

BANKSIA ROAD LANDFILL AS CONSTRUCTED REPORTING - MONITORING EQUIPMENT INSTALLATION ADDENDUM

Monitoring sensors were installed at Cleanaway's Banksia Rd Dardanup Landfill between 20-23 March 2019. A schematic of the monitoring locations is attached as are installation photos.

Weather Station

The Junior Weather station has been installed upslope of the lysimeter with the galvanised post installed 60 cm below the surface and reinforced with a concrete collar. The solar panel is facing north. The rainfall gauge has been placed approx. 10 m upslope of the weather station and dynabolted to a level concrete paver with excess cable stored in the split conduit. Cables to Field Station 1 and Field Station 4 are attached to the post and excess cable stored below the screened housing.

A summary of sensors installed is shown in Table 1. Sensors noted as requiring routine maintenance will be added to the routine checklist (see attached).

Table 1 Weather Station Sensors

Weather Station	Installed	Working as at 12/	Routine Maintenance required	
Solar Panel	✓	Yes	Yes	Panel clean and facing north
Rainfall	✓	0.2 mm 11/4	Yes	Funnel clean
Temperature	✓	Yes	No	
Relative humidity	✓	Yes	No	
Wind Speed	✓	Yes	No	
Wind direction	✓	Yes	No	
Solar Radiation	✓	Yes	Yes	Clear dome clean

Field stations and Sensors

Three field stations were installed adjacent to the lysimeter bund and moisture sensors placed within the lysimeter approximately 2-3 m east of the field station. Two field stations were installed

adjacent to the control area (nominally 5 m buffer west of lysimeter to control area) and moisture sensors placed 2-3 m west of the field stations. Field stations are connected via cables placed in split conduit.

All moisture sensors were installed by excavating a small pit to approximately 25 cm depth and then hand augering four holes (nominally 40 mm diameter) to the required depths of 140 cm, 100 cm, 70 cm and 40 cm below the surface. Sensors were installed by threading the cable through 20 mm rigid conduit and then pressing the sensor vertically into the soil. The final sensor was placed horizontally at 20 cm into the wall of the pit. All cables were placed in conduit and then buried. Excess cable was buried in the pit.

The large tipping bucket gauge (TB1L) measuring runoff and small tipping bucket gauge (TB6) have been installed in the small housing approximately 20 m downslope of the lysimeter. Both gauges have been levelled and dynabolted to a concrete paver as far as practically allowed. Cables have been placed in split conduit and are connected Field Station 3. A plastic storage box has been used to house the tipping bucket gauges to prevent rainfall from entering. A padlock has been used to secure the storage contained with the code 236 (i.e. the last 3 letters of the Dardanup postcode).

A summary of sensors installed is shown in Table 2. Sensors noted as requiring routine maintenance will be added to the routine checklist with instructions.

Table 2 Field Stations and Sensors

ID	Location	Channel	Sensor	Working as at 12/4	Routine Maintenance required
1	Lysimeter upslope	1	SM150T @ 20 cm	Yes	No
		2	SM150T @ 40cm	Yes	No
		3	SM150T @ 70 cm	Yes	No
		4	SM150T @ 100 cm	Yes	No
		5	SM150T @ 140 cm	Yes	No
2	Lysimeter midslope	1	SM150T @ 20 cm	Yes	No
		2	SM150T @ 40cm	Yes	No
		3	SM150T @ 70 cm	Yes	No
		4	SM150T @ 100 cm	Yes	No
		5	SM150T @ 140 cm	Yes	No
3	Lysimeter downslope	1	SM150T @ 20 cm	Yes	No
		2	SM150T @ 40cm	Yes	No
		3	SM150T @ 70 cm	Yes	No

ID	Location	Channel	Sensor	Working as at 12/4	Routine Maintenance required	
		4	SM150T @ 100 cm	Yes	No	
		5	SM150T @ 140 cm	Yes	No	
		7	Drainage (TB6; small gauge)	Yes	Yes	Funnel and buckets clean
		8	Runoff (TB1L; large gauge)	Yes	Yes	Funnel and buckets clean
4	Control upslope	1	SM150T @ 20 cm	Yes	No	
		2	SM150T @ 40cm	Yes	No	
		3	SM150T @ 70 cm	Yes	No	
		4	SM150T @ 100 cm	Yes	No	
		5	SM150T @ 140 cm	Yes	No	
5	Control downslope	1	SM150T @ 20 cm	Yes	No	
		2	SM150T @ 40cm	Yes	No	
		3	SM150T @ 70 cm	Yes	No	
		4	SM150T @ 100 cm	Yes	No	
		5	SM150T @ 140 cm	Yes	No	

Routine Monitoring

Routine monitoring should be undertaken on a weekly to fortnightly basis or as required. The routine monitoring and instructions are attached.

Yours sincerely,

[redacted]

Enc Plates – Monitoring equipment installation and proposed photo points

Banksia Road Landfill Routine Inspection of Monitoring Equipment Checklist

cc [redacted]

Attachment 1 – Monitoring Equipment Installation and Proposed Photo Points

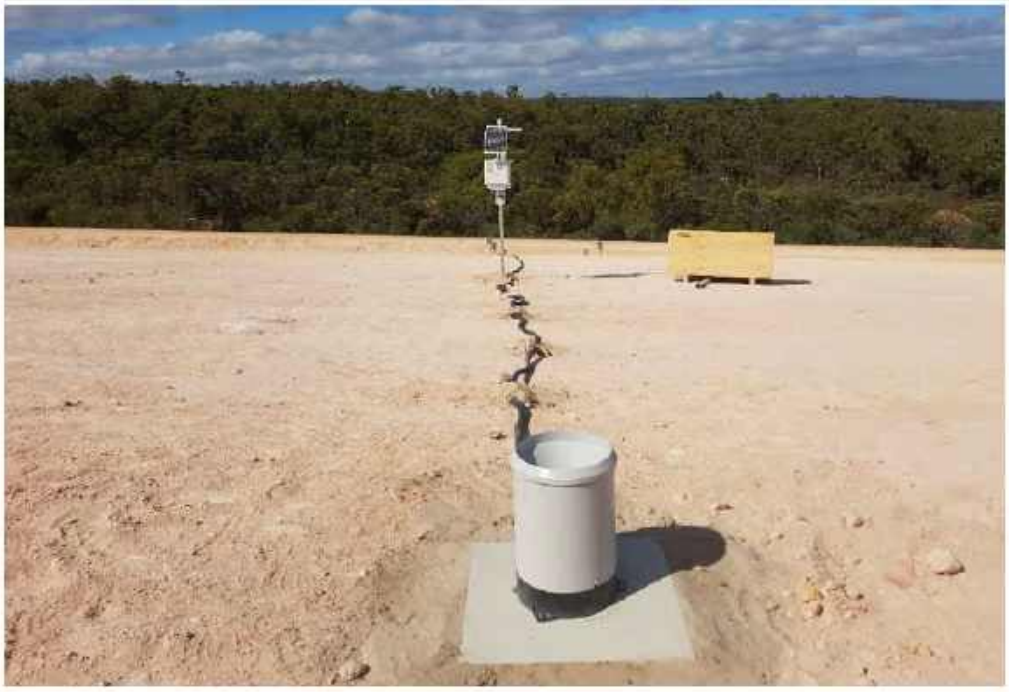


Plate 1 Site looking south showing rainfall gauge at top of slope and weather station. Bunds of lysimeter visible middle left

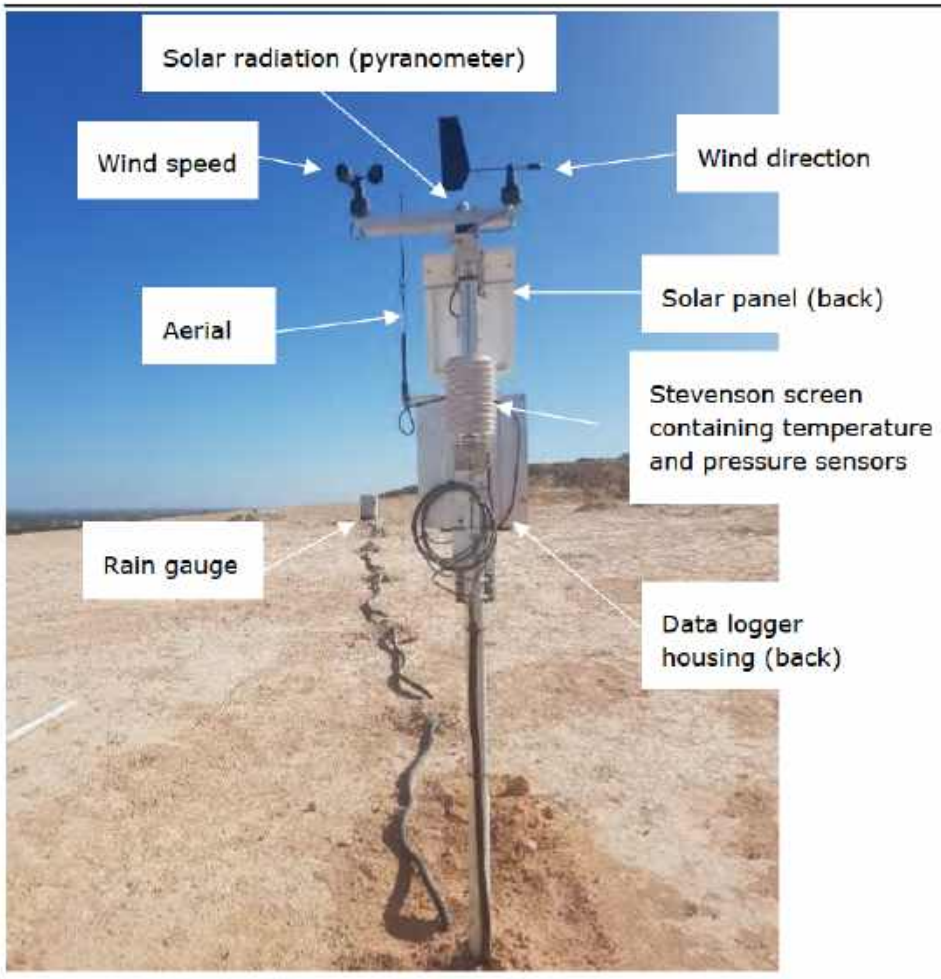


Plate 2 Site looking north showing weather station in foreground and rainfall gauge at top of slope

Plate 3 Proposed photo point 1. Standing at rainfall gauge looking south.

Plate 4 Proposed Photo Point 2. Standing at north-western corner of lysimeter. Five field station locations and conduit to monitoring nests shown

Plate 5 Field Station 2. Channels 1-5 contain moisture sensors with Channel 1 with shallowest senor and Channel 5 deepest sensor

Plate 6 Sensors installed using a narrow hand auger after excavating a shallow trench

Plate 7 Shallow trench showing backfilled deeper sensors (installed vertically) and the shallow sensor at 20 cm installed horizontally in trench wall

Plate 8 Runoff gauge (left) and drainage gauge (right) installed in storage tub downslope of lysimeter

Attachment 2 – Banksia Road Landfill Routine Inspection of Monitoring Equipment Checklist

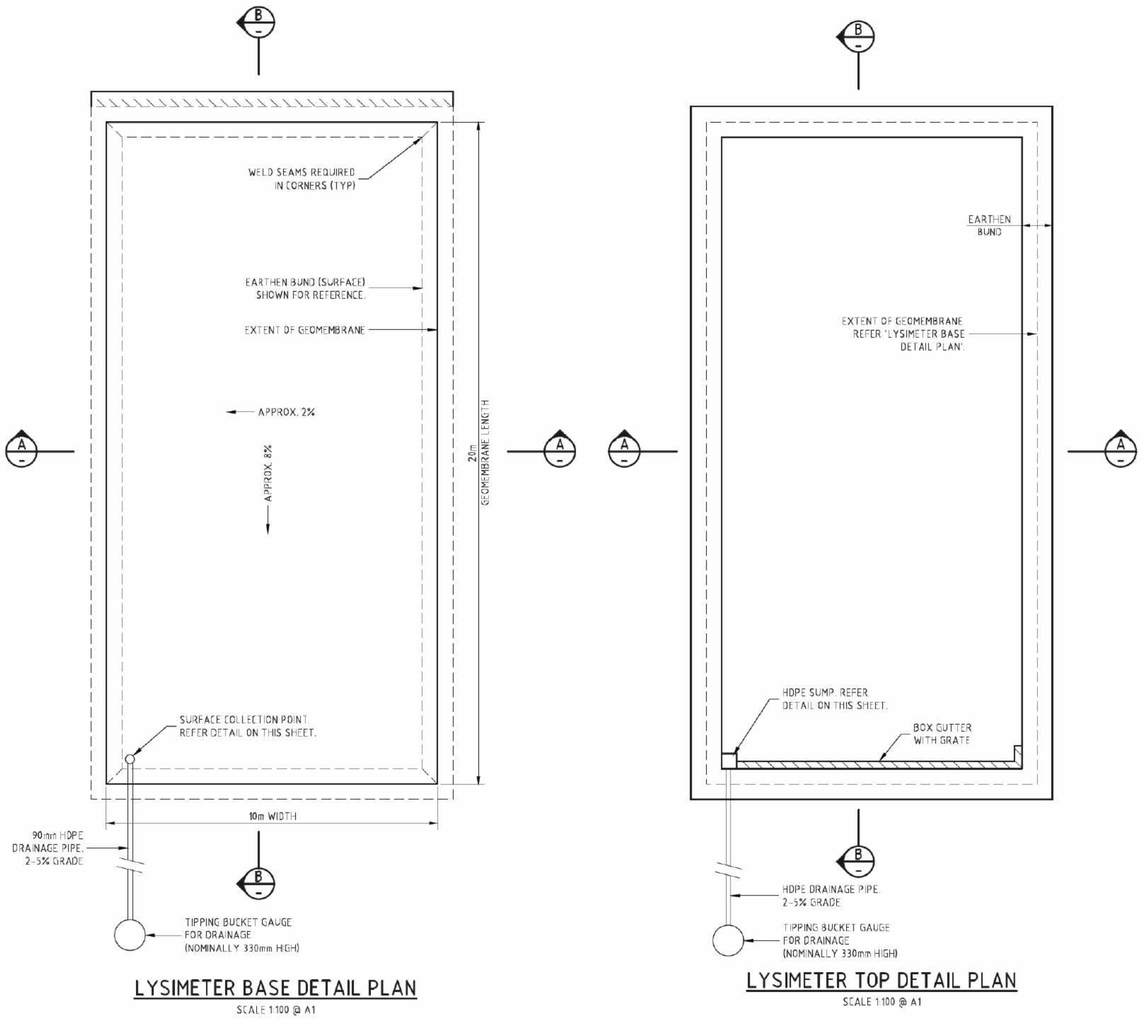
Banksia Road Landfill Routine Inspection of Monitoring Equipment

Sensor	Clean?	Notes
Rain gauge 		Dry brush if possible. If needs water, remove housing first to prevent buckets tipping
Solar Panel & Pyranometer  		Use a soft cloth and water
Runoff gauge 		CODE for BOX is 236 Dry brush to remove blockages
Drainage gauge  		Dry brush if possible. Remove housing to clean. Wash with CLR if really dirty. Try not to tip buckets whilst cleaning but note here how many tips if occurs

Name: ..... Signature: .....

Date: .....

ANY PROBLEMS PHONE [redacted] Please email completed form to [redacted]

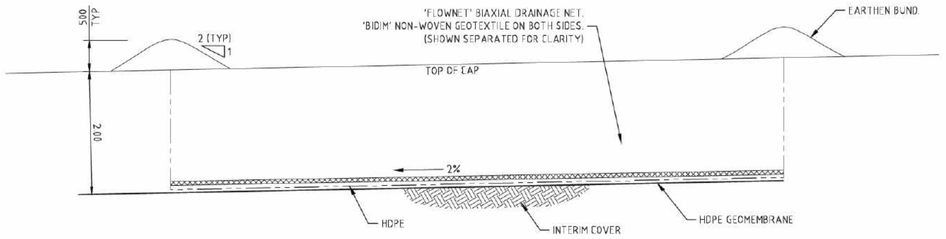


LYSIMETER BASE DETAIL PLAN

SCALE 1:100 @ A1

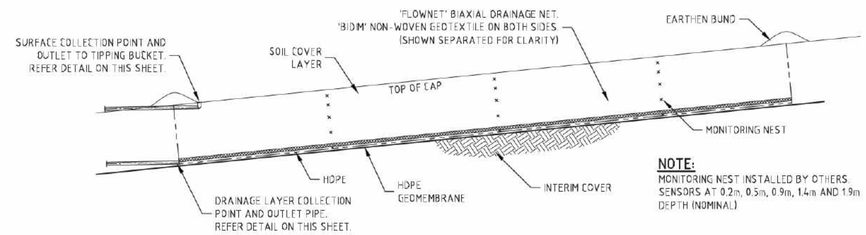
LYSIMETER TOP DETAIL PLAN

SCALE 1:100 @ A1



SECTION A

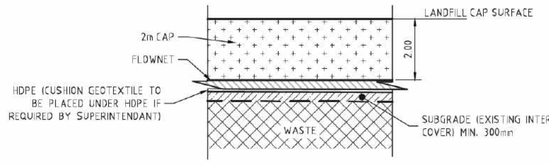
SCALE 1:50 @A1



NOTE:
MONITORING NEST INSTALLED BY OTHERS. SENSORS AT 0.2m, 0.5m, 0.9m, 1.4m AND 1.9m DEPTH (NOMINAL)

SECTION B

SCALE 1:100 @A1

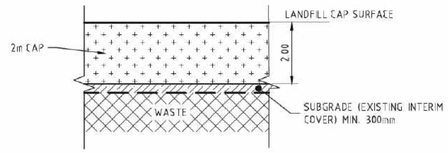


LYSIMETER PROFILE

SCALE 1:100

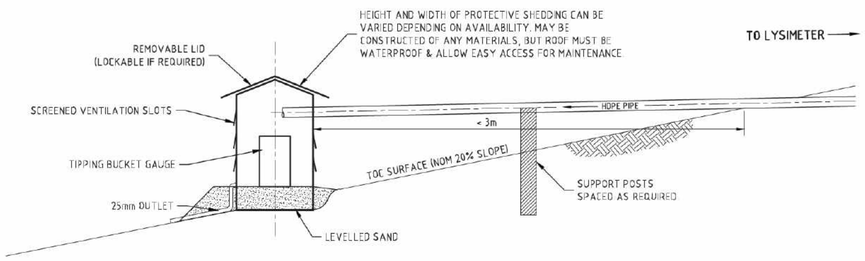
NOTE:

- CUSHION GEOTEXTILE MAY BE REQUIRED UNDER HDPE IF SUBGRADE IS NOT ROCK FREE AS DIRECTED BY SUPERINTENDENT.



VEGETATED PAD PROFILE

SCALE 1:100



TIPPING BUCKET TYPICAL SECTION

SCALE 1:20 @ A1

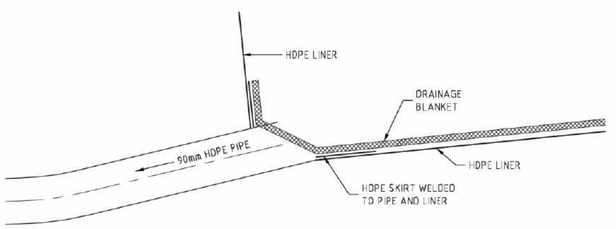
NOTE:
PROTECTIVE SHEDDING AND GAUGE TO BE INSTALLED BY OTHERS

0 0.1 0.2 0.3 0.4 0.5 Metres
SCALE 1:5

0 0.5 1.0 1.5 2.0 Metres
SCALE 1:20

1.0 0.5 0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 Metres
SCALE 1:50

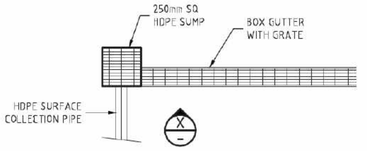
1 0 1 2 3 4 5 6 7 8 9 Metres
SCALE 1:100



BASE COLLECTION POINT ENLARGEMENT DETAIL

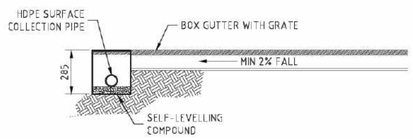
SCALE 1:5 @ A1

NOTE:
DETAIL SHOWN WITH EXAGGERATED COMPONENTS FOR CLARITY



SURFACE COLLECTION POINT PLAN

SCALE 1:20 @ A1



SURFACE COLLECTION POINT VIEW X

SCALE 1:20 @ A1

REV	AMENDMENT / REASON FOR ISSUE	DATE	DES.	DWN.	DWGCHK.	VERIFIED	APPROVED
2	ISSUED FOR DER APPROVAL	22.08.16	M.S./A.W.	P.Sm.			
1	ISSUED FOR COMMENT		M.S./A.W.	P.Sm			

NOTES:

100mm ON ORIGINAL DRAWING - DO NOT SCALE DRAWING

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- ELECTRICAL, MECHANICAL AND AUTOMOTIVE

SHEET SIZE	A1
SCALE:	AS SHOWN
ORIGINAL SURVEY BY	AUSTRALIAN UAV
SURVEY DATE:	17.06.16
COORDS & DATUM	COORDINATES TO (GDA94) ALL LEVELS TO Mahd

CLEANAWAY WASTE MANAGEMENT LTD.

BANKSIA ROAD LANDFILL CAPPING
STAGES A & B CAPPING DESIGN
LYSIMETER DETAILS & TYPICAL SECTIONS

FILENAME:	JOB NUMBER	SHEET NUMBER	REVISION
20155261_BANKSIA CAPPING PLAN.DWG	20155261	06	2

C:\USERS\BRADLEY.ROLSTER\APPDATA\LOCAL\TEMP\ACPUBLISH_13764\20155261_BANKSIA CAPPING PLAN.DWG | 06 LYSIMETER DETAILS | 29-Aug-2016 - 10:44am

APPENDIX D: LANDSCAPING PLAN (TONKIN)

Banksia Road Landfill Rehabilitation and Closure Plan

Appendix D - Landscaping Plan

Cleanaway Waste Management

29 August 2022
Ref: 201515R003

tonkin

Building exceptional outcomes together

Document History and Status

Rev	Description	Author	Reviewed	Approved	Date
A	For Client Comment	[redacted]			11/09/2020
B	For Client Comment				29/09/2020
0	For Issue				01/10/2020
1	Updated for CWY Comments				09/11/2020
2	Updated for Shire submission in response to third party review				22/01/2021
3	Minor updates to document Updated for Shire submission in response to third party review				5/02/2021
4	Updated Figure 2				10/02/2021
5	Minor update to document P3 TOW contour details				10/09/2021
6	Update for Phytocap Report by Tonkin Jan 2022				31/01/2022
7	Update to Appendix A Species List				29/08/2022

Contents

Project: Banksia Road Landfill Rehabilitation and Closure Plan | Appendix D - Landscaping Plan
Client: Cleanaway Waste Management
Ref: 201515R003

Tables

Figures

Appendices

Figures

Appendix A – Standard Species List

Appendix B – South West Region Threatened And Priority Flora List (5 December 2018) for Whicher Scarp and Dardanup

1 Introduction

Tonkin was engaged by Cleanaway Waste Management to prepare a Landscaping Plan (the Plan) for the Dardanup Landfill (Landfill). The site is located in the Shire of Dardanup local government area. Department of Water and Environmental Regulation (DWER) Licence 8904/2015/1 incorporates Lot 2 on Plan 65861, Banksia Road, Crooked Brook WA.

1.1 Aims and Objectives

The Plan aims to provide a clear, concise and practical framework for the landscaping of the final landform of the Landfill, in accordance with the requirements of the *DWER Revegetation Guideline* (DWER, 2018) and the *Rehabilitation and Closure Plan* (Cleanaway, 2022) for the site. The final landform and landscaping are intended to facilitate a final land use as passive open recreational space.

The objectives of the Landscaping Plan are to:

- determine local vegetation characteristics;
- describe the landscaping activities necessary to restore the native vegetation;
- describe the maintenance program to ensure establishment;
- utilise cost efficient restoration techniques;
- restore the Landfill in a manner which minimises management costs in perpetuity; and
- provide an indication of the costing for the landscaping work.

1.2 Relationship with Existing Reports

The Plan has taken into consideration the impacts of the following documentation:

- Rehabilitation and Closure Plan, Updated V6 (Cleanaway, 2022).
- Rehabilitation Staging Plan (Drawing F001 Rev B, Cleanaway, 2022).
- Phytocap Performance Trial Final Report (ref:20171422L02RevA, Tonkin 2022)
- Capping Design Report (ref: 201515R001Rev2, Tonkin, 2020);
- Southern Boundary Vegetation Buffer Plan (Cleanaway, 2016);
- Stormwater Management Plan (Golder, 2020)

All work to be performed on site will be in accordance with the following guidelines, or updated versions thereafter:

- Florabank Guideline Series
- Regional forest Agreement for the South-West Forest Region of Western Australia 1999.
- Fire Management Strategy (DPaW, 2019)
- A Revegetation Guide for Eucalypt Woodlands (DWEWPC, Greening Australia and Landcare, undated).

1.3 Relevant Legislation

The Plan has been prepared in accordance with the provisions contained in relevant legislation and policy guidelines, including but not limited to the following:

- *Biodiversity Conservation Act 2016* (WA) provides protection for biodiversity, including threatened species and ecological communities and critical habitat;

- *Bush Fires Act 1954* (WA) provides for prevention control and extinguishment of bush fires and diminishing bush fire danger for the public.
- *Conservation and Land Management Act 1984* (WA) provides for the management of land for native vegetation conservation purposes;
- *Environment Protection Act 1986* (WA) provides for the establishment of environment protection policies, regulation of clearing for development and definition of prescribed premises, works, approvals and licences
- *Environment Protection and Biodiversity Conservation Act 1999* (Cth) provide protection of the environment on matters of national significance and identifies species and communities which are under threat;
- *Soil and Land Conservation Act 1945* (WA) provides for the conservation of soil and land resources to mitigate the effects of erosion, salinity and flooding and includes the management of native vegetation to conserve land;

2 Description of Proposed Development

This section provides a general description of the proposed development based on discussions with Cleanaway and the existing report listed in Section 1.2

The site operates in accordance with the Licence L8904/2015/1 issued by DWER. Cleanaway proposes to continue landfilling the Dardanup Landfill site to the approved DWER top of waste height contour with capping design and settlement allowances in addition to this. Landfilling rates are not expected to differ substantially from current levels. Site operations require the ongoing use of site facilities including stormwater management infrastructure. Refer to Section 2 of the *Capping Design Report* for additional site setting and background information.

The final landform for the site has been designed to account for the following considerations:

- Providing a long-term stable barrier between waste and the environment
- Providing land suitable for its intended after use.

2.1 Landfill Capping System

The landfill capping will be constructed in accordance with Section 2 of the *Rehabilitation and Closure Plan* which nominates a geosynthetic capping system including (from bottom to top):

- min 500mm Daily cover layer;
- geosynthetic clay layer (GCL);
- linear low-density polyethylene (LLDPE);
- geo-composite drainage layer
- 1.3-1.5m growing medium planted to appropriate vegetation (grasses and/or small shrubs).

In 2019, a phytocap trial was constructed on a portion of Cell 5 using 2 m of locally available soil planted to endemic trees, shrubs and grasses. The *Phytocap Performance Trial Final Report* concluded "*The phytocap trial at Banksia Road was constructed in accordance with the technical specification but the establishment of plants did not occur. Native plants are slow to establish and require intensive maintenance to ensure their establishment. As a result of the highly erodible site-won soil which requires vegetation to be established quickly alternative approaches to revegetation would be required and would require a higher level of management and maintenance*". This did not meet Cleanaway's requirements for capping so a phytocap was deemed unlikely to provide a suitable capping solution for Banksia Road and a geosynthetic cap option has been selected.

2.2 Surface Water

An extensive infrastructure system has been installed / maintained to manage stormwater runoff from and across the site incorporating the following:

- Two stormwater ponds;
- A network of vegetated swales, stormwater drains, channels and bunds;
- Secondary underground drainage on the side of the Southern Haul Road via pit and pipe systems;
- Maintained surface grades to prevent ponding of surface water.

The system relies on the principle of preventing 'run-on' to active areas and runoff from active areas and the separation of clean and 'dirty' runoff throughout the site. The Stormwater Management Plan for the site details the stormwater management practices at the site and the design of the above infrastructure.

3 Landscaping Plan

The following information provides an assessment of the opportunities and constraints at the site in relation to landscaping and a detailed description of all activities required to implement the Landscaping Plan. The opportunities have been developed using desk top research or existing reports relevant to the site, current vegetation maps and restoration guidelines, previous field investigations and liaison with Cleanaway.

3.1 Site Opportunities and Constraints

The restoration of such a large area provides numerous opportunities and constraints. To ensure the success of the project it is important to identify these prior to developing a design or undertaking any works.

3.1.1 Opportunities

The opportunities that this project provides include:

- Restoring a large area of native vegetation/habitat;
- Providing valuable bird habitat through the mass installation of native shrubs;
- Linking with local habitat corridors;
- Improving aesthetics of the area;
- Providing a passive recreation area for local residents;
- Utilising 'best practice' vegetation restoration techniques;
- Integrating ecological function and engineering design to achieve balanced landscape outcomes; and
- Improving water quality at the site;
- Providing future use areas for activities such as active recreation (e.g. courts, playing fields), shed-based commercial industries (e.g. farm supplies) or on-going waste related activities (e.g. energy from waste plant, material recovery and recycling facility).

3.1.2 Constraints

Constraints to be considered during project design include:

- Highly modified/artificial site conditions;
- Low summer rainfall;
- Erodible natural soil;
- Depleted natural seed source;
- Weed burden from green waste materials transported to site;
- Settling of landfill and production of landfill gas during early stages;
- Maintenance requirements of the landscaped area.

3.2 Restoration Zones

The Landfill site is divided into five distinct areas that require different vegetation management approaches. These areas are:

Zone 1 Infrastructure –an infrastructure zone near the landfill perimeter and includes access roads and tracks and stormwater drains and channels. No vegetation will be required in this area.

Zone 2 Grassland – a grassed area on the upper crest of the landfill and over the Tronox ponds to facilitate use of the site for passive recreation. Native gardens may be included in this space where the growing medium is of sufficient depth and include small trees and shrubs where the soil is of sufficient depth.

Zone 3 Native Woodland – The western batter slopes of the landfill will be planted to native shrubs and grasses to provide a visual screen and reduce the visual impact of the landfill topography by blending into the surrounding Dardanup Conservation Park vegetation.

Zone 4 Buffer – buffer zone around the landfill comprised of native vegetation, including trees, shrubs and groundcover species to link with adjacent Dardanup Conservation Park vegetation. This area is not over landfill.

Zone 4a Established– this area has already been planted to trees and has a grass understorey
Zone 4b Groundcovers – this area is along the batter slope of the leachate ponds. The pond wall provides a visual screen between adjacent forest and the landfill. Native grasses and forbs will be planted along this section.
Zone 4c Establishing – some native shrubs and small trees are present in this area; however additional planting is required to further improve the visual screen.
Zone 4d Proposed – requires planting of a range native vegetation to provide a link to the adjacent Dardanup Conservation Park.
Zone 4e Retained Native Vegetation – Remnant native vegetation in this area will be retained and protected.

These buffer zones are nominally 20 m wide except where restricted by the topography along portions of the southern boundary. These areas of narrower buffers are described in the *Southern Boundary Native Buffer Plan*:

- 12 metre to 21 metre for Eastern Half of Southern Boundary, and
- 5.5 metre to 11 metre for Western Half of Southern Boundary

Zone 5 Wetland - a wetland zone around the stormwater basins and leachate ponds, consisting of native shrubs and groundcovers. This area is not over landfill.

Figure 1 shows the location of the zones and Figure 2 is an impression of the final landscaped site. A species list for Zones with native vegetation is provided in Appendix A with selected photographs and a list of threatened or rare species for Whicher Range and Dardanup is included in Appendix B.

3.3 Seed Collection and Supply

Native seed and tube stock will be purchased from Revegetation Industry Association of WA (RIAWA) accredited seed collector and suppliers (riawa.com.au) and will be local provenance, where possible, for trees and shrubs. One potential supplier is Nindethana Seed Suppliers (part of Greening Australia (WA)) who are RIAWA accredited and located in Albany so able to supply local provenance seed and provided the seed for the phytocap trial (Table 1). To allow sufficient lead-in time for the propagation of provenance species, native plant orders must be placed prior to spring for sufficient stock to be available. The vegetation supplied should be consistent with those listed in Appendix A and Appendix B, noting species may be substituted as required and that native seed availability is highly variable. Where practical, threatened and rare plants should also be included. A list of these species for the Whicher Range and near Dardanup plants, as current on 5 December 2018, is presented in Appendix B.

Non-native grasses will be purchased from companies which meet the seed certification standards specified by the Australian Seed Federation. One potential supplier is PGG Wrightson Turf which supplies certified seed and is located in Perth and has previously provided ryegrass seed for stabilisation

of embankments (Table 1). They also can supply sterile grass seed which can be used as a cover crop prior to establishment of native seed.

Table 1 Contact Details for Potential WA-Accredited Vegetation Suppliers

Vegetation type	Supplier
Native seed and tubestock	[redacted]
Native tubestock (including installation)	
Non-native grasses	

3.4 Plant Propagation

Plant propagation refers to the germination of collection seed and the 'growing on' of plants in enviro cells, hiko cells or forestry tubes. This will be undertaken by a suitably qualified and experienced native plant production nursery.

3.5 Site Preparation

3.5.1 Site Protection

Once the bulk earthworks are complete and to ensure the success of plant establishment, it will be necessary to control access into the area. Machine access should be limited inside the landscaping zones other than for landscaping purposes and re-shaping areas of erosion or maintaining a free draining surface.

3.5.2 Erosion Control

At the completion of earthworks, appropriate sediment control fencing will be installed as specified in the detailed design for capping. Consideration will be given to alternative control structures, particularly those shown in "Best Practice Erosion and Sediment Control" (IECA, 2008).

Areas of high erosion potential may require the installation of jute matting or hydromulching. The Hydromulch "mixture" will include jute fibre and a mixture of pre-treated native seed. Experience has

shown that using a mixture of native peas and Acacia's in the hydro mulch is an inexpensive way to establish native vegetation at difficult sites.

3.5.3 Litter Removal

All litter from the site should be removed prior to the commencement of landscaping works.

3.5.4 Weed control

Being highly modified, the site is unlikely to contain significant weed seed loads at the completion of the bulk earthworks, other than those growing on existing batters. Inspection for and removal of any noxious weeds prior to any landscaping works should be undertaken. All weed control activities are to be completed by a suitably qualified contractor.

3.5.5 Installation of Irrigation System

Before revegetation activities commence an irrigation system, e.g. drippers or sprinklers, will be installed throughout Zones 2, 3, 4B, 4C and 5 (refer Figure 3) to assist in establishing vegetation. Once established the irrigation may be retained or removed. As far as practical, the system should be buried to prevent damage and is anticipated to be required for at least 3 years. Installation of an irrigation system helps ensure establishment targets are achieved.

3.6 Sowing/Planting Techniques

A combination of landscaping techniques should be employed in each of the zones to maximise the potential for good establishment of plants. Due to the different characteristics of each zone and the different type of vegetation to be established (as described in Section 3.2 and Appendix A), the landscaping techniques recommended for each zone are also different. The landscaping techniques to be used for each zone are summarised in Table 2 and described in more detail below.

Table 2 Sowing/Planting Technique for Each Zone

Technique	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Hydromulch	NR	✓	✓	✓	✓
Tube stock	NR	Garden beds	✓	✓	✓
Native seed	NR	✓	✓	✓	✓
Lawn seed	NR	✓			

NR – not required

3.6.1 Hydromulch

Hydromulch is the means by which mulch in the form of plant fibre can be placed onto topsoil using water as a carrier. Pre-treated seed, including native seed can be added to the mulch; native seed must be added with minimal agitation to minimise seed damage. Hydromulch encourages vegetation cover and provides protection against erosion. Initially, it is recommended that blends of the appropriate pre-treated native seed mix be added to the mulch and spread across the Zones. It is recommended that 2-3 kg/ha of seed be added to the mulch.

3.6.2 Tube Stock

Native tube stock may also be used across the Zones by hand planting across smaller areas (up to 10 ha). Machinery is available but is not currently recommended for tube stock. The recommended planting density for trees and shrubs for each zone is 1 per 10 m^2 with 5 m interrow spacings to achieve a recommended density of 1 per 20 m^2 when trees and shrubs are established. It is recommended that groundcovers are planted in the interrow at 4 per m^2.

Most plants will be planted as hiko or enviro cells. Each plant will have a surface mulch ring placed around its base and then protected using a tree guard, stabilised by stakes. This is to prevent herbivory and weed competition and to encourage optimum growing conditions.

In general, autumn is the best season for planting to reduce stress on young plants from high temperatures or frost. Planting in early spring can be effective provided a suitable watering regime is implemented; however, has higher risk of lower survival rates.

3.6.3 Seeders

Non-native grass and native seed, particularly native grasses, may be mechanically sown on-site. Modified air seeders with trailing harrows have been successfully used across large areas to provide a light cover to native seed. Seeders may be used in the inter-row of tree and shrub tube stock. It is recommended that 3-5 kg/ha of seed be used.

3.6.4 Hand Broadcasting of Seed

To supplement the establishment of vegetation, grass seed may be hand broadcast throughout the maintenance period of the landscaping program.

3.6.5 Fertiliser

Fertiliser will only be applied to native vegetation areas if required due to low nutrient conditions. Fertiliser for the native vegetation will be a low or no phosphorus fertiliser suitable for native vegetation and applied at low rates to minimise weed competition.

Fertiliser will be applied to the non-native grass areas to improve establishment as recommended by the seed supplier.

3.7 Maintenance Program

At the completion of the planting a 36-month maintenance program will commence. The maintenance program will optimise plant establishment and weed control. Activities will include watering, herbicide spraying, replacement planting and general maintenance. The aim of the maintenance program is to sustain:

- No bare patches > 4 m^2.

3.7.1 General Maintenance

Six-monthly general maintenance visits will be scheduled throughout the three - year maintenance period. These activities will include repairing and removing tree guards, monitoring survival and growth rates (see Section 3.8.3), installing replacement plants as required, weeding and continued follow-up spot spraying.

3.7.2 Watering

All plants will be ‘watered in’ on installation, with each plant receiving a minimum five litres. All plantings will receive a further three applications of water during the first 6 weeks to assist

establishment, depending on rain fall. Irrigation will be undertaken by drip or sprinkler irrigation or by hand watering, depending on the zone and resources available.

3.7.3 Weed Control

To ensure the success of the revegetation activities it is essential to control weeds. Weeds compete with the newly installed plants for nutrients and water thereby limiting their survival and growth rates. In Zones 2, weed control will include the removal of any emergent tree species to minimise the potential for roots to penetrate the landfill capping.

Weed spraying will be instigated as required from General Maintenance. All spraying will be carried out by suitably trained contractors.

3.8 Monitoring and Reporting

In order to accurately evaluate the success of the landscaping works, a monitoring and evaluation program will be put into place. The monitoring and reporting requirements are:

- An implementation report;
- Maintenance checklists;
- Vegetation assessment – Zones 3 and 4 only; and
- Landscape Report.

All reports should be prepared by suitably experienced and qualified consultants.

3.8.1 Implementation Report

When the landscape works are completed, an Implementation Report will be prepared as an addendum to the As Constructed Report prepared for final capping. These final capping reports will be completed following the construction of each stage of final capping as detailed in Table B of the *Rehabilitation and Closure Plan*. This report will provide written certification that:

- The individual or company that supplied seed/tube stock is suitably accredited;
- The landscape works have been implemented substantially in accordance with the approved plans. Minor variations to the approved plans, such as small changes in plant species and quantities, are acceptable subject to Cleanaway approval;
- The landscape works have been implemented in accordance with best practice industry standards; and
- A landscape maintenance program has been established.

3.8.2 Maintenance Checklists

As part of the General Maintenance program a checklist will be completed to record all measurements and observations.

3.8.3 Zone 3 and Zone 4 Vegetation Assessment

In Zones 3 and 4 only, vegetation assessment for survival and establishment will be undertaken at 6 monthly intervals after planting for the first 3 years and then annually until vegetation is fully established, which is anticipated to be around 10 years following planting.

The vegetation assessment involves:

- Zone 3 & 4: Visual assessment for tree and shrub death
- Zone 3 only: Assessment of ground cover using aerial survey to identify bare ground > 4 m^2

It is important for this assessment to be undertaken initially on a six-monthly basis to inform the maintenance program including, weed and pest management, replanting requirements and irrigation requirements.

3.8.4 Three Year Landscape Report

After three years, a landscape report will be prepared which details:

- Summarizes the maintenance undertaken;
- Analyses the survival, establishment and ground cover of vegetation
- Determines if vegetation has matured or whether any additional actions are required.

4 Program of Works

Landfill capping and the corresponding landscaping works will be undertaken in stages as described in Table B of the *Rehabilitation and Closure Plan*.

5 Costings

Approximate costs to complete the landscape plan are provided in Table 3. These costs are indicative only (+/- 40% at present value) and are provided for budgeting purposes only and should not be utilised for any other purpose. If required, a detailed cost estimate will need to be requested prior to commencing construction works on site.

Table 3 Estimated Costs for Revegetation Works

Task	Area (ha)	Estimated Cost	Basis
Seed - grass	58	[redacted]	
Seed - native	27		
Hydromulching	85		
Tubestock	6.5		
Planting	6.5		
Tree guards	6.5		
Fertiliser	93		
Irrigation	93		
Weed Control	93		
Replacement	93		
Project Management			
Monitoring and Reporting			
Total (ex. GST)			

6 References

Casson, N, Downes, S and Harris, A. 2009, *Native vegetation condition assessment and monitoring manual for Western Australia*. Department of Environment and Conservation, Western Australia

Cleanaway. 2020. *Banksia Road Landfill Rehabilitation and Closure Plan*. V2 Dated 15 September 2020. Bunbury, WA.

Department of the Environment and Energy. undated., *Australia's bioregions – Maps*. Australian Government. www.environment.gov.au/land/nrs/science/ibra/australias-bioregions-maps

DWER. 2018. *A Guide to Preparing Revegetation Plans for Clearing Permits*. Dated March 2018, Department of Water and Environmental Regulation, Perth, WA.

DSEWPC, Greening Australia and Landcare Australia. undated. *A Revegetation Guide for Eucalypt Woodlands*. Department of Sustainability, Environment, Water, Population and Communities.

Environmental Protection Authority. 2006. *Guidance for the assessment of environmental factors: rehabilitation of terrestrial ecosystems*. Guidance no. 6, EPA, Western Australia.

Golder Associates. 2020. Dardanup Landfill Stormwater Management Plan Updates, Revision 2, 15 September 2020, Ref: 19124751-001-M-Rev2.

Ironbank Environmental & Eco Logical Australia. 2009. *Shire of Dardanup Local Biodiversity Strategy Discussion Paper*. Dated May 2009

Keighery, G., Keighery, B., Gibson, N. undated. *Floristics of Reserves and Bushland Areas of the Whicher Scarp 1: Flora and Vegetation of Dardanup Forest Block*

Keighery, G., Keighery, B. Webb, A., Longman, V.M. and Griffin, E.A. 2008. *A Floristic Survey of the Whicher Scarp.* Department of Environment and Conservation and E.A. Griffin and Associates

Schirmer, J. and Field, J. 2000. *The Cost of Revegetation.* ANU Forestry and Greening Australia Dated January 2000

Tonkin 2022 *Phytocap Performance Trial Final Report*. Ref:20171422L02RevA Tonkin Consulting Adelaide ,SA.

Tonkin. 2020. *Capping Design Report.* Ref 201515R001Rev2. Tonkin Consulting, Adelaide, SA

Tonkin. 2016. *Phytocap Technical Specification*. Ref 20155261R002B. Tonkin Consulting, Adelaide SA.

Western Australia Herbarium. 2020. Florabase – the Western Australia Flora. Department of Biodiversity, Conservation and Attractions. https://florabase.dpaw.wa.gov.au accessed 29/09/20

Western Australian Planning Commission and Department for Planning and Infrastructure. 2007. *Visual Landscape Planning in Western Australia. A Manual for Evaluation, Assessment Siting and Design*. Western Australian Planning Commission, Perth WA

WMAA (2011). Guidelines for the Assessment, Design, Construction and Maintenance of Phytocaps as Final Covers for Landfills, Waste Management Association of Australia

Figures

Figure 1 Landscaping Plan

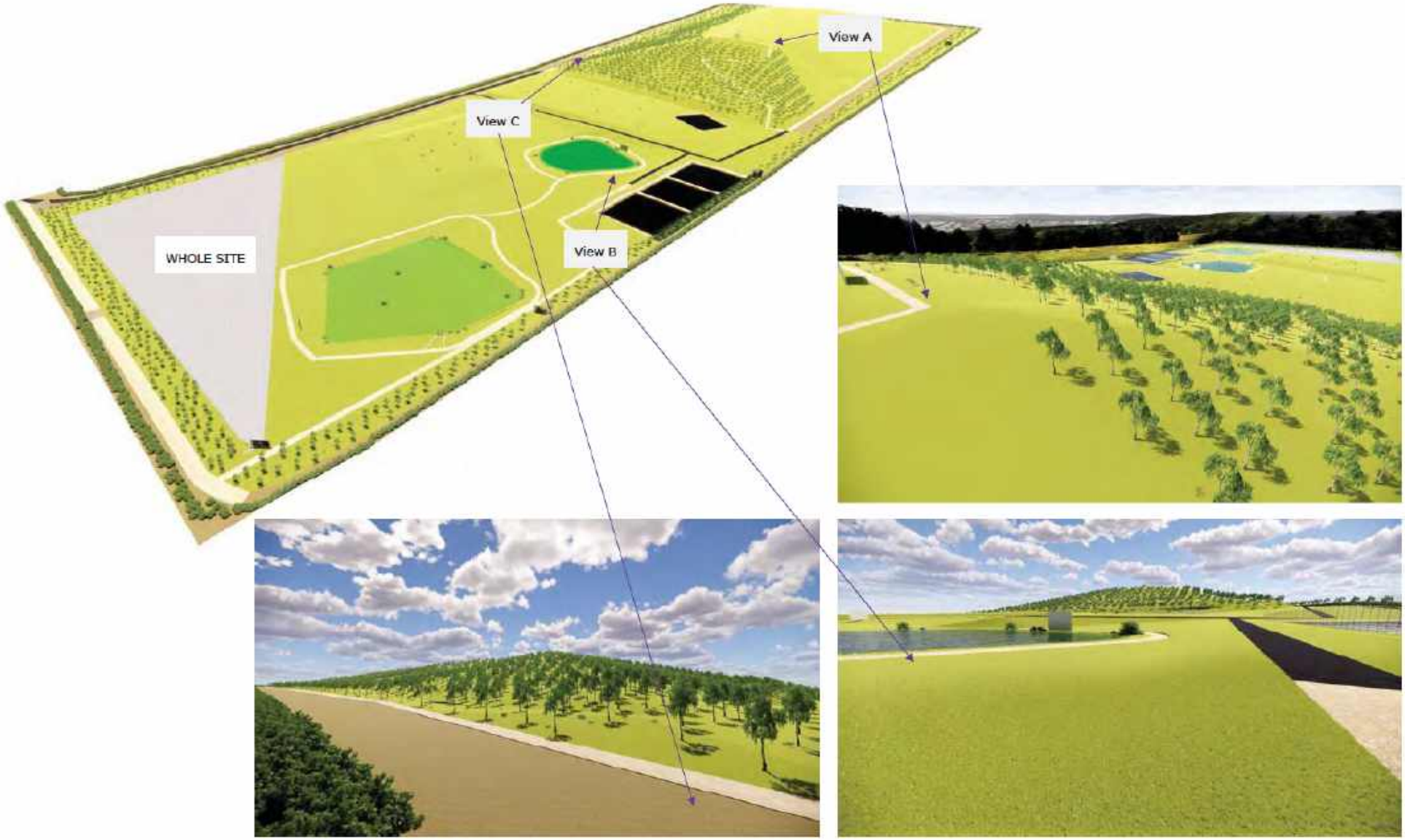


Figure 2 Isometric and Vantage Point Photos of Final Landscape

Appendix A – Standard Species List

It is expected that a selection of plants from the list following will be planted in the various zones. The selection of plants will be based on ensuring a variety of plants of different forms and Families are selected, with availability of supply expected to be the main limitation. Where appropriate, alternate species may be substituted to ensure variety. A current list of rare and threatened species is included as Appendix B and, where practical, some species should also be selected from this list, or as current at the time of planting.

Zone 2 Grassland – localised gardens may be created from any of the species listed below, depending on soil depth.

Zone 3 Native Woodland –a variety of native shrubs and grasses from the list below will be planted

Zone 4b Groundcovers –native grasses and forbs from the right-hand columns in the list below will be planted

Zone 4c Establishing –additional planting of native trees and shrubs from the left-hand column of the list below will be planted
Zone 4d Proposed – a variety of native trees, shrubs and grasses from the list below will be planted.
Zone 5 Wetland - native grasses and forbs from the right-hand columns in the list below will be planted with a predominance of rushes and sedges.

Native Trees and Shrubs		Zone	Native grasses and forbs		Zone
Species	Common Name		Species	Common Name	
Corymbia calophylla	Marri – Red Gum	4c, 4d	*Austrodanthonia spp*	Wallaby Grass	2,3,4,5
Eucalyptus decipiens	Redheart moit	4c, 4d	*Austrostipa compressa*	Compact needlegrass	2,3,4,5
Eucalyptus drummondii	Drummond's gum	4c, 4d	*Austrostipa semibarbata*	Bearded spear-grass	2,3,4,5
Corymbia haematoxylon	Mountain Marri	4c, 4d	*Ficinia nodosa*	Club rush	2,3,4,5
Eucalyptus marginata	Jarrah	4c, 4d	*Hypolaena exsulca*	Hypolaena	2,3,4,5
Eucalyptus megacarpa	Bullich	4c, 4d, poss. 5	*Lomandra nutans*	-	2,3,4,5
Eucalyptus patens	Blackbutt	4c, 4d	*Lomandra sericea*	Silky mat rush	2,3,4,5
Acacia flagelliformis	Wattle	3, 4c, 4d, 5	*Lyginia barbata*	-	2,3,4,5
Acacia lasiocarpa var lasiocarpa	Wattle	3, 4c, 4d, 5	*Mesomelaena tetragona*	Semaphore sedge	2,3,4,5
Acacia pulchella var glaberrima	Prickly moses	4c, 4d	*Microalaena stipoides var stipoides*	Weeping grass	2,3,4,5

Native Trees and Shrubs		Zone	Native grasses and forbs		Zone
Species	Common Name		Species	Common Name	
Acacia saligna	Golden Wreath Wattle	4c, 4d	*Patersonia occidentalis*	Swamp flag	2,3,4,5
Allocasuarina fraseriana	Sheoak	4c, 4d	*Patersonia umbrosa*	Purple flag	2,3,4,5
Banksia attenuata	Candlestick banksia	4c, 4d	*Themeda triandra*	Kangaroo grass	2,3,4,5
Banksia grandis	Bull Banksia	4c, 4d			
Banksia littoralis	Swamp Banksia	4c, 4d, 5			
Bossiaea eriocarpa	Common brown pea	3,4c, 4d, 5			
Daviesia physodes	Prickly Bitter Pea	3, 4c, 4d			
Hakea cyclocarpa	Ramshorn	4c, 4d			
Hakea ruscifolia	Candle Hakea	3, 4c, 4d			
Hakea undulata	Way leaf Hakea	4c, 4d, poss. 3			
Hibbertia hypericoides	Yellow buttercups	3, 4c, 4d			
Hibbertia subvaginata	-	3, 4c, 4d, 5			
Jacksonia horrida	-	3, 4c, 4d, 5			
Kunzea glabrescens	Spearwood	4c, 4d			
Kunzea micrantha	-	3, 4c, 4d, 5			
Leucopogon glabellus	-	3, 4c, 4d, 5			
Melaleuca preissiana	Stout Paperback	4c, 4d			
Melaleuca viminea	Mohan	4c, 4d			
Persoonia longifolia	Long-leaf Persoonia	4c, 4d			
Hemiphora bartlingii	Woolly Dragon	3, 4c, 4d			

Native Trees and Shrubs		Zone	Native grasses and forbs		Zone
Species	Common Name		Species	Common Name	
Podocarpus drouynianus	Wild Plum	4c, 4d			
Pultenaea reticulata	Bush Pea	3, 4c, 4d, 5			

Picture Source: Florabase.dpaw.wa.gov.au

Eucalyptus decipiens Endl. Redheart

Endl., Fenzl, Benth. & Schott, Enum.Pl. 49 (1837)

Conservation Code: Not threatened
Naturalised Status: Native to Western Australia
Name Status: Current

Eucalyptus marginata Sm. Jarrah

Trans.Linn.Soc.London 6:302 (1802)

Conservation Code: Not threatened
Naturalised Status: Native to Western Australia
Name Status: Current

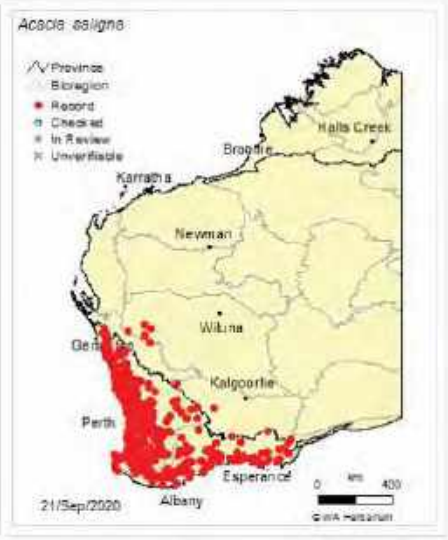
Acacia lasiocarpa Benth. var. *lasiocarpa*

Conservation Code: Not threatened
Naturalised Status: Mixed (Native in Part of Range, Naturalised Elsewhere)
Name Status: Current

Acacia saligna (Labill.) H.L.Wendl. Orange Wattle

Comm.Acac.Aphyll. 26-27 (1820)

Conservation Code: Not threatened
Naturalised Status: Native to Western Australia
Name Status: Current



Allocasuarina fraseriana (Miq.) L.A.S.Johnson Sheoak

J.Adelaide Bot.Gard. 6:75 (1982)

Conservation Code: Not threatened
Naturalised Status: Native to Western Australia
Name Status: Current

Hakea undulata R.Br. Wavy-leaved Hakea

Trans.Linn.Soc.London 10:185 (1810)

Conservation Code: Not threatened
Naturalised Status: Native to Western Australia
Name Status: Current

Kunzea micrantha Schauer

Lehm., Pl.Preiss. 1:125 (1844)

Conservation Code: Not threatened
Naturalised Status: Native to Western Australia
Name Status: Current

Melaleuca preissiana Schauer Moonah

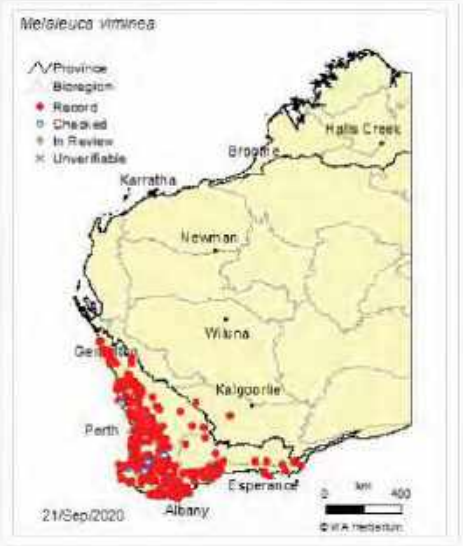
Lehm., Pl.Preiss. 1:143 (1844)

Conservation Code: Not threatened
Naturalised Status: Native to Western Australia
Name Status: Current

Melaleuca viminea Lindl. Mohan

Sketch Veg.Swan R. 8 (1839)

Conservation Code: Not threatened
Naturalised Status: Native to Western Australia
Name Status: Current



Pultenaea reticulata (Sm.) Benth.

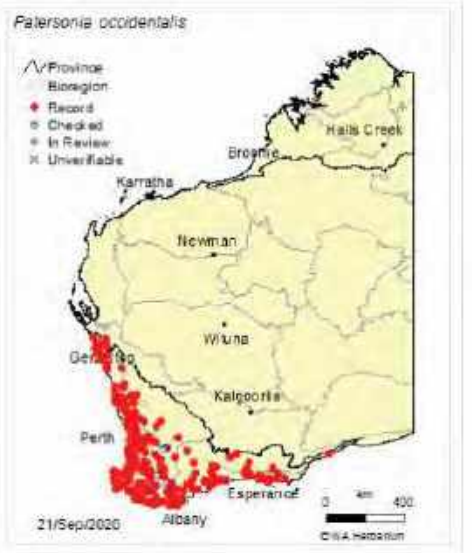
Fl.Austral. 2:119-120 (1864)

Conservation Code: Not threatened
Naturalised Status: Native to Western Australia
Name Status: Current

Patersonia occidentalis R.Br. Purple Flag

Prodr. 304 (1810)

Conservation Code: Not threatened
Naturalised Status: Native to Western Australia
Name Status: Current



Ficinia nodosa (Rottb.) Goetgh., Muasya & D.A.Simpson Knotted Club Rush

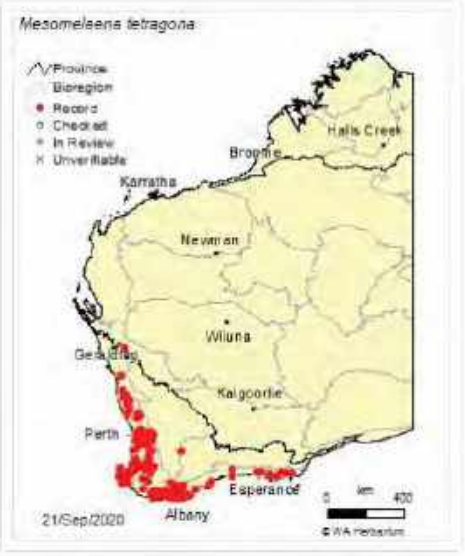
Novon 10:133 (2000)

Conservation Code: Not threatened
Naturalised Status: Native to Western Australia
Name Status: Current

Mesomelaena tetragona (R.Br.) Benth. Semaphore Sedge

Fl.Austral. 7:379-380 (1878)

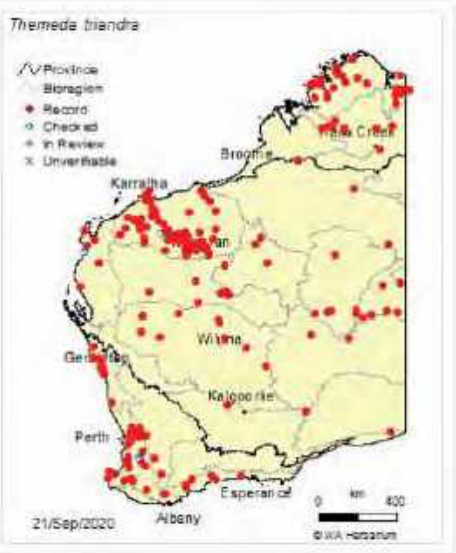
Conservation Code: Not threatened
Naturalised Status: Native to Western Australia
Name Status: Current



Themeda triandra Forssk.

Fl.Aegypt.-Arab. 178 (1775)

Conservation Code: Not threatened
Naturalised Status: Native to Western Australia
Name Status: Current



Appendix B – South West Region Threatened And Priority Flora List (5 December 2018) for Whicher Scarp and Dardanup

Source: https://www.dpaw.wa.gov.au/plants-and-animals/threatened-species-and-communities/threatened-plants

NameID	Taxon	Status	Rank	IUCN Criteria	EPBC	DPaW Region	DPaW District	Distribution	Flowering Period	Recovery Plan
19258	Actinotus whicheranus	2				SWST	BLACKWOOD	Whicher Range		
4586	Amperea micrantha	2				SWAN, SWST	BLACKWOOD, PERTH HILLS	Mokine, Yoongarillup, Busselton, Capel, Whicher Range, Ruabon NR	Sep-Oct	
6303	Andersonia barbata	2				SWST, WARR	BLACKWOOD, DONNELLY	Busselton, Whicher Range, Nannup, Windy Harbour	Aug-Nov	
18102	Andersonia ferricola	1				SWST	BLACKWOOD	Whicher Range, Hithergreen		
6315	Andersonia longifolia	2				SWST	BLACKWOOD	Whicher Range, Blackwood River N.P.	Aug, Oct	
32211	Banksia mimica	T	VU	D1	EN	MWST, SWAN, SWST, WHTB	BLACKWOOD, MOORA, PERTH HILLS, SWAN COASTAL, CENTRAL WHEATBELT	Whicher Range, Kalamunda, Mogumber, Gingin	Dec-Jan	
32204	Banksia nivea subsp. uliginosa	T	EN	A2c	EN	SWST	BLACKWOOD	Whicher Range, Scott River, Tutunup	Aug-Sep	IRP
32046	Banksia squarrosa subsp. argillacea	T	VU	B1ab(iii)+2ab(iii); C1	VU	SWST	BLACKWOOD	Ruabon, Tutunup, Whicher Range, Upper Capel	Jul-Aug	IRP
17804	Boronia tetragona	3				SWST	BLACKWOOD	Capel, Busselton, Whicher Range, Cowaramup	Oct-Dec	
35796	Calothamnus quadrifidus subsp. teretifolius	4				SWST	BLACKWOOD	Whicher Range		
759	Carex tereticaulis	3				SWAN, SWST, WARR	BLACKWOOD, DONNELLY, SWAN COASTAL, WELLINGTON	Dardanup, Bridgetown, Blackwood River, Guildford, (Harvey), Mungalip	Nov,Feb	
35657	Chamelaucium sp. Yoongarillup (G.J. Keighery 3635)	4				SWST	BLACKWOOD	Whicher Range, S of Busselton, Yoongarillup	Nov-Jan	
34765	Darwinia whicherensis	T	CR	A4ce; B1ab(iii)+2ab(iii); C2a(ii)	EN	SWST	BLACKWOOD, WELLINGTON	Williamson (below Whicher Range), Boyanup	Oct, Dec	IRP
19852	Dillwynia sp. Capel (P.A. Jurjevich 1771)	1				SWST, WARR	BLACKWOOD, DONNELLY	Whicher Range, Nannup, Donnybrook, Pemberton	Sept-Oct	
20852	Eucalyptus relicta	2				SWST	BLACKWOOD	Whicher Range, Sabina River, Busselton, Nannup	?Dec	
16915	Eucalyptus x mundijongensis	1				SWAN, SWST	SWAN COASTAL, WELLINGTON	Wilbinga, Matilda Bay, Dardanup		
20509	Gastrolobium papilio	T	CR	B1ab(iii)+2ab(iii); C1+2a(ii)	EN	SWST	BLACKWOOD	Williamson (below Whicher Range), Busselton, Abba Block	Sep-Oct	IRP

NameID	Taxon	Status	Rank	IUCN Criteria	EPBC	DPaW Region	DPaW District	Distribution	Flowering Period	Recovery Plan
30453	Gastrolobium sp. Yoongarillup (S.Dilkes s.n. 1/9/1969)	1				SWST	BLACKWOOD	Dardanup, Yoongarillup	Oct	
20474	Gastrolobium whicherense	2				SWST	BLACKWOOD	Whicher Range, Dardanup	Oct	
19414	Grevillea brachystylis subsp. grandis	T	CR	A4c; B1ab(iii)+B2ab(iii)	CR	SWST	BLACKWOOD	Busselton (Whicher Range), Jindong	Aug,Dec	IRP
12219	Grevillea bronwenae	3				SWST	BLACKWOOD	Whicher Range, Margaret River, Nannup	June-Nov	
14526	Grevillea elongata	T	EN	C2a	VU	SWST	BLACKWOOD	Ruabon, Abba SF, Whicher Range, Butler SF	Oct	IRP
18436	Grevillea manglesioides subsp. ferricola	3				SWST	BLACKWOOD	Scott River, Whicher Range	Jul-Dec	
2190	Hakea oldfieldii	3				MWST, SCST, SWST, WHTB	BLACKWOOD, ALBANY, GERALDTON, GREAT SOUTHERN	Katanning, Champion Bay, Busselton, Stirling Range, Whicher Range, Woogenilup, Treeton	Sep	
17734	Lambertia echinata subsp. occidentalis	T	CR	A3e; B1ab(iii,v)+2ab(iii,v); C1	EN	SWST	BLACKWOOD	Busselton, Whicher Range	Oct-Dec	IRP
16879	Lambertia rariflora subsp. rariflora	4				SWST	BLACKWOOD	Margaret River, Jarrahwood, Whicher Range	Jan-Mar	
45084	Lasiopetalum laxiflorum	3				SWST, WARR	BLACKWOOD, DONNELLY	Cowaramup, Whicher Range, Acton Park, Chapman Hill, Manjimup	Oct,Nov	
29492	Leucopogon sp. Busselton (D. Cooper 243)	2				SWST	BLACKWOOD	Capel, Ruabon N.R., Dardanup	Aug-Sep	
33298	Lomandra whicherensis	3				SWST	BLACKWOOD	Whicher Range, Dardanup	Dec	
37320	Loxocarya striata subsp. implexa	1				SWST	BLACKWOOD	Whicher Range		
46256	Orianthera wendyae	1				SWST	BLACKWOOD	Capel, Dardanup	Oct	
8163	Pithocarpa corymbulosa	3				SWAN, SWST	BLACKWOOD, PERTH HILLS	John Forrest NP, Lesmurdie NP, Helena Valley, Dardanup, Busselton	Apr	
4179	Pultenaea pinifolia	3				SWST, WARR	BLACKWOOD, DONNELLY	Busselton, Karridale, D'Entrecasteaux N.P., Lake Charley, Whicher Range, Margaret River, Mt Manypeaks	Oct	
4183	Pultenaea skinneri	4				SWST	BLACKWOOD, WELLINGTON	Collie, Binningup, Boyanup, Whicher Range, Jalbarragup, Nannup, Bunbury	Jul-Jan	

NameID	Taxon	Status	Rank	IUCN Criteria	EPBC	DPaW Region	DPaW District	Distribution	Flowering Period	Recovery Plan
31872	Stylidium ferricola	1				SWST	BLACKWOOD	Whicher Range	Oct-Nov	
25805	Stylidium hygrophilum	1				SWST	BLACKWOOD	Whicher Range		
25800	Stylidium paludicola	3				SWAN, SWST	BLACKWOOD, SWAN COASTAL, WELLINGTON	Bullsbrook, Ruabon, Mandogalup, Lake Clifton, Cookernup, Capel, Dardanup		
33381	Stylidium perplexum	1				SWST	WELLINGTON	Dardanup	Dec	
16769	Synaphea hians	3				SWST, WARR, WHTB	BLACKWOOD, DONNELLY, WELLINGTON, GREAT SOUTHERN	Busselton, Collie, Ludlow, Capel, Crooked Brook, Unicup, Elgin, Beaufort River	Sep-Oct	
31767	Synaphea polypodioides	3				SWST	BLACKWOOD, WELLINGTON	Dardanup, Boyanup, Donnybrook	Sep-Oct	
18590	Synaphea sp. Fairbridge Farm (D. Papenfus 696)	T	CR	B1ab(iii)	CR	SWAN, SWST	SWAN COASTAL, WELLINGTON	Pinjarra, Dardanup, Serpentine, Kooljerrenup N.R., Dardanup	Oct	IRP

KEY TO CODES USED IN LIST

STATUS Conservation status of taxon - refer to definitions.

T Threatened Flora (Declared Rare Flora - Extant)

X Presumed Extinct (Declared Rare Flora - Extinct)

1 Priority One - Poorly known Species

2 Priority Two - Poorly known Species

3 Priority Three - Poorly known Species

4 Priority Four - Rare, Near Threatened and other species in need of monitoring

RANK The threat category the taxon is recognised as in Western Australia (see definitions)

CR Critically Endangered

EN Endangered

VU Vulnerable

EX Extinct

CRITERIA The criteria that the taxon meets to be listed under the category of threat. Categories and criteria follow IUCN guidelines.

https://www.iucnredlist.org/resources/categories-and-criteria

EPBC The category that the taxon is listed under the Commonwealth's Environmental Protection and Biodiversity Conservation Act 1999. Note this list is maintained by the Commonwealth and the official list should be sourced at the Commonwealth's website

CR Critically Endangered

E Endangered

V Vulnerable

X Extinct

DBCA REGION

GOLD Goldfields

KIMB Kimberley

MWST Midwest

PILB Pilbara

SCST South Coast

SWST South West

SWAN Swan

WARR Warren

WHTB Wheatbelt

DISTRIBUTION Listed according to the nearest town/place name. Includes historical records. NP=National Park, NR=Nature Reserve, Stn=Station, Mt=Mount, Is=Island, Rg=Range

RECOVERY PLAN Whether the taxon has a Recovery Plan (RP), Interim Recovery Plan (IRP) or Multiple Species Plan (MSP).

CHANGE CODE Type of change that has occurred:

ADDITION Added to list – new entry to State (WCA or Priority) or Commonwealth list (EPBC). If already on one state list and needs to be changed to another see either upgrade or downgrade.

UPGRADED Species that is on the Priority list has been upgraded to Threatened or Presumed Extinct under the Wildlife Conservation Act.

CAT_CHG The category under which a species is listed (e.g. EPBC Act VU to EN or Priority 1 to P3) has been changed.

DOWNGRAD A Species has been downgraded from Threatened or Presumed Extinct under the Wildlife Conservation Act to the Priority list.

NAME_CHG Species has undergone a name change.

OTHER Records a change to other details not related to Conservation status (e.g. Location and Recovery Plan details).

DELISTED Species removed from the particular list it was on. Note that a taxon may be delisted from the "Priority" list and added to the "WCA" list or vice versa. Delistings should be reviewed in the context of other additions, upgrades or downgrades.

RELISTED Species has been added to the list which it was once previously listed on.

LIST CODE Priority Priority Flora List

WCA_1991 Wildlife Conservation Act 1950 DRF Schedule [1991 amendments]

CONSERVATION CODES FOR WESTERN AUSTRALIAN FLORA

T: Threatened Flora - Specially protected under the Wildlife Conservation Act 1950, listed under Schedules 1, 2 and 3 of the Wildlife Conservation (Rare Flora) Notice (which may also be referred to as Declared Rare Flora).

Taxa which have been adequately searched for and are deemed to be, in the wild, either rare, at risk of extinction, or otherwise in need of special protection, and have been gazetted as such.

The assessment of the conservation status of these species is based on their national extent.

Ranking:

CR · Schedule 1 - taxa that are extant and considered likely to become extinct or rare, as critically endangered flora, and therefore in need of special protection.

EN · Schedule 2 - taxa that are extant and considered likely to become extinct or rare, as endangered flora, and therefore in need of special protection.

VU · Schedule 3 - taxa that are extant and considered likely to become extinct or rare, as vulnerable flora, and therefore in need of special protection.

EX: Presumed extinct Flora - Specially protected under the Wildlife Conservation Act 1950, listed under Schedule 4 of the Wildlife Conservation (Rare Flora) Notice (which may also be referred to as Declared Rare Flora). Taxa which have been adequately searched for and there is no reasonable doubt that the last individual has died, and have been gazetted as such. Threatened flora are ranked according to their level of threat using IUCN Red List categories and criteria. For example Acacia splendens is specially protected as Declared Rare Flora under the Wildlife Conservation Act 1950 and is a threatened species with a ranking of Critically Endangered.

EX · Schedule 4 - taxa that are presumed to be extinct in the wild and therefore in need of special protection.

A list of the current rankings can be downloaded from the Department of Biodiversity, Conservation and Attractions Threatened Species and Communities webpage at http://dpaw.wa.gov.au/plants-and-animals/threatened-species-and-communities/.

Taxa that may be threatened or near threatened, but are data deficient or have not yet been adequately surveyed to be listed under the Wildlife Conservation (Rare Flora) Notice, are added to the Priority Flora List under Priorities 1, 2 or 3. These three categories are ranked in order of priority for survey and evaluation of conservation status, so that consideration can be given to their declaration as threatened flora. Taxa that are adequately known and are rare but not threatened, or meet criteria for near threatened, or that have been recently removed from the threatened list for other than taxonomic reasons, are placed in Priority 4. These taxa require regular monitoring.

Assessment of Priority codes is based on the Western Australian distribution of the species, unless the distribution in WA is part of a contiguous population extending into adjacent States, as defined by the known spread of locations.

1: Priority One: Poorly-known species

Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small; or on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more locations, but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. Such species are in urgent need of further survey.

2: Priority Two: Poorly-known species

Species that are known from one or a few locations (generally five or less), some of which are on lands managed primarily for nature conservation, e.g. national parks, conservation parks, nature reserves and other lands with secure tenure being managed for conservation. Species may be included if they are comparatively well known from one or more locations, but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes. Such species are in urgent need of further survey.

3: Priority Three: Poorly-known species

Species that are known from several locations, and the species do not appear to be under imminent threat, or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well known from several locations, but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. Such species are in need of further survey.

4: Priority Four: Rare, Near Threatened and other species in need of monitoring

(a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection, but could be if present circumstances change. These species are usually represented on conservation lands.

(b) Near Threatened. Species that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable.

(c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

The conservation codes for Western Australian flora and fauna can be downloaded from the Department's website at:

https://www.dpaw.wa.gov.au/plants-and-animals/threatened-species-and-communities

*Species includes all taxa (plural of taxon - a classificatory group of any taxonomic rank, e.g. a family, genus, species or any infraspecific category i.e. subspecies, variety or forma).

Reference

Smith M.G. & Jones A. (2018) Threatened and Priority Flora List, 5 December 2018. Department of Biodiversity, Conservation and Attractions: Kensington, WA.