



Upper Lachlan Shire Council
Crookwell Landfill
Technical Specification for Landfill Construction Works

December 2017

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1. Introduction

1.1 General

This Specification contains the technical requirements for materials and procedures to be implemented for the construction of the Works at Crookwell Landfill (the site) and must be read in conjunction with the other Contract Documents.

Where the Specification and any other Contract Documents do not agree, the Contractor shall seek clarification from the Superintendent.

1.2 Definitions – TO BE FINALISED WITH COUNCIL CONTRACT DOCUMENTS

The Definitions described in XXXX of the Contract Documents apply to this document. The following additional terms used in this Specification shall have the meanings ascribed to them below unless the context otherwise requires:

‘Contract’ – The agreement between the Principal and Contractor

‘Contract Drawings’ – The construction drawings which form part of the Contract Documents

‘Contract Documents’ – The documents which form the Contract

‘Contractor’ – The person bound to execute the work under the Contract

‘Contractor’s Independent Testing Firm’ – Independent testing firm(s) engaged by the Contractor to conduct construction quality control (CQC) testing

‘Construction Quality Assurance (CQA) Engineer’ – Suitably qualified professional responsible for administering the CQA requirements for the Works

‘Construction Quality Assurance (CQA) Engineer’s Independent Testing Firm’ – Independent testing firm(s) engaged by the CQA Engineer to conduct construction quality assurance testing

‘Construction Quality Assurance (CQA) Plan’ – Plan forming part of the Contract Documents, describing the construction quality assurance requirements for the Works

‘ENM’ – Excavated natural material. As defined in the NSW EPA excavated natural material exemption 2014 (<http://www.epa.nsw.gov.au/resources/waste/rre14-excavated-natural-material.pdf>)

‘Field Crew Foreman’ – Foreman for the Geosynthetic Installer’s field crew, as defined by the Contractor

‘Geosynthetic’ – Synthetic material (man-made plastic and fabric) used in geotechnical and construction applications

‘Geosynthetic Installer’ – Firm subcontracted by the Contractor to complete the installation of geosynthetic for the Works

‘MARV’ – Minimum average roll value

‘MaxARV’ – Maximum average roll value

‘Regulatory Authority’ – Authority responsible for licencing the Works

‘Seaming Crew’ – Crew responsible for the seaming activities performed by the Geosynthetic Installer, as defined by the Contractor

'Seaming Foreman' – Foreman for the seaming activities performed by the Geosynthetic Installer, as defined by the Contractor

'Specification' – This document

'Superintendent' – As defined in the Conditions of Contract

'PE' – Polyethylene

'Principal' – As defined in the Conditions of Contract

'VENM' – Virgin excavated natural material. As defined in Schedule 1 of the *Protection of the Environment Operations Act 1997*

'Work under the Contract' – The work which the Contractor is or may be required to execute under the Contract and includes variations, remedial work, constructional plant and temporary works

'Works' – The whole of the work to be executed in accordance with the Contract, including variations provided for by the Contract, which by the Contract is to be handed over to the Principal

'Works Area' – As shown on the Contract Drawings.

1.3 Lines of communication

The lines of communication for the Works are illustrated in Figure 1. The Superintendent shall be the main point of liaison between the Contractor and the CQA Engineer, as well as the Contractor and the Principal.

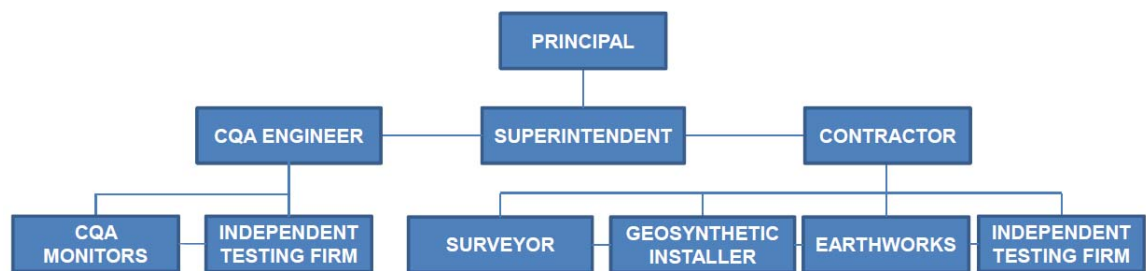


Figure 1 Lines of communication

1.4 Materials

The Contractor shall be responsible for the sourcing, delivery, storage, preparation, handling and installation of all materials, except as modified in individual sections of this Specification.

Material and installation specifications are included in the individual sections of this Specification for each material type.

1.5 Sequencing and scheduling

The Contractor shall be responsible for sequencing the installation of all materials, including surveys, testing and field trials.

In general, installation sequencing shall proceed from higher elevations to lower elevations to prevent precipitation runoff from flowing into and/or below installed products.

Individual components shall not be covered with the subsequent component until the underlying component has been accepted by the Superintendent.

1.6 Submittals

Submittals for each material are included in the individual chapters of this Specification. Each submittal shall be submitted alongside the relevant submittal forms found in Appendix C. The following pre-qualification submittals are required to be submitted by the Contractor at least 10 working days prior to construction for approval by the Superintendent.

1.6.1 Pre-qualification of the Geosynthetic Installer

Prior to construction, the Contractor shall provide a list documenting completed facilities for which the Geosynthetic Installer has completed the installation of a geosynthetic lining and capping systems similar to this Specification. For each facility, the following information shall be provided:

- The name and purpose of the facility, its location, and the date of installation
- The name of the owner, project manager, designer, manufacturer, and fabricator (if any)
- If requested, the name and telephone number of a reference contact at the facility who can discuss the project
- The name and qualifications of the supervisor(s) of the installer's crew(s)
- The type(s) of seaming, patching, and tacking equipment
- Any available information on the performance of the geosynthetic lining or capping system at the facility.

The Contractor shall also provide:

- Certification indicating an approval or licence from the proposed geosynthetic manufacturers for the Contractor to install the manufacturer's materials
- Certification that the Geosynthetic Installer's Field Crew Foreman has a minimum of 200 hectares of actual geosynthetic installation experience and a minimum of 100 hectares of supervisory experience for geosynthetic installation on a minimum of 10 different projects
- Certification that the Geosynthetic Installer's Seaming Foreman is an International Association of Geosynthetic Installer's Certified Welding Technician and has a minimum of 100 hectares of actual geosynthetic seaming experience and a minimum of 50 hectares of supervisory experience during the seaming of geosynthetic materials
- Certification that each individual on the Geosynthetic Installer's Seaming Crew has a minimum of 10 hectares of geosynthetic seaming experience and a minimum of 5 hectares of seaming experience with geosynthetics similar to this Specification. This condition may be relaxed at the discretion of the Superintendent to allow training of installation staff.

1.6.2 Pre-qualification of the Contractor's Independent Testing Firm

Prior to construction, the Contractor shall provide a listing of qualifications for the proposed Contractor's Independent Testing Firms(s) and its key personnel who shall perform the work described in this Specification. The Contractor's Independent Testing Firms(s) shall be National Association Testing Authorities (NATA) accredited and proof of accreditation shall be maintained throughout the duration of the Works.

A listing of testing apparatus and testing standards typically performed by the testing firm shall be provided along with a letter stating that the testing firm is independent and has no financial interest in the Contractor, the Geosynthetic Installer or any of the manufacturers/suppliers that are providing materials for the Works.

1.6.3 Works program

The Contractor shall prepare a program for the Works. The program shall encompass all phases of the Works. The Contractor shall submit a draft of the program to the Superintendent for review and approval at least 10 working days prior to construction. The Contractor shall not undertake any works on the site until approval for such is given by the Superintendent. The program shall include regular progress meetings with the Superintendent.

1.6.4 Procurement plan

Prior to construction, the Contractor shall provide a procurement plan which considers each material to be supplied for the Works. For each material, the plan shall consider:

- Material sources and relevant quantities from each source
- Estimated timeframe for pre-qualification testing, provision of results and subsequent approval to deliver to site
- Estimated timeframe for delivery of material on-site
- Estimated timeframe for independent conformance testing, provision of results and subsequent approval for use (where required, refer Section 1.8.2).

The procurement plan shall align with the Works program, including installation timeframes.

1.6.5 Construction quality control plan

The Contractor shall prepare and implement a construction quality control (CQC) Plan for the Works, and the plan shall address all quality considerations identified or outlined in this Specification. The CQC plan shall incorporate, as necessary, field testing, field verification, manufacturer's certifications and quality control testing at the manufacturing plant, to demonstrate that all Works comply with this Specification. The CQC plan shall also demonstrate how construction will occur and the methods by which the materials will be supplied, placed and tested to ensure compliance with this Specification.

Works shall not commence until the CQC plan has been approved by the Superintendent.

The Principal may at their discretion, audit the Contractor's implementation of the CQC plan. The Contractor shall co-operate with all such auditing.

1.7 Construction quality control

All construction quality control (CQC) testing shall be arranged by the Contractor and shall be carried out by the Contractor's Independent Testing Firm. The cost of CQC testing shall be borne by the Contractor. Unless noted otherwise, copies of all test results shall be sent to the Superintendent as soon as available but in any event within two days of becoming available. The minimum testing frequencies shall be as nominated within this Specification.

At any stage throughout the Works, the Superintendent may arrange for independent testing and/or surveying to be carried out. If that testing reveals that any works are found to be not compliant with the requirements of this Specification and the Contract Drawings, the Contractor shall undertake rectification of the non-compliant items and conduct re-testing in accordance with this Specification. All costs of undertaking such rectification work and re-testing shall be borne by the Contractor.

1.8 Construction quality assurance

1.8.1 General

A Construction Quality Assurance (CQA) Plan has been developed in conjunction with this Specification and shall be implemented by the Principal to verify that the Works are undertaken in a manner that meets the requirements of the Contract Documents.

The Principal shall engage an independent organisation (the CQA Engineer), under contract to the Principal, who shall facilitate the requirements of the CQA Plan. This shall include independent CQA monitoring, observation, testing and documentation on behalf of the Principal.

The Contractor shall cooperate fully with the Superintendent and all representatives of the CQA Engineer during any independent CQA sampling, testing, and certification and shall ensure, at all times, safe access to the Works for the purpose of monitoring, observation, and CQA implementation. This shall include sampling of geosynthetic materials by the Geosynthetic Installer under the supervision of the CQA Engineer.

1.8.2 Independent conformance testing

The CQA Engineer shall arrange for independent conformance testing of the materials used in the Works, in accordance with the CQA Plan, to assure conformance with this Specification. Samples shall be collected at locations designated by the CQA Engineer and all independent conformance sampling shall be witnessed by the CQA Engineer. Where sampling of geosynthetics is necessary, the sampling shall be undertaken by the Geosynthetic Installer from the relevant materials for the independent conformance testing of the material. The Contractor shall make a suitable allowance for this testing within their construction program.

The sample frequency shall be in accordance with Table 1. The table also identifies the indicative sample size. The sample sizes shall be confirmed by the CQA Engineer prior to construction. Sampling shall include the first and last roll. The specified frequency assumes all rolls are from a single manufacturing run. If rolls are from different manufacturing runs then the frequency shall be applied to each manufacturing run. The test frequency for all rolls where, in the opinion of the CQA Engineer, the manufacturing run cannot be identified shall be every roll for all test types. Samples shall not be taken from the outer wrap of the roll.

Table 1 Independent sample size and frequency schedule

Material	Indicative size	Frequency
Polyethylene geomembrane	1 metre by roll width	1 per 5,000 m ² including the first and last rolls (based on production order): minimum of two tests
Geotextile	1 metre by roll width	1 per 2,500 m ² including the first and last rolls (based on production order): minimum of two tests
Drainage aggregate	20 kg bucket	1 per 2,000 m ³
Geonet drainage geocomposite	1 metre by roll width	1 test 1,250 m ² including the first and last rolls (based on production order): minimum of two tests

As a minimum, a period of 8 weeks shall be allowed for from the completion of on-site sampling of all geosynthetic materials on-site to the receipt of independent conformance testing results and subsequent approval/rejection of the materials for use. This shall be confirmed by the CQA Engineer prior to construction.

If a sample records a non-conforming test result, it may be re-tested. If it passes this retest, both results shall be provided in the laboratory report from the relevant independent testing firm. If the retest produces a non-conforming test result, the Contractor shall remove and replace all

rolls between the sampled roll and the nearest conforming rolls either side (based on the production order of the rolls). The Contractor may, by testing and verification of these intermediate rolls, reduce the range of rolls to be removed in this way. Such additional testing shall be for the full range of specified tests, not just the test or property which yielded a failure.

In the event of discrepancies between the CQA Engineer’s test results and the Contractor’s test results, the Contractor shall be responsible for arranging a third independent testing firm to verify the test results.

Any replacement material shall receive the independent conformance testing in accordance with the CQA Plan.

1.9 Work method statements

Prior to the commencement of each type of work, the Contractor shall submit to the Superintendent work method statements that detail how the work is to be carried out and the plant and equipment proposed.

The Contractor shall submit such work method statements to the Superintendent at least 5 working days prior to undertaking any work addressed by the work method statement.

The Superintendent may reject the submitted work method statement if, in the opinion of the Superintendent, the statement does not comply with the Specification or any other Contract Documents provided to the Contractor prior to or during construction.

Where a work method statement is rejected the Contractor shall revise and resubmit the statement. No work addressed by the work method statement shall be undertaken by the Contractor until the work method statement is approved by the Superintendent.

Acceptance by the Superintendent of a proposed work method statement in no way reduces the Contractor’s liability to achieve the requirements described in this Specification.

Appendix A contains a schedule of activities for which the Contractor shall produce work method statements.

1.10 Survey requirements

Prior to beginning construction, the Contractor shall establish a survey grid over the Works footprint. The survey grid shall be a maximum 10 m spacing over the works, as well as any locations at which there is a change or break in grade and set out points identified on the Contract Drawings. The elevation of excavated surfaces and placed materials shall be recorded at these grid locations.

Survey data shall be provided to the Superintendent in graphical and tabular formats. All survey shall be to MGA and levels shall be based on Australian Height Datum (AHD).

Table 2 contains a schedule of survey requirements for the Works.

Table 2 Survey requirements

Component	Survey requirements
Subgrade	Following the formation of subgrade surfaces, survey the elevation of the completed layer at all grid locations and at any changes in grade.
Clay rich fill	Following the formation of clay rich fill surfaces, survey the elevation of the completed layer at all grid locations and at any changes in grade. A conformance survey shall also be provided (with consideration to the surveyed elevations of the underlying surface) showing conforming layer thickness within the allowable tolerances.

Component	Survey requirements
Groundwater drainage system	Following installation of the groundwater drainage system, survey the levels and alignments of all pipework.
Leachate drainage pipes	Following installation of the leachate drainage pipes, survey the levels and alignments of all pipework.
Drainage aggregate	Following placement of the drainage aggregate, survey the elevation of the completed layer at all grid locations and at any changes in grade. A conformance survey shall also be provided (with consideration to the surveyed elevations of the underlying surface) showing conforming layer thickness within the allowable tolerances.
Landfill gas system	Following installation of the landfill gas system, survey the levels and alignments of all pipework.
Leachate toe drain	Following installation of the leachate toe drain, survey the levels and alignments of all pipework.
Seal bearing layer	Following placement of the seal bearing layer, survey the elevation of the completed layer at all grid locations and at any changes in grade. A conformance survey shall also be provided (with consideration to the surveyed elevations of the underlying surface) showing conforming layer thickness within the allowable tolerances.
Revegetation layer	Following placement of the subsoil layer, survey the elevation of the completed layer at all grid locations and at any changes in grade. A conformance survey shall also be provided (with consideration to the surveyed elevations of the underlying surface) showing conforming layer thickness within the allowable tolerances.
	Following placement of the topsoil layer, survey the elevation of the completed layer at all grid locations and at any changes in grade. A conformance survey shall also be provided (with consideration to the surveyed elevations of the underlying surface) showing conforming layer thickness within the allowable tolerances.
Surface water drains	Following completion of the surface water drains, survey the levels and alignments of drain invert at maximum 10 m spacing and at any changes in grade.

1.11 Witness and hold points

The following information applies to witness and hold points for the Works:

- A hold point is a defined position in the Works beyond which work shall not proceed without mandatory verification and acceptance by the Superintendent
- A witness point is a nominated position in the Works where the option of attendance may be exercised by the Superintendent, after notification of the requirement
- It shall be the Contractor's responsibility to ensure that all obligations are fulfilled in regards to the witness and hold points within the Contract
- The Contractor shall give the Superintendent a minimum 2 days notice prior to the required inspection
- Where the witness or hold point relates to the condition of a surface or installed material, the Contractor shall verify that the completed surface has achieved full conformance with the Contract Documents
- Witness or hold points may be released for part of the Works Area only, as defined by the Superintendent, so that the Works can be completed in a sequenced manner. The

Superintendent's approval of the completed items is required prior to the release of each witness or hold point.

Appendix B contains a list of activities to which witness and hold points apply.

1.12 Works as Executed Drawings

The Contractor shall provide one (1) set of Works as Executed Drawings, which shall include all corrections and as-constructed information done in a professional draftsman-like manner. All Works as Executed Drawings shall be certified by a Registered Surveyor.

The following Works as Executed Drawings shall be prepared as a minimum:

- Finished installed contours of subgrade levels
- Finished installed lines and levels of groundwater drainage system
- Finished installed contours of the clay rich fill layer
- Finished installed contours of the leachate drainage aggregate
- Finished installed lines and levels of leachate pipework
- Finished installed lines and levels of landfill gas system
- Finished installed lines and levels of leachate toe drain and sump
- Finished installed contours of the seal bearing layer
- Finished installed contours of the subsoil layer
- Finished installed contours of the topsoil layer
- Finished installed lines and levels of surface water drains

All Works as Executed Drawings shall include test locations, showing as a minimum the approximate location, identification number, date sampled and type of testing completed.

1.13 Erosion and sediment control

1.13.1 General

The Contractor shall provide all temporary erosion and sediment controls necessary to protect the areas immediately adjacent to the Works Area from negative impacts.

The removal of temporary erosion and sediment control works shall be the responsibility of the Contractor. The extent of removal of the temporary works shall be confirmed by the Contractor with the Superintendent before the end of the Contract. Materials used for the temporary erosion and sediment control works shall be removed from the Works Area or otherwise disposed of by the Contractor to the satisfaction of the Superintendent. Maintenance of permanent control measures entrusted into the care and control of the Contractor by the Contract up until the Date of Practical Completion shall be the responsibility of the Contractor.

1.13.2 Control Plan

It is the Contractor's responsibility to prepare and implement their own erosion and sediment control plan (ESCP) for the Works with consideration to this Specification, the Contract Drawings and the site Environment Protection Licence (EPL No. 6054)¹. The Contractor shall prepare this plan with reference to:

¹ The Contractor shall ensure that the version of EPL No. 6054 considered shall be the version applicable at the time of the works

- Landcom (2004) Managing Urban Stormwater: Soils and Construction – Volume 1 (4th Ed.), informally known as the “Blue Book”
- NSW EPA (2009) Managing Urban Stormwater: Soils and Construction – Volume 2B, Waste Landfills.

The plan shall be signed off by a Certified Professional in Erosion and Sediment Control (CPESC) under the International Erosion Control Association (Australasia). The personnel who will prepare and sign off on the plan shall undertake a minimum of one (1) site visit prior to submission and sign off of the plan.

The plan shall identify all erosion and sediment control measures the Contractor shall implement during the Works (including staging). The plan shall identify monitoring the Contractor shall undertake to ensure the Contractor complies with the surface water release criteria at the site (as per EPL No. 6054). The plan shall be submitted to the Superintendent for review and approval at least 10 working days prior to commencing the Works. The Works shall not be initiated until the plan is approved by the Superintendent.

1.13.3 Vegetation establishment

It is noted that erosion and sediment control measures for the Works are crucial following placement of the subsoil/topsoil layer and prior to vegetation establishment, to prevent any significant erosion of the subsoil/topsoil layers (and the layers beneath them). This is particularly important on the landform batters exceeding a gradient of 25 per cent. The Contractor shall be responsible for establishing suitable controls for managing erosion and sediment control during this period, including inspection of non-vegetated or partially vegetated areas following rain events. The Contractor shall consider relevant guidance provided in the Blue Book when developing and implementing these control measures.

Any erosion of the final landform areas identified following rainfall shall be remediated by the Contractor to the satisfaction of the Superintendent, including any damage the erosion causes to other components of the Works.

2. Earthworks

2.1 General

This section contains the technical requirements for earthworks.

The Superintendent may reject any earthworks that do not meet or exceed the requirements of this section.

Any earthworks rejected by the Superintendent shall be remediated at the expense of the Contractor.

2.2 Standards

2.2.1 Australian standards

Relevant Australian standards are as follows:

- 1152 Specification for test sieves
- 1289 Methods of testing soils for engineering purposes
- 1289.2.1.1 Determination of the moisture content of a soil - oven drying method
- 1289.3.1.1 Soil classification tests - Calculation of the plasticity index of a soil
- 1289.3.6.1 Soil classification tests - Determination of the particle size distribution of a soil - Standard method of analysis by sieving
- 1289.3.6.3 Soil classification tests - Determination of the particle size distribution of a soil - Standard method of fine analysis using a hydrometer
- 1289.3.8.1 Soil classification tests - Dispersion - Determination of emerson class number of a soil
- 1289.5.1.1 Soil compaction and density tests - Determination of the dry density/moisture content relation of a soil using standard compactive effort
- 1289.5.6.1 Soil compaction and density tests - Compaction control test - Density index method for a cohesionless material
- 1289.5.7.1 Soil compaction and density tests - Compaction control test - Hilf density ratio and Hilf moisture variation (rapid method)
- 1289.5.8.1 Soil compaction and density tests - Determination of field density and field moisture content of a soil using a nuclear surface moisture density gauge
- 1289.6.7.2 Determination of the permeability of a soil - Falling head method for a remoulded specimen
- 1289.6.7.3 Determination of the permeability of a soil - Constant head method using a flexible wall permeameter
- 1726 Geotechnical site investigations
- 2868 Classification of machinery for earthmoving, construction, surface mining and agricultural purposes
- 3798 Guidelines on earthworks for commercial and residential developments
- 4419 Soil for landscaping and garden use

2.3 Submittals

2.3.1 Prior to delivery of fill material to site

The Contractor shall submit the following to the Superintendent for review and approval prior to delivery of each type of fill material to site (per material source):

- Material source
- Certification that the material is VENM or ENM
- Pre-qualification test results/reports demonstrating that the material complies with the relevant material property requirements of this Specification
- Estimated quantity of material which is represented by the pre-qualification test results/reports.

2.3.2 Prior to placement of fill material

The Contractor shall submit the following to the Superintendent for review and approval prior to placement of each type of fill material:

- Survey of the underlying surface in accordance with Section 1.10
- Work method statement(s) for the placement of the fill material, including testing and repair procedures (refer Appendix A).

2.3.3 Following completion of earthworks

The Contractor shall submit the following to the Superintendent for review and approval following completion of earthworks (per layer and/or segment):

- As-built survey of the completed surface/s showing conforming layer thickness within the allowable tolerances
- CQC testing results/reports showing compliance with the requirements of this Specification
- Defect and repairs log, showing details of all defects identified and any repairs completed.

2.4 Materials

2.4.1 Unsuitable material

Fill material shall not contain any of the following:

- Organic soils, such as top soils, severely root-affected subsoils and peat (not applicable for topsoils)
- Materials contaminated through past site usage which may contain toxic substances or soluble compounds harmful to water supply or agriculture
- Materials containing substances that can be dissolved or leached out in the presence of moisture, or which undergo volume change or loss of strength when disturbed and exposed to moisture
- Silts or materials that have the deleterious engineering properties of silt
- Materials containing fire ant infestation/s
- Fill that contains wood, metal, plastic, boulders or other deleterious material
- Actual or potential acid sulphate soils (ASS)

- High plasticity clays
- Material susceptible to combustion.

2.4.2 Unclassified fill

Unclassified fill material shall:

- Be selectively sourced material from on-site or imported from an approved source. Imported material shall be classed as VENM or ENM
- Not contain any unsuitable materials identified in Section 2.4.1 unless approved by the Superintendent
- Be well graded in accordance with AS 1726
- Comply with the acceptance criteria specified in Table 3.

The Contractor shall supply pre-qualification testing results in accordance with the testing frequencies identified in Table 3 showing that the proposed material meets the requirements of this table. Samples taken shall be representative of the whole material source and shall be evenly distributed across the material source.

If required by the Superintendent, a sample of the material shall be provided (per source) and the Superintendent and/or CQA Engineer may undertake an inspection of the material source. The Contractor shall cooperate fully with the Superintendent and CQA Engineer to allow this inspection to occur.

Table 3 Acceptance criteria – unclassified fill

Property	Test method	Acceptance criteria	Minimum test frequency
Particle size distribution: - Passing 150 mm	AS 1141.11,12,13 or AS 1289.3.6.1, 3.6.3	100%	Greater of: 1 per 5,000 m ³ of material or 3 per source
California Bearing Ratio (CBR)	AS1289.5.7.1	> 3	Greater of: 1 per 5,000 m ³ of material or 3 per source

2.5 Equipment

All earthworks shall be undertaken using conventional earthmoving equipment and methods typical to this type of project. Equipment shall be industry standard and operated in accordance with the equipment manufacturer's instructions.

Blasting is not permitted.

2.6 Quantities

The Contractor shall monitor all earthworks and shall be responsible for verifying the quantities of cut and fill available for constructing the Works.

Quantities of cut and fill provided in the Contract Documents are provided for bidding purposes only and do not account for shrinkage and swell or excess material.

The Contractor shall be responsible for any assumptions made in relation to the nature, hardness and types of materials to be encountered in excavations and the bulking and compaction characteristics of materials.

2.7 Extent of disturbed areas

The Contractor shall confine machinery operations within the Works Area as shown on the Contract Drawings.

All disturbed, compacted or spoiled ground outside of the designated Works Area shall be cultivated and sown with an approved grass mix. The Contractor shall ensure that this operation is programmed to enable germination of seed prior to the Date of Practical Completion.

2.8 Lines and levels

All earthworks shall be to the lines and levels shown in the Contract Drawings.

Earthworks shall be trimmed to line and level by machine and/or hand as necessary to produce profiles to the tolerances required.

2.9 Clearing and grubbing

The Contractor shall undertake all clearing and grubbing necessary to execute the Works including all vegetation, both living and dead, all minor man-made structures (such as fences and livestock yards), all rubbish and other materials which, in the opinion of the Superintendent, are unsuitable for use in the Works, the chipping of the crowns of trees and the branches of shrubs, and the grubbing of trees and stumps from the Works Area. Clearing and grubbing shall also include the disposal of all materials that have been cleared and grubbed. All natural landscape features, including natural rock outcrops, natural vegetation, soil and watercourses are to remain undisturbed except where affected by the Works.

Cleared vegetation material shall be retained on site (chipped/reused). If required, vegetation for disposal shall be disposed of by the Contractor at a facility approved by the Superintendent.

During clearing and grubbing works, the Contractor may ascertain material which can be utilised as topsoil for the outlined in this Specification. Subject to approval, the Contractor may stockpile this material for use as topsoil. Stockpiling of topsoil shall be undertaken in accordance with Section 2.16.

2.10 Excavation

Excavation shall consist of all excavation required to complete the Works unless separately designated.

Material which is suitable for the works or suitable for use in site operations shall be stockpiled on site as directed by the Superintendent and as outlined in Section 2.16.

Material that is unsuitable for use shall be excavated and disposed by the Contractor as directed by the Superintendent.

If excavated material is unsatisfactory for its specified use because of high moisture content, the Contractor may be directed by the Superintendent to either process the material to reduce the moisture content or to remove the material and replace it with suitable material.

Excavation slopes shall be finished in conformance with the lines and grades shown on the Contract Drawings or as re-determined by the Superintendent on the basis of site inspection and investigation during the works. All debris and loose material shall be removed.

The tops of excavation slopes and the end of excavations shall be rounded where shown on the Contract Drawings.

If the Contractor excavates beyond the slope line and the tolerance applicable, the Contractor shall request and the Superintendent may authorise a minor change in the general slope of the

surface. This shall not be regarded as a redetermination of the final grades and levels. If the Contractor's request is denied, the Contractor shall submit details of the material and/or methods proposed to restore the specified slope and stability of the surface for approval.

2.11 Filling

Filling includes all operations associated with the preparation of the Works on which fill material is to be placed and the placing and compacting of approved fill material to the alignment, grading and dimensions shown on the Contract Drawings, including any pre-treatment such as breaking down, blending or drying out material containing excess moisture.

All fill shall be placed, spread, mixed, watered and compacted in accordance with the Specification.

The ground surface prepared to receive fill shall be firm and unyielding. This shall be determined by undertaking compaction testing and roll testing.

Prior to filling, the ground surface shall be scarified, disked, or bladed until it is uniform and free from uneven features which may prevent uniform compaction. The scarified ground surface shall then be brought to appropriate moisture content, mixed as required and compacted. If the scarified zone is greater than 300 mm in depth, the excess shall be removed and placed in compacted lifts not greater than 200 mm compacted thickness, unless otherwise specified.

Unless otherwise specified, fill material shall be placed in thin lifts with a maximum compacted lift thickness of 200 mm. Each lift shall be spread evenly and thoroughly mixed to obtain a near uniform condition in each lift. In areas of excess lift thickness, regrading of the surface to the maximum lift thickness shall be completed prior to construction of additional lifts.

Handling and spreading of all fill material shall produce a gradation of the materials when compacted to comply with this Specification.

All fill materials shall be placed in such a manner that the distribution and gradation of the materials throughout will be such that the fill will be free from lenses, pockets, streaks, or layers of material differing substantially in texture or gradation from the surrounding material within the zone.

Where work is interrupted by rain, fill operations shall not be resumed until observations and field tests by the Contractor indicate that the moisture content and density of the in-place fill materials and/or materials intended for placement are within the limits identified in this Specification. This requirement does not preclude the Contractor from disked or aerating excessively wet areas to enhance drying.

2.12 Compaction

Unless stated otherwise, all fill shall be compacted at a moisture content of -2 to +2% of optimum moisture content (OMC) in accordance with Table 4.

Table 4 Minimum relative compaction

Application	Minimum relative compaction (%)	
	Minimum density ratio (cohesive soils)	Minimum density index (cohesionless soils)
Subgrade materials, embankments/bunds and trench backfill	98 std	60
Clay rich fill	95 std	-
Seal bearing material	95 std	-
Subsoil and topsoil material	Refer Section 12.6	-

2.13 Construction quality control testing

Unless stated otherwise, the Contractor shall undertake CQC testing of all fill in accordance with Table 5 (general filling works) and Table 6 (trench filling works) as a minimum. Sampling locations for testing shall be agreed with the Superintendent and CQA Engineer.

The Superintendent may request additional tests at any time, where in the opinion of the Superintendent, a deficiency is suspected.

The Superintendent shall direct the extent of work rejected due to non-conforming CQC test results based on the area represented by the non-conforming test results (with respect to test locations and frequencies). Following a thorough re-working of a non-conforming area, retesting shall be performed by the Contractor to evaluate whether the re-worked area meets the requirements of the Specification. The Contractor shall undertake all necessary remedial work, including retesting, to reinstate the work to the requirements of the Specification. Further details are provided in Section 2.17.

CQC testing for all earthworks shall be carried out by the Contractor's Independent Testing Firm who shall supply reports identifying the material type, the Specification requirements, and associated results.

The Contractor shall maintain a register of in-situ test results, which shall record the following details:

- Test number
- Description of the fill material
- Location/Grids or co-ordinates of the tests
- Lift tested
- Density ratio
- Moisture content
- Method of testing in accordance with AS 1289.

Where tests do not conform to the Specification requirements, retests shall be undertaken and these shall be clearly identified in the register.

Table 5 Construction quality control testing – earthworks (general)

Property	Test method	Minimum test frequency
Moisture content	AS 1289.5.1.1 or AS 1289.5.7.1	Greater of: 1 per layer per 2,500 m ² or 1 per 500 m ³ or 3 per lift
Dry density	AS 1289.5.8.1 AS 1289.5.1.1 or AS 1289.5.7.1	Greater of: 1 per layer per 2,500 m ² or 1 per 500 m ³ or 3 per lift

Table 6 Construction quality testing – earthworks (trenches)

Property	Test method	Minimum test frequency
Moisture content	AS 1289.5.1.1 or AS 1289.5.7.1	1 per 2 layers per 120 linear metres
Dry density	AS 1289.5.8.1 AS 1289.5.1.1 or AS 1289.5.7.1	1 per 2 layers per 120 linear metres

2.14 Tolerances

Unless specified otherwise, tolerances shall meet the acceptance criteria in Table 7.

The Contractor may excavate and re-compact the existing material if necessary to assist in achieving this tolerance.

Notwithstanding these allowable tolerances, the Contractor shall be responsible for meeting grading requirements across the surfaces of earthworks materials as shown on the Contract Drawings.

Plus (+) refers to the following:

- Elevation: Plus (+) is higher than design
- Layer thickness: Plus (+) is thicker than design
- Depth: Plus (+) is deeper than design
- Width: Plus (+) is wider than design.

Minus (-) refers to the following:

- Elevation: Minus (-) is lower than design
- Layer thickness: Minus (-) is thinner than design
- Depth: Minus (-) is shallower than design
- Width: Minus (-) is narrower than design.

Table 7 Tolerances

Element	Measurement	Acceptance criteria
General excavation	Elevation	±100 mm
Subgrade	Elevation	+0, -100 mm
Sidewalls: At the toe of the batter 2 m above toe of batter and higher Between toe of batter and 2 m above toe of batter	Elevation	+0, -100 mm ± 100 mm pro rata basis
Embankments/bunds	Elevation	+100, -0 mm
All trenches	Depth Width	+100, -0 mm +100, -0 mm
Clay rich fill layer	Layer thickness	+50, -0 mm
Leachate drainage aggregate layer	Layer thickness	+50, -0 mm
Seal bearing layer	Layer thickness	+100, -0 mm
Revegetation layer	Layer thickness	+100, -0 mm

2.15 Anchoring of geosynthetics

Anchor trench excavation, backfill, and compaction shall be completed to the line and grades shown on the Contract Drawings. A work method statement shall be prepared for the excavation and backfill of anchor trenches during the Works with consideration to the guidance below.

Anchor trenches shall be prepared with slightly rounded corners where the geosynthetics adjoin the trench so as to avoid sharp bends in the geosynthetic material. The base of the anchor trench must be a smooth uniform surface that is free of defects and loose material.

The geosynthetic layers shall be placed in the trench as per the Contract Drawings to ensure effective anchorage. Fill material shall be placed in maximum 100 mm loose lifts if compacted

with hand-operated compaction equipment, or maximum 200 mm loose lifts if compacted with a self-propelled compactor.

The Contractor shall repair or replace any geosynthetics damaged as a result of placement or compaction of backfill.

2.16 Stockpiles

The Contractor shall be responsible for managing stockpiles of fill materials for the Works until the Date of Practical Completion. It is the Contractor's responsibility to prevent the fill material stockpiles to become contaminated with unsuitable material (refer Section 2.4.1) or by other methods (such as fines contamination) which may result in the fill material no longer meeting the relevant acceptance criteria in this Specification. The Superintendent may organise independent inspections and/or testing of the fill material stockpiles to verify conformance with these requirements. In the Superintendent's opinion, if remediation of any contaminated fill materials is not viable then the fill shall be rejected by the Superintendent and removed from the site at the expense of the Contractor.

All stockpiles shall be located so that drainage from the stockpile flows into the site or to the existing or new stormwater dams. Where a stockpile cannot be located such that drainage flows into the site, the stockpile shall have a drainage swale placed on the uphill side of the stockpile to divert surface water from the stockpile area and sediment traps at its base to capture sediment running off the stockpile. These drainage measures shall be constructed as per the Blue Book. Stockpile management shall be considered as part of the ESCP submitted for the Works.

In addition, all stockpiles shall:

- Have maximum slopes not exceeding 1(V):2(H)
- Have rounded shoulders and base of batters to minimise wind and water erosion
- Be surrounded by filter fence.

2.17 Defects and repairs

Compacted fill material with non-conforming CQC test results shall be remediated as Table 8. This includes non-conformances resulting from independent testing commissioned by the Superintendent or CQA Engineer.

Material with non-conforming CQC test results after remedial work has been implemented (that is, tested for a second time) shall be removed and replaced.

The Contractor shall submit to the Superintendent for review a log containing details of any defects identified and repairs carried out.

Table 8 Remedial actions for compacted fill

Category	Density ratio result	Density index result	Moisture result	Remedial action ²
A	Non-conforming by less than 1%	Non-conforming by less than 3%	Conforming	Re-compact (maximum of three passes)
B	Non-conforming by 1% or more	Non-conforming by less than 5%	Conforming, but not more than 1.0% wet of OMC	Rip, re-water, re-compact and re-test

² Should the Superintendent deem the depth of insufficiently compacted material to be greater than can be effectively compacted from the surface, material shall be removed to a depth at which compaction is satisfactory and replaced and compacted in layers

Category	Density ratio result	Density index result	Moisture result	Remedial action ²
C	Non-conforming by 1% or more	N/A	Pass, but 1.0% or more wet of OMC	Rip, re-compact and re-test
D	Conforming	N/A	Non-conforming	Rip, re-water, re-compact and re-test
E	Non-conforming	Non-conforming by more than 5%	Non-conforming	Remove fill, replace, compact and re-test

2.18 Acceptance

The Contractor shall retain ownership and responsibility for the earthwork activities until final acceptance of earthworks by the Principal.

The earthworks shall be accepted by the Principal when all of the following conditions are met:

- Required submittals are provided by the Contractor to the Superintendent and approved
- The Contractor has submitted the required as-built surveys of the completed earthworks showing conformance with the Contract Drawings within the allowable tolerances, and this has been approved by the Superintendent
- CQC test results showing compliance with the requirements of this Specification have been provided by the Contractor to the Superintendent and approved
- Details of all defects identified and repairs performed have been provided by the Contractor to the Superintendent and approved
- The CQA Engineer has provided the Superintendent with a recommendation that the conditions of final acceptance have been met
- The Superintendent has inspected and approved the finished surface/s.

3. Subgrade

3.1 General

This section contains the technical requirements for the subgrade preparation. The relevant requirements for the earthworks in Section 2 shall be considered alongside guidance provided in this section.

The Superintendent may reject any component of the subgrade that does not meet or exceed the requirements of this section.

Any subgrade rejected by the Superintendent shall be remediated at the expense of the Contractor.

3.2 Standards

3.2.1 Australian standards

Relevant Australian standards are as follows:

- 1152 Specification for test sieves
- 1289 Methods of testing soils for engineering purposes
- 1289.2.1.1 Determination of the moisture content of a soil - oven drying method
- 1289.3.1.1 Soil classification tests - Calculation of the plasticity index of a soil
- 1289.3.6.1 Soil classification tests - Determination of the particle size distribution of a soil - Standard method of analysis by sieving
- 1289.3.6.3 Soil classification tests - Determination of the particle size distribution of a soil - Standard method of fine analysis using a hydrometer
- 1289.3.8.1 Soil classification tests - Dispersion - Determination of emerson class number of a soil
- 1289.5.1.1 Soil compaction and density tests - Determination of the dry density/moisture content relation of a soil using standard compactive effort
- 1289.5.6.1 Soil compaction and density tests - Compaction control test - Density index method for a cohesionless material
- 1289.5.7.1 Soil compaction and density tests - Compaction control test - Hilf density ratio and Hilf moisture variation (rapid method)
- 1289.5.8.1 Soil compaction and density tests - Determination of field density and field moisture content of a soil using a nuclear surface moisture density gauge
- 1289.6.7.3 Methods of testing soils for engineering purposes - Soil strength and consolidation tests - Determination of permeability of a soil - Constant head method using a flexible wall permeameter
- 1726 Geotechnical site investigations
- 2868 Classification of machinery for earthmoving, construction, surface mining and agricultural purposes
- 3798 Guidelines on earthworks for commercial and residential developments
- 4419 Soil for landscaping and garden use

3.3 Submittals

3.3.1 Prior to placement of fill material

Refer Section 2.11.

3.3.2 Prior to subgrade preparation

The Contractor shall submit the following to the Superintendent for review and approval prior to subgrade preparation:

- Work method statement for the subgrade preparation, including testing, proof rolling and repair procedures (refer Appendix A).

3.3.3 Following completion of subgrade preparation

The Contractor shall submit the following to the Superintendent for review and approval following completion of subgrade preparation:

- As-built survey of the completed surface showing conforming layer grade, level and thickness within the allowable tolerances
- CQC testing results/reports showing compliance with the requirements of this Specification
- Defect and repairs log, showing details of all defects identified and any repairs completed.

3.4 Preparation

The Contractor shall prepare a work method statement for subgrade preparation outlining the preparation methodology and proposed construction plant to be used (refer 2.5). The work method statement shall be submitted to the Superintendent for review and comment prior to placement.

The work method statement and construction methodology for the subgrade shall be developed in accordance with the guidance provided below:

- Where unsuitable material is found (refer Section 2.4.1), such material shall be removed to the extent directed by the Superintendent
- Unclassified fill material (refer Section 2.4.2) shall be used to achieve the required lines and levels where the subgrade has been over-excavated or unsuitable material has been removed
- Soil berms and undulations shall be graded out on site to provide a smooth and unyielding surface
- Proof-rolling operations shall be carried out as necessary to determine the soundness and suitability of the prepared subgrade (refer Section 3.8)
- The surface shall be sealed (by smooth drum rolling) at the end of each day to minimise the penetration of water, with erosion protection measures provided and drainage systems (permanent and temporary) maintained
- The Contractor shall match compaction methods to the material and location, with consideration of the following guidelines:
 - Rubber-tyred rollers are preferable to prevent bridging of softer materials
 - Double smooth drum rolling may be used provided that careful inspection is undertaken to monitor and prevent bridging

- Proof-rolling equipment should, in general, provide more compaction effort than backfill compaction equipment, to assure integrity
- Hand compaction equipment such as impact rammers or plate or small drum vibrators should be used to sound material
- Any desiccations, cracks, or inconsistencies in the subgrade shall be remediated as directed by the Superintendent.

3.5 Compaction

All subgrade material shall be placed and compacted to the requirements of Section 2.12.

3.6 Construction quality control testing

The Contractor shall undertake CQC testing of the subgrade material in accordance with Section 2.13.

3.7 Tolerances

The completed subgrade shall be within the tolerances provided in Section 2.14.

3.8 Proof rolling

Proof rolling shall be used throughout preparation of the subgrade to assist in identifying soft spots and unsuitable material.

The prepared subgrade shall be proof rolled by a mechanical self-propelled smooth drum roller (or equivalent) in the presence of the Superintendent to assess the soundness and suitability of the subgrade.

Proof rolling shall be conducted upon the full width and length of the subgrade. A final proof roll shall be conducted over the finished surface prior to acceptance.

To show conformance with the requirements of the Specification, during final proof rolling of the prepared subgrade the surface shall not exhibit visible deformation, rutting, yielding and/or show signs of distress or instability.

3.9 Finished surface

The finished surface of the subgrade shall exhibit the following characteristics:

- The surface shall be smooth, flat, firm and unyielding to the satisfaction of the Superintendent
- The surface shall not exhibit visible deformation, rutting, yielding and/or show signs of distress or instability during final proof rolling
- The surface shall be free of debris, roots, angular material (such as sharp rocks), desiccation cracks, abrupt breaks, indentations, sudden changes in grade, defects and/or imperfections that may result in damage to the overlying materials
- No loose, coarse-grained material shall remain on the surface. If required, the surface shall be raked or graded to remove any material penetrating out of the surface greater than 50 mm
- The surface shall promote drainage and excessive water shall not be allowed to pond on the surface

- The surface shall not be pebbly, tracked, rutted or otherwise disturbed by the equipment deploying overlying materials or other traffic. Pockets, holes, or discontinuities shall be repaired
- All construction stakes, hubs, or other items used for grade control shall be removed and any voids filled. Any unsuitable material shall be over-excavated to a depth of 100 mm and replaced with approved material
- The surface shall be maintained at sufficient moisture content to prevent desiccation during the Works.

3.10 Defects and repairs

Any areas of prepared subgrade that does not conform to the required compaction and moisture content testing criteria shall be repaired by the Contractor in accordance with Section 2.17. This includes non-conformances resulting from independent testing commissioned by the Superintendent or CQA Engineer.

The Contractor shall submit to the Superintendent for review a log containing details of any defects identified and repairs carried out.

3.11 Acceptance

The Contractor shall retain ownership and responsibility for the subgrade until final acceptance of the subgrade by the Principal.

The subgrade shall be accepted by the Principal when all of the following conditions are met:

- Required submittals are provided by the Contractor to the Superintendent and approved
- The Contractor has submitted the required as-built surveys of the completed subgrade showing conformance with the Contract Drawings within the allowable tolerances, and this has been approved by the Superintendent
- CQC test results showing compliance with the requirements of this Specification have been provided by the Contractor to the Superintendent and approved
- Details of all defects identified and repairs performed have been provided by the Contractor to the Superintendent and approved
- The CQA Engineer has provided the Superintendent with a recommendation that the conditions of final acceptance have been met
- The Superintendent has inspected and approved the finished surface/s.

4. Clay rich fill

4.1 General

This section contains the technical requirements for the clay rich fill. The relevant requirements for the clay rich fill in Section 2 shall be considered alongside guidance provided in this section.

The Superintendent may reject any component of the clay rich fill that do not meet or exceed the requirements of this section.

Any component of the clay rich fill rejected by the Superintendent shall be remediated at the expense of the Contractor.

4.2 Standards

4.2.1 Australian standards

Relevant Australian standards are as follows:

- 1152 Specification for test sieves
- 1289 Methods of testing soils for engineering purposes
- 1289.2.1.1 Determination of the moisture content of a soil - oven drying method
- 1289.3.1.1 Soil classification tests - Calculation of the plasticity index of a soil
- 1289.3.6.1 Soil classification tests - Determination of the particle size distribution of a soil - Standard method of analysis by sieving
- 1289.3.6.3 Soil classification tests - Determination of the particle size distribution of a soil - Standard method of fine analysis using a hydrometer
- 1289.3.8.1 Soil classification tests - Dispersion - Determination of emerson class number of a soil
- 1289.5.1.1 Soil compaction and density tests - Determination of the dry density/moisture content relation of a soil using standard compactive effort
- 1289.5.6.1 Soil compaction and density tests - Compaction control test - Density index method for a cohesionless material
- 1289.5.7.1 Soil compaction and density tests - Compaction control test - Hilf density ratio and Hilf moisture variation (rapid method)
- 1289.5.8.1 Soil compaction and density tests - Determination of field density and field moisture content of a soil using a nuclear surface moisture density gauge
- 1289.6.7.3 Methods of testing soils for engineering purposes - Soil strength and consolidation tests - Determination of permeability of a soil - Constant head method using a flexible wall permeameter
- 1726 Geotechnical site investigations
- 2868 Classification of machinery for earthmoving, construction, surface mining and agricultural purposes
- 3798 Guidelines on earthworks for commercial and residential developments
- 4419 Soil for landscaping and garden use

4.3 Submittals

4.3.1

4.3.2 Prior to placement of clay rich fill

The Contractor shall submit the following to the Superintendent for review and approval prior to placement of the clay rich fill:

- Survey of the underlying surface in accordance with Section 1.10
- Work method statement for placement of the clay rich fill, including testing and repair procedures (refer Appendix A).

4.3.3 Following placement of clay rich fill

The Contractor shall submit the following to the Superintendent for review and approval following placement of clay rich fill:

- As-built survey of the completed surface showing conforming layer thickness within the allowable tolerances
- CQC testing results/reports showing compliance with the requirements of this Specification
- Defect and repairs log, showing details of all defects identified and any repairs completed.

4.4 Material

Compacted clay material shall consist of site-won clay materials from the cell excavation works or from existing onsite stockpiles. Any unsuitable material as outlined in Section 2.4.1 shall be removed.

4.5 Preparation of receiving surface

Prior to placement of the clay rich fill, the receiving surface shall exhibit the following characteristics:

- The surface shall be smooth, flat, firm and unyielding to the satisfaction of the Superintendent
- The surface shall not exhibit visible deformation, rutting, yielding and/or show signs of distress or instability during final proof rolling (if required)
- The surface shall be free of debris, roots, angular material (such as sharp rocks), desiccation cracks, abrupt breaks, indentations, sudden changes in grade, defects and/or imperfections that may result in damage to the overlying materials
- No loose, coarse-grained material shall remain on the surface. If required, the surface shall be raked or graded to remove any material penetrating out of the surface greater than 50 mm
- The surface shall promote drainage and excessive water shall not be allowed to pond on the surface
- The surface shall not be pebbly, tracked, rutted or otherwise disturbed by the equipment deploying overlying materials or other traffic. Pockets, holes, or discontinuities shall be repaired

- All construction stakes, hubs, or other items used for grade control shall be removed and any voids filled. Any unsuitable material shall be over-excavated to a depth of 100 mm and replaced with approved material
- The surface shall be maintained at sufficient moisture content to prevent desiccation during the Works.

The receiving surface shall be surveyed as per the requirements of Section 1.10

Placement of the clay rich fill shall not proceed until the receiving surface has been inspected and approved by the Superintendent.

4.6 Installation

The Contractor shall prepare a work method statement for placement of the clay rich fill outlining the measures taken to moisture condition the clay material prior to placement, placement methodology and proposed construction plant to be used (refer Appendix A). The work method statement shall be submitted to the Superintendent for review and approval prior to commencement of the required field trial.

The work method statement and construction methodology for the clay rich fill shall be developed in accordance with the guidance provided below:

- The clay material shall be moisture conditioned uniformly throughout the material prior to placement
- If the clay material requires significant moisture content adjustment, the Contractor shall use a moisture conditioning area to allow hydration or dehydration of material to meet moisture content requirements
- Should the clay material be too wet to permit proper compaction, all work on the portions of the clay material affected shall be delayed until the material has dried to the required moisture content
- Prior to placement, the clay material shall be mixed and processed to ensure no clods greater than 50 mm diameter are present
- The material shall be constructed in a minimum of 4 lifts with each lift having a maximum compacted thickness of 150 mm
- The material shall be placed to the required compaction and moisture content using a sheepsfoot roller, with feet/pads that penetrate the full depth of the placed loose lift of clay material
- Prior to placement of the overlying lift, the surface of the underlying lift shall be scarified as necessary to allow sufficient bonding of the lifts and prevent a lateral zone of higher permeability to be formed
- The surface of the clay material lifts shall be maintained as necessary prior to placement of the overlying lifts or overlying materials to prevent any moisture variations outside the requirements of the Specification. The Contractor shall be required to rework areas which do not meet this requirement
- The Contractor shall seal surfaces (by smooth drum rolling) at the end of each day to minimise the penetration of water, provide erosion protection measures and ensure drainage systems (permanent and temporary) are maintained
- Should joints be required between adjacent lift layers or to tie-in to existing clay layers, existing edge/face shall be trimmed back to remove any desiccated material such that the material exposed in the face complies with the Specification. The clay material to be

placed shall be benched into the existing face/edge such that no continuous alignment of the vertical joints occurs.

4.7 Compaction

All compacted clay fill material shall be placed in compacted lifts not exceeding 150 mm at a moisture content of 0 to +3% of the optimum moisture content, to a minimum density ratio of 95% standard (as per Table 4). The Superintendent may modify these compaction and moisture content requirements based on the results of the material testing submitted prior to placement. Fill is to be placed to at least half of the width of the roller beyond the finished surface of the Clay rich fill shown on the Contract Drawings, such that when it is trimmed back to the finished surface, all of the cut face is compacted.

4.8 Construction quality control testing

The Contractor shall undertake CQC testing of the compacted clay in accordance with Table 16 as a minimum and the relevant requirements of Section 2.13. Sampling locations for testing shall be agreed with the Superintendent and CQA Engineer. Each compacted lift is required to be individually tested prior to the construction of subsequent lifts.

Table 9 Construction quality control testing – compacted clay

Property	Test method	Minimum test frequency
Moisture content	AS 1289.5.1.1 or AS 1289.5.7.1	Greater of: 3 per 500 m ³ or 3 per lift
Dry density	AS 1289.5.8.1 AS 1289.5.1.1 or AS 1289.5.7.1	Greater of: 3 per 500 m ³ or 3 per lift

4.9 Tolerances

The Contractor shall place the clay rich fill within the tolerances provided in Section 2.14.

4.10 Finished surface of clay rich fill

The finished surface of the clay rich fill shall exhibit the following characteristics:

- The surface shall be smooth, flat, firm and unyielding to the satisfaction of the Superintendent. The surface shall be proof rolled by the Contractor using a mechanical self-propelled smooth drum roller (or equivalent) in the presence of the Superintendent to assess the soundness and suitability of the finished surface. The surface shall not exhibit visible deformation, rutting, yielding and/or show signs of distress or instability during final proof rolling
- The surface shall be free of debris, roots, angular material (such as sharp rocks), desiccation cracks and sudden changes in grade. If required, the surface shall be raked or graded to remove any material penetrating out of the surface greater than 10 mm
- The surface shall promote drainage and excessive water shall not be allowed to pond on the surface
- The surface shall not be rutted or otherwise disturbed by the equipment deploying overlying materials or other traffic
- The surface shall be maintained at sufficient moisture content to prevent desiccation during the Works

- Any voids resulting in the compacted clay due to extraction from tube samples (testing requirements) shall be filled with water, and then backfilled with sodium bentonite pellets, hand rammed into the void.

It is essential that the compacted clay not dry out after compaction otherwise severe desiccation can occur in which case shrinkage cracks will appear in the compacted clay and act as conduits for flow. At the discretion of the Superintendent, clay rich fill shall be removed and re-compacted after conditioning with additional moisture if shrinkage cracks appear prior to the placement of overlying material.

4.11 Defects and repairs

Any areas of placed clay rich fill that do not conform to the required compaction and moisture content testing criteria shall be repaired by the Contractor in accordance with Section 2.17. This includes non-conformances resulting from independent testing commissioned by the Superintendent or CQA Engineer.

The Contractor shall submit to the Superintendent for review details of any defects identified and repairs carried out.

4.12 Acceptance

The Contractor shall retain ownership and responsibility for the clay rich fill until final acceptance of the clay rich fill by the Principal.

The clay rich fill shall be accepted by the Principal when all of the following conditions are met:

- Required submittals are provided by the Contractor to the Superintendent and approved
- The Contractor has submitted the required as-built surveys of the completed clay rich fill showing conformance with the Contract Drawings within the allowable tolerances, and this has been approved by the Superintendent
- CQC test results showing compliance with the requirements of this Specification have been provided by the Contractor to the Superintendent and approved
- Details of all defects identified and repairs performed have been provided by the Contractor to the Superintendent and approved
- The CQA Engineer has provided the Superintendent with a recommendation that the conditions of final acceptance have been met
- The Superintendent has inspected and approved the finished surface/s.

5. PE geomembrane

5.1 General

This section contains the technical requirements for (PE) polyethylene geomembrane.

The Superintendent may reject any PE geomembrane that does not meet or exceed the requirements of this section.

Any PE geomembrane rejected by the Superintendent shall be removed from the site and replaced at the expense of the Contractor.

5.2 Standards

5.2.1 American Society for Testing and Materials Standards

Relevant American Society for Testing and Material (ASTM) standards are as follows:

- D792 Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
- D1004 Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting
- D1204 Standard Test Method for Linear Dimensional Changes of Non-rigid Thermoplastic Sheeting or Film at Elevated Temperature
- D1238 Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
- D1505 Standard Test Method for Density of Plastics by the Density Gradient Technique
- D1603 Standard Test Method for Carbon Black in Olefin Plastics
- D3895 Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Colorimetry
- D4218 Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
- D4354 Standard Practice for Sampling of Geosynthetics and Rolled Erosion Control Products(RECPs) for Testing
- D4437 Standard Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes
- D4439 Standard Terminology for Geosynthetics
- D4833 Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products
- D4873 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples
- D5199 Standard Test Method for Measuring the Nominal Thickness of Geosynthetics
- D5397 Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test
- D5596 Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
- D5641 Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber
- D5721 Standard Practice for Air-Oven Aging of Polyolefin Geomembranes

- D5820 Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes
- D5885 Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Colorimetry
- D5994 Standard Test Method for Measuring the Core Thickness of Textured Geomembranes
- D6370 Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry (TGA)
- D6392 Standard Test Method for Determining the Integrity of Non-Reinforced Geomembrane Seams Produced Using Thermo-Fusion Methods
- D6395 Standard Practice for Non-destructive testing of Geomembrane Seams using Spark Test
- D6693 Standard Test Method for Determining Tensile Properties of Non-Reinforced Polyethylene and Non-Reinforced Flexible Polypropylene Geomembranes
- D7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus
- D7466 Standard Test Method for Measuring Asperity Height of Textured Geomembranes

5.2.2 Geosynthetic Research Institute Standards

Relevant Geosynthetic Research Institute (GRI) standards are as follows:

- GM9 Standard Practice for Cold Weather Seaming of Geomembranes
- GM10 Specification for the Stress Crack Resistance of Geomembrane Sheet
- GM13 Standard Specification for Test Methods, Test Properties, and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes
- GM14 Standard Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes
- GM17 Standard Specification for Test Methods, Test Properties, and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes
- GM19 Standard Specification for Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes
- GM20 Standard Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts
- GM29 Standard Practice for Field Integrity Evaluation of Geomembrane Seams (and Sheet) Using Destructive and/or Non-destructive Testing

5.3 Submittals

5.3.1 Prior to selection of the polyethylene geomembrane manufacturer

The Contractor shall submit the following to the Superintendent for review and approval prior to selection of a PE geomembrane manufacturer (per manufacturer and product):

- Product manufacturer
- Product name
- Material data sheet showing the material properties of the proposed PE geomembrane

- A list documenting no less than 40 completed facilities totalling a minimum of 200 hectares for which the manufacturer has manufactured PE geomembrane similar to this Specification. For each facility the following information shall be provided:
 - Name and purpose of the facility
 - The location and date of installation
 - The name of the owner, the project manager, designer, fabricator (if any), and the installer
 - If requested, the name and telephone number of the contact at the facility who can discuss the project
 - The PE geomembrane type, thickness, and total square metres of the installation surface.
- Documentation indicating that the polymer supplier has previously produced a minimum of 1,000 tonne of polymer of the same composition as that proposed for use in the manufacture of the PE geomembrane for the Works
- Manufacturer's quality control and assurance procedures.

5.3.2 Prior to delivery of polyethylene geomembrane to site

The Contractor shall submit the following to the Superintendent for review and approval prior to delivery of PE geomembrane to site (per PE geomembrane product):

- Manufacturer's certificate of compliance outlining conformance with the requirements of this Specification
- Manufacturer's quality control and assurance test results
- Certification that the PE geomembrane supplied for this work was manufactured as consecutive rolls from a single lot or from consecutive lots. If the PE geomembrane is not manufactured from consecutive lots, the resin manufacturer shall provide certification of quality and consistency of the resin characteristics
- Statement on the origin of the resin, its identification (type and lot number), resin supplier's name and production plant, resin brand name and type, and the maximum amount of recycling polymer material added to the raw resin
- Copies of quality control certificates issued by the resin supplier which shall include testing conducted to verify conformance with Table 10
- Certifications that the PE geomembrane and extrudate produced for the Works have the same properties and are of the same resin
- Complete description of the manufacturer's shipping, handling and storage procedures
- Manufacturer's installation procedures and requirements
- Work method statement for PE geomembrane delivery, storage, handling and installation. This shall include seaming and jointing, welding, procedures for testing and repairing, proposed handling equipment and restraining methods, and other information that shall promote proper use
- Relevant results of interface strength testing (refer Section 13).

5.3.3 Prior to installation of polyethylene geomembrane

The Contractor shall submit the following to the Superintendent for review and approval prior to installation of the PE geomembrane:

- Delivery, storage and handling log for all PE geomembrane rolls to be used in the Works, including delivery dockets, roll number and identification, delivery inspection checklist, details of storage and handling
- Proposed panel placement drawing, showing the location and reference number of all panels and expected seams, connections and penetrations, panel dimensions and layout, and the order of panel installation
- Survey of the underlying surface in accordance with Section 1.10
- Results of independent material conformance testing as provided by the CQA Engineer.

5.3.4 Following installation of polyethylene geomembrane

The Contractor shall submit the following to the Superintendent for review and approval following installation of the PE geomembrane:

- Panel placement log, providing details on panel number and associated roll number, date and time placed, condition of receiving surface, weather conditions and precipitation events, QA checks performed, and all other relevant information
- Trial weld log, recording all trial welds and testing undertaken
- Field welding log providing details of all field welding undertaken, including:
 - Weld type
 - Weld ID number
 - ID numbers of panels to be joined
 - Name of welder
 - Details of equipment used
 - Ambient air temperature
 - Geomembrane surface temperature
 - Weld temperature
 - Any problems or issues arising during welding.
- Field sampling and testing results, including non-destructive and destructive tests
- Finalised panel placement drawing showing the as-built location of all panels, seams, connections and penetrations
- Defects and repairs log, showing details of all defects identified and repairs completed.

5.4 Manufacturer's quality control

The manufacturer shall follow a quality control program, approved by the Superintendent, throughout the manufacturing of all PE geomembrane for the Works.

Manufacturer's quality control submissions shall include:

- Date of manufacture
- Lot number, roll number, length and width
- Manufacturer quality control documentation for the particular lot of resin used in the production of the rolls delivered
- Cross-referencing list delineating the corresponding resin used in the production of the rolls delivered
- Quality control program laboratory-certified reports

- The manufacturer's approved quality assurance stamp and the technician's signature.

The frequency of sampling and testing shall be in accordance with Table 10.

The Superintendent may reject any PE geomembrane rolls that have not been sampled and/or tested in accordance with this section.

All PE geomembrane rolls rejected by the Superintendent shall be removed from the site and replaced at the expense of the Contractor.

5.5 Manufacturer's quality assurance

The manufacturer shall follow a quality assurance program, approved by the Superintendent, throughout the manufacturing of all PE geomembrane for the Works.

The frequency of sampling and testing shall be in accordance with ASTM D4354.

The Superintendent may reject any PE geomembrane rolls that have not been sampled and/or tested in accordance with this section.

All PE geomembrane rolls rejected by the Superintendent shall be removed from the site and replaced at the expense of the Contractor.

5.6 Material

The PE geomembrane shall:

- Be manufactured of new, first-quality resin and shall be compounded and continuously manufactured specifically for the Works. The resin manufacturer shall certify each batch for the acceptance criteria listed in Table 10
- Comply with the acceptance criteria specified in Table 10
- Not contain more than 1 percent non-volatile pigment or fillers other than carbon black
- Not be factory seamed.

The Contractor shall supply manufacturer's quality control and assurance testing results in accordance with the testing frequencies identified in Table 10 showing that the proposed material meets the requirements of this table. Samples taken shall be representative of the whole material source and shall be evenly distributed across the roll lots.

If required by the Superintendent, a sample of the PE geomembrane shall be provided (per product) and the Superintendent and/or CQA Engineer may undertake an inspection of the manufacturer's facility. The Contractor shall cooperate fully with the Superintendent and CQA Engineer to allow this inspection to occur.

Table 10 Acceptance criteria – PE geomembrane

Property	Test method	Acceptance criteria			Minimum testing frequency
		2 mm HDPE (Smooth)	2 mm HDPE (Textured)	2 mm LLDPE (Textured)	
Resin ⁽³⁾					
Density (HDPE min., LLDPE max.)	ASTM D1505 or D792 (method B)	0.932 g/cm ³	0.932 g/cm ³	0.926 g/cm ³	per resin lot
Melt index (maximum) ⁽⁴⁾	ASTM D1238	1.0 g/10 min	1.0 g/10 min	1.0 g/10 min	per resin lot
Sheet					
Thickness (min. average)	ASTM D5199 (smooth) ASTM D5994 (textured)	2.0 mm	1.9 mm	1.9 mm	every roll
Thickness (min.) - Lowest individual of 8 of 10 readings - Lowest individual of 10 readings	ASTM D5199 (smooth) ASTM D5994 (textured)	- 1.8 mm	1.8 mm 1.7 mm	1.8 mm 1.7 mm	every roll
Asperity height (min. average) ⁽⁵⁾	ASTM D7466	-	0.4 mm	0.4 mm	every 2 nd roll
Density (HDPE min., LLDPE max.)	ASTM D1505 or D792 (method B)	0.94 g/cm ³	0.94 g/cm ³	0.939 g/cm ³	90,000 kg
Tensile properties (min. average) ⁽⁶⁾ - yield strength - break strength - yield elongation - break elongation	ASTM D6693	29 N/mm 53 N/mm 12% 700%	29 N/mm 21 N/mm 12% 100%	- 21 N/mm - 250%	9,000 kg
2% modulus (max.)	ASTM D5323	-	-	840 N/mm	per each formulation
Tear resistance (min. average)	ASTM D1004	249 N	249 N	200 N	20,000 kg
Puncture resistance (min. average)	ASTM D4833	640 N	534 N	400 N	20,000 kg
Stress crack resistance ⁽⁷⁾	ASTM D5397	600 hours	600 hours	-	per each formulation
Axi-symmetric break resistance (min.)	ASTM D5617	-	-	30%	per each formulation
Dimensional stability	ASTM D1204	<u>±2%</u>	<u>±2%</u>	<u>±2%</u>	90,000 kg

³ Base resin density without carbon black or additives added

⁴ Conducted at 190°C with 2.16 kg mass applied

⁵ Alternate the measurement side for double sided textured sheet

⁶ Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of five test specimens each direction:

- HDPE yield elongation is calculated using a gage length of 33 mm
- HDPE break elongation is calculated using a gage length of 50 mm
- LLDPE break elongation is calculated using a gage length of 50 mm at 50 mm/min

⁷ The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials. The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing

Property	Test method	Acceptance criteria			Minimum testing frequency
		2 mm HDPE (Smooth)	2 mm HDPE (Textured)	2 mm LLDPE (Textured)	
Carbon black content (range)	ASTM D4218 ⁽⁸⁾	2 to 3%	2 to 3%	2 to 3%	9,000 kg (HDPE) or 20,000 kg (LLDPE)
Carbon black dispersion (category) ⁽⁹⁾	ASTM D5596	Cat 1 or 2 only	Cat 1 or 2 only	Cat 1 or 2 only	20,000 kg
Oxidative induction time (OIT) (min. average) ⁽¹⁰⁾ - standard OIT <u>AND</u> - high pressure OIT	ASTM D3895	100 min	100 min	100 min	90,000 kg
	ASTM D5885	400 min	400 min	400 min	
Oven aging at 85°C (min. average) - standard OIT <u>AND</u> - high pressure OIT	ASTM D5721				per each formulation
	ASTM D3895	55% retained at 90 days	55% retained at 90 days	35% retained at 90 days	
	ASTM D5885	80% retained at 90 days	80% retained at 90 days	60% retained at 90 days	
UV resistance (min. average) ⁽¹¹⁾ - high pressure OIT ⁽¹²⁾	ASTM D7238	50% retained after 1600 hours	50% retained after 1600 hours	35% retained after 1600 hours	per each formulation
	ASTM D5885				

5.7 Roll and sample identification

All PE geomembrane rolls and samples shall be identified in accordance with ASTM D4873.

Each roll or panel shall carry a label which identifies, as a minimum:

- Product name, grade and name of manufacturer
- Date of manufacture, batch number
- Material thickness
- Roll number
- Roll length
- Roll weight
- Roll width
- Handling guidelines
- Reference numbers to raw material batch and laboratory certified reports
- The manufacturer's approved quality assurance stamp and the technician's signature.

⁸ Other methods such as ASTM D1603 (tube furnace) or ASTM D6370 (TGA) are acceptable if an appropriate correlation to ASTM D4218 (muffle furnace) can be established

⁹ Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 10 in categories 1 or 2 only, none in category 3

¹⁰ Samples to be evaluated at 30 and 60 days to compare with the 90 day response

¹¹ The condition of the test should be 20 hour UV cycle at 75°C followed by 4 hour condensation at 60°C

¹² UV resistance is based on percent retained value regardless of the original high pressure OIT value

The Superintendent may reject any PE geomembrane rolls or samples that have not been identified in accordance with this section.

All PE geomembrane rolls rejected by the Superintendent shall be removed from the site and replaced at the expense of the Contractor.

5.8 Delivery, storage and handling

The Contractor shall prepare a work method statement for delivery, storage, handling and installation of PE geomembrane, including repair methods (refer Appendix A). The work method statement shall be submitted to the Superintendent for review and comment prior to delivery of the PE geomembrane to site.

The delivery, storage and handling components of the work method statement shall be developed in accordance with the guidance provided below:

- Delivery, storage and handling of all PE geomembrane rolls and samples shall be undertaken in accordance with the manufacturer's instructions and ASTM D4873 as a minimum
- Rolls shall be delivered to site, handled and stored in such a manner that no damage occurs to the rolls
- Roll cores shall be sufficiently strong to ensure that they do not deflect by more than half their diameter during delivery, storage and handling
- Rolls shall be stored in a location away from construction traffic but sufficiently close to the installation area to minimise handling. The storage area shall be level, dry, well-drained and stable, and shall protect the product from precipitation, chemicals, excessive heat, UV radiation, standing water, vandalism and animals
- PE geomembrane roll stacks shall be limited to the height at which installation personnel can safely manoeuvre the handling equipment. The recommended maximum stack height is three rolls
- Rolls shall be handled using a spreader stinger bar. The bar shall be capable of supporting the full weight of the rolls without significant bending. Under no circumstances shall the rolls be dragged, lifted from one end, lifted in the middle of the roll, lifted with the forks of a forklift or pushed to the ground from the delivery vehicle. The Contractor may nominate alternate handling equipment and plant for approval by the Superintendent as part of their work method statement
- The Contractor shall inspect all PE geomembrane rolls for defects and damage upon delivery.

The Superintendent may reject any PE geomembrane rolls that have not been delivered, stored or handled in accordance with this section.

All PE geomembrane rolls rejected by the Superintendent shall be removed from the site and replaced at the expense of the Contractor.

5.9 Preparation of receiving surface

Prior to placement of PE geomembrane, the underlying geosynthetic shall be free of:

- Any of debris, roots, angular material (such as sharp rocks), or loose, coarse-grained material on or immediately below the underlying geosynthetic
- Excessive wrinkles preventing intimate contact between the underlying geosynthetic and PE geomembrane

- Any GCL panels that have hydrated prematurely without confinement
- Excessive bentonite powder and/or paste on the surface of any GCL panels.

Placement of PE geomembrane shall not proceed until the underlying geosynthetic has been inspected and approved by the Superintendent. The overlying PE geomembrane shall be placed immediately following acceptance of the underlying geosynthetic panels to protect the underlying geosynthetic.

The Superintendent may reject any underlying geosynthetic or underlying foundation material which does not meet these requirements. Any GCL rejected by the Superintendent shall be removed from the site at the expense of the Contractor. Any rejected foundation material shall be removed and/or remediated to the satisfaction of the Superintendent.

5.10 Installation

5.10.1 General

The Contractor shall prepare a work method statement for delivery, storage, handling and installation of PE geomembrane (refer Appendix A). The work method statement shall be submitted to the Superintendent for review and comment prior to delivery of the PE geomembrane to site.

The installation component of the work method statement shall be developed in accordance with the guidance provided below.

The Superintendent may reject any PE geomembrane rolls that have not been installed in accordance with this section.

All PE geomembrane rolls rejected by the Superintendent shall be removed from the site and replaced at the expense of the Contractor.

5.10.2 Weather conditions

The Contractor shall consider the weather conditions on a daily basis to confirm they are suitable for placement of PE geomembrane.

PE geomembrane shall not be placed or seamed:

- If moisture prevents proper subgrade preparation, panel placement and/or panel seaming
- During precipitation, during hail, during periods of excessive fog, during periods of excessive dust, in standing water, on excessively wet surfaces, in the presence of excess moisture (such as dew and/or ponded water)
- During periods of excessive winds (>30 kph) or when gusting wind conditions interfere with handling operations
- When sheet temperatures are lower than 0° or higher than 65° as measured by a calibrated infrared thermometer or surface thermocouple.

5.10.3 Traffic

Equipment used shall not damage the PE geomembrane by handling, trafficking, leakage of hydrocarbons, or by other means.

No vehicle shall be allowed to travel directly on the PE geomembrane unless approved by the Superintendent. Prior to approval, the Contractor shall provide the Superintendent the following information:

- Guidance from the manufacturer on suitable plant for trafficking for the proposed PE geomembrane and confirmation that the Contractor shall only use this plant
- Guidance from the manufacturer on suitable trafficking method for the proposed PE geomembrane and confirmation that the Contractor shall only use this trafficking method
- Certification from the manufacturer that the above trafficking method and plant shall not void the warranty for the proposed PE geomembrane.

5.10.4 Placement

PE geomembrane shall be placed in accordance with the following:

- The PE geomembrane shall be placed and seamed in accordance with this Specification, the Contract Drawings, the approved work method statement and the manufacturer's instructions. Any contradictions shall be clarified with the Superintendent
- Prior to placement, each roll shall be inspected by the Contractor for damage and/or defects, including tears, abrasion, indentation, cracks, thin spots or any other faults or defects. If damage or defects are identified, the roll shall be inspected by the Superintendent and approved or rejected
- PE geomembrane shall be protected from damage due to exposure to sunlight, dirt, dust and other hazards
- PE geomembrane shall be placed such that the panels are anchored at the crest of the slope and form a continuous layer down the side walls and slopes and across the base
- The arrangement of the PE geomembrane panels shall be in accordance with the approved panel placement drawing and any changes approved by the Superintendent
- Installation shall progress from the highest elevations to the lowest
- PE geomembrane rolls shall be placed in an orderly fashion which shall minimise or prevent surface water from flowing below previously installed PE geomembrane
- PE geomembrane shall not be allowed to 'bridge over' voids or low areas. The PE geomembrane shall be placed to allow intimate contact with the subgrade or underlying geosynthetic
- PE geomembrane shall be installed without undergoing excessive buckling, wrinkling or tensioning
- PE geomembrane shall not be dragged across an unprepared surface. If the PE geomembrane is dragged across an unprepared surface, it shall be inspected for defects and repaired or rejected if necessary
- Where there is a geosynthetic layer below, the installation of the PE geomembrane shall be undertaken in a matter so as not to damage the underlying layer
- Sandbags or equivalent ballast shall be used as necessary to temporarily hold the PE geomembrane in position and prevent uplift by wind. In case of high winds, continuous loading shall be placed along edges of panels to minimise wind flow under the panels. Sandbag material shall be sufficiently close-knit to prevent soil fines from working through the bags and discharging on the PE geomembrane
- Only those PE geomembrane rolls which can be seamed or permanently anchored on at least two sides on the same day shall be placed on a daily basis. All other sides shall be temporarily anchored

- PE geomembrane installed on slopes shall be fixed in anchor trenches as shown on the Contract Drawings and Section 2.15. PE geomembrane panels shall be anchored as soon as possible. The Geosynthetic Installer shall program anchor trenches backfilling when the temperature is coolest to minimise effects of material expansion
- Personnel working on the PE geomembrane shall not smoke, wear damaging shoes, excessively traffic or engage in other activities which may damage the PE geomembrane. PE geomembrane in heavy traffic areas shall be protected by a geosynthetic overlay
- PE geomembrane shall be cut from each roll with an approved hook blade knife with flat zones on each end
- PE geomembrane rolls shall be freely suspended during placement
- The method used to unroll the PE geomembrane shall not cause bridging, excessive wrinkles, scores, scratches and/or crimps
- Folds and wrinkles caused by PE geomembrane panel placement or thermal expansion shall be minimised
- After placement, the PE geomembrane shall be free of excessive buckles, wrinkles, ripples, creases, folds and irregular stressing before the overlying cover material or geosynthetic is placed.

5.10.5 Seaming

PE geomembrane shall be seamed in accordance with the following guidance.

General

- The PE geomembrane shall be field seamed into a continuous sheet across the Works by using either dual hot wedge fusion welding or extrusion welding seams
- Dual hot wedge fusion welding shall be the preferred method of welding and shall be used for primary welds between adjacent PE geomembrane panels. Extrusion welding shall only be used for detailed work, repair work, or in areas inaccessible for dual hot wedge fusion welding (where approved by the Superintendent)
- PE geomembrane placement shall be limited to that which can be seamed in one day
- Trail seams shall be completed each day as per Section 5.11
- All seams shall be 'shingled' down-slope to promote runoff (roof tile fashion)
- All field seaming operations shall be supervised by the Seaming Foreman and no field seams shall be made without the Seaming Foreman present
- Prior to welding, the prepared weld surfaces shall be free of dust, dirt, debris, markings foreign material and any other potential contaminants that would inhibit welding. Where contamination does occur, the prepared surfaces shall be thoroughly cleaned and the weld completed
- There shall be no free moisture in the weld area during welding. If free moisture is located in the weld area, mitigation measures during seaming shall be employed as approved by the Superintendent
- The Geosynthetic Installer shall have an independently calibrated handheld temperature measuring device to confirm the 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

- Any electric generators used in welding shall be placed on a smooth base such that no damage occurs to the underlying PE geomembrane
- Adjacent to anchor trenches, seaming shall extend up the panels a minimum of 300 mm past the crest of the anchor trench.

Weld locations

PE geomembrane panel placement shall take into consideration the site geometry including:

- Field seams shall be orientated parallel to the line of maximum slope
- For batters with a 10% grade or steeper, transverse (cross-slope) seams shall not be permitted
- No cross seams shall be allowed within 1,500 mm of the toe of any slope
- In corners and odd shaped geometric locations, the number and total length of field seams shall be minimised
- Seams shall not be located at low points
- All cross seams shall be offset at least 600 mm from the cross seam of the adjacent panel and be extrusion or wedge welded where they intersect
- All primary welds used to connect panel ends to sheets shall form T-joints (tees). These T-connections shall have a distance of at least 500 mm. The welding seams of the PE geomembrane cannot cross (no cruciform connections).

Dual hot wedge fusion welding

- The dual hot wedge fusion welding shall be conducted using the split head wedge fusion weld method, fusing the upper and lower overlapped PE geomembrane panels
- The welding equipment shall be capable of continuously monitoring and controlling the temperature in the zone of contact where the machine is actually fusing the PE geomembrane so as to ensure that changes to environmental conditions shall not adversely affect the integrity of the weld
- Seams shall have a finished overlap of a minimum of 150 mm for dual hot wedge fusion welding but in any event, sufficient overlap shall be provided to allow peel tests to be performed on the seam
- The dual hot wedge fusion welding shall form 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.

Extrusion welding

- The extruder may be a combination sheet pre-heat and extruder type or a combination dynamic mixing assembly and extruder type
- The extrudate shall be manufactured from the same resin type used in the manufacture of the relevant PE geomembrane being welded. All physical properties shall be identical to those possessed by the raw PE geomembrane material. The Geosynthetic Installer shall provide certification from the manufacturer that the relevant PE geomembrane and extrudate produced for the Works have the same properties and are of the same resin for each batch
- During welding, the Geosynthetic Installer shall be responsible for regularly checking, calibrating and recording of:

- Preheat air flow and temperature at the nozzle
- Extrudate flow and temperature at the barrel outlet
- Seams shall have a finished overlap of a minimum of 75 mm for extrusion welding but in any event, sufficient overlap shall be provided to allow peel tests to be performed on the seam
- The minimum width of the surface extruded bead shall be 30 mm
- Prior to welding, oxidation by-products shall be removed from the weld area by grinding or buffing. Grind marks shall not be deeper than 10% of the PE geomembrane thickness. Seam grinding shall be completed less than one hour before seam welding. The end of welds more than five minutes old shall be ground to expose new material before restarting a weld
- Prior to welding, the extruder shall be purged until all the heat-degraded extrudate is removed
- Welding shall be undertaken in one direction only
- A smooth insulating plate or fabric shall be placed beneath the hot welding apparatus after use.

Pipe boots

- Pipe boots may be constructed in the factory or in the field in accordance with the detail shown on the Contract Drawings from relevant PE geomembrane conforming to this Specification.

5.11 Trial seams

Trial seams shall be performed on fragment pieces of PE geomembrane to verify that seaming conditions are satisfactory and to supply test specimens for the CQA program.

Trial seams shall be conducted at the beginning of each seaming period and at least once each four hours for each seaming apparatus used that day. Trial seams shall be repeated if any welding stoppage exceeds one hour and if weather conditions change. Trial seams shall be made under the identical conditions as the actual seams.

Each seamer shall make at least one trial seam each day for each seam method for each seaming equipment apparatus to be used that day.

Trial seams shall be a minimum of 1,350 mm by 300 mm with seam centred.

The trial seam sample shall be cut into three subsamples (450 mm by 300 mm with seam centred).

The two subsamples from each end shall immediately be tested onsite for peel and shear strength in accordance with GM19.

If either specimen does not meet the acceptance criteria, the seamer and seaming apparatus and/or methods shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive trial seams are successful.

The central portion of the trial seam sample shall be labelled and provided to the CQA Engineer for destructive testing at the CQA Engineer's Independent Testing Firm. A minimum one trial seam sample per day shall be subjected to destructive testing. The Superintendent may reduce the frequency of trial seam destructive testing at the CQA Engineer's Independent Testing Firm, in consultation with the CQA Engineer, if the field tensiometer appears adequate for assuring trial seam quality.

If a trial seam sample records a non-conforming result for a test conducted at the CQA Engineer's Independent Testing Firm, a destructive test seam sample shall be taken by the Contractor from the seams completed by the seamer during the shift related to the considered trial seam. These samples shall be forwarded to the CQA Engineer's Independent Testing Firm by the Contractor and, if they recording non-conforming test results, the length of seam represented by the test sample shall be rejected.

The conditions of this section are considered as met for a given seam if a destructive seam test sample has already been taken from the considered seam(s).

5.12 Field seam sampling and testing

5.12.1 General

Testing parameters, requirements and anticipated schedules shall be continuously reviewed by the Contractor to ensure that adequate personnel and proper equipment shall be available.

Field seam sampling and testing shall be performed after seaming to verify that the mechanical characteristics of the seams do not compromise the PE geomembrane integrity.

Test results shall be provided to the Superintendent in accordance with Section 1.7

5.12.2 Destructive seam testing

Destructive seam samples shall be taken and tested in accordance with Table 11.

Repair patches shall be extrusion welded over the areas where destructive seam samples have been taken and shall be subjected to non-destructive testing.

The location of each destructive seam sample shall be up to the discretion of the Superintendent and CQA Engineer and designated on a copy of the panel placement drawing, along with the date and time of sampling and the sample number.

Destructive test samples shall be a minimum of 1350 mm by 300 mm with seam centred.

The destructive seam sample shall be cut into 3 subsamples (450 mm by 300 mm with seam centred).

The two subsamples from each end shall be taken and tested on-site for peel and shear strength.

If both on-site subsamples meet the acceptance criteria of Table 11, the central portion of the test sample shall be labelled and provided to the CQA Engineer for destructive testing at the CQA Engineer's Independent Testing Firm.

If either on-site or off-site test results do not meet the acceptance criteria listed in Table 11, the length of seam represented by the test sample shall be rejected.

Table 11 Destructive seam testing requirements

Test description	Test method	Minimum test frequency ⁽¹³⁾	Acceptance criteria ⁽¹⁴⁾
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¹³ A minimum of one series of destructive tests shall be performed each day that seaming is performed

¹⁴ All destructive test results shall be based on Film-Tear Bond (FTB) criteria. All samples which produce seam failures shall be considered unacceptable

Peel strength ⁽¹⁵⁾	ASTM D6392	1 test per 150 m ⁽¹⁶⁾ (or part thereof)	As per GM19
Shear strength	ASTM D6392	1 test per 150 m ⁽¹⁷⁾ (or part thereof)	As per GM19

5.12.3 Non-destructive seam testing

All seams shall be non-destructively tested over the entire length of seam by at least one of the methods in Table 12. The tests shall be undertaken no earlier than one hour after welding. In addition to the above tests, the welds shall be visually inspected to assess the quality of the workmanship and the appearance of the welded seam.

Table 12 Non-destructive seam testing requirements

Test description	Test method	Minimum test frequency	Acceptance criteria
Vacuum box	ASTM D5641	All seams shall be tested by at least one of these three test methods as appropriate	No imperfections
Air pressure ⁽¹⁸⁾	ASTM D5820		Refer Table 13
Spark test	ASTM D6365		No spark

Table 13 Air pressure test schedule

Geomembrane thickness	Minimum pressure	Maximum pressure	Maximum pressure differential ⁽¹⁹⁾
2.0 mm	210 kPa	250 kPa	10 kPa

5.12.4 Pipe boot seam testing

All pipe boot seams shall be spark tested with acceptable pipe boots showing no spark.

Alternative testing methods may be allowed at the discretion of the Superintendent.

5.12.5 Non-conforming test results

If any test specimen does not meet the acceptance criteria listed, the test series shall be considered unacceptable and all material or length of seam represented by the test series shall be rejected. The Geosynthetic Installer may, at no additional compensation, take additional samples for quality control testing in an attempt to minimise the amount of material represented by the non-conforming test result.

In the event of discrepancies between the CQA Engineer's test results and the Contractor's test results, the Contractor shall be responsible for arranging a third independent testing firm to verify test results.

An acceptable length of seam shall be defined as a length of seam which lies between conforming destructive test locations and has passed non-destructive seam testing.

¹⁵ Peel strength testing shall be performed on both Weld A and Weld B

¹⁶ When ambient air temperatures during seaming operations are less than 10°C, testing frequency shall be increased to one test per 75 linear meters

¹⁷ When ambient air temperatures during seaming operations are less than 10°C, testing frequency shall be increased to one test per 75 linear meters

¹⁸ All hypodermic needle punctures shall be repaired as per the requirements of this Specification

¹⁹ Observe and record the pressure 5 min after the initial reading. If the loss of pressure exceeds that shown, or if the pressure does not stabilize, the faulty area should be located and repaired

5.12.6 Field testing summary

The Geosynthetic Installer shall prepare a field testing summary for all installed PE geomembrane. For each PE geomembrane layer, a separate copy of the panel placement drawing shall be utilised for this summary and shall indicate the PE geomembrane layer represented. On each sheet, the following information shall be recorded:

- The location, date, sample number and test result (conforming/non-conforming) of each destructive test series
- The location, identification number and date of each non-destructive air pressure seam test including the length of the tested seam and the result of the test (conforming/non-conforming)
- The location, date and lengths of non-destructive vacuum box testing performed on a daily basis and the result of the tests (conforming/non-conforming)
- The location, identification number and date of each non-destructive spark test including the length of the tested seam and the result of the test (conforming/non-conforming).

5.13 Defects and repairs

The Contractor and shall be responsible for inspecting the placed PE geomembrane to identify any damage or faults in the material. The Superintendent and/or CQA Engineer may also undertake inspections of the placed PE geomembrane to identify any damage or faults in the material. Any areas of PE geomembrane damaged during installation shall be repaired by the Contractor. All repairs shall be verified by the Superintendent.

The Contractor shall prepare a work method statement for delivery, storage, handling and installation of PE geomembrane (refer Appendix A). The work method statement shall be submitted to the Superintendent for review and comment prior to delivery of the geomembrane to site.

The installation component of the work method statement shall include work methods for defects and repairs, developed in accordance with the guidance provided below:

- All repairs shall be undertaken in accordance shall be undertaken in accordance with this Specification, the approved work method statement and the manufacturer's instructions. Any contradictions shall be clarified with the Client's Representative. All repairs shall be verified by the Client's Representative
- Patches and cap strips shall have rounded edges (minimum radius of 75 mm), shall be made of the same geomembrane and shall extend a minimum of 150 mm beyond the edge of defects. All patches shall be of the same compound and thickness as the PE geomembrane being patched over. Patches shall be seamed using extrusion (fusion) welding
- Punctures, pin holes, blisters, small tears and localised imperfections shall be repaired using a patch
- Large tears and lengths of seam shall be repaired using a cap strip. No reseaming over existing seams shall be permitted
- Tears which lie on slopes greater than 5% or which lie in areas of stress and have sharp ends shall have all sharp ends rounded prior to repair
- The PE geomembrane below large patches and cap strips shall be cut as necessary to prevent moisture or gas collection between sheets

- Excessive wrinkles which exist at the end of seaming operations and which may become creased during backfilling shall be cut and resealed. Excessive wrinkles shall be defined as a wrinkle which at the time of covering, and in the opinion of the Superintendent, meets any of the following criteria:
 - Is nominally >200 mm in height
 - May fold during backfilling
 - May adversely impede the flow along the surface of the geomembrane
- 'Fishmouths' or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut 'fishmouths' or wrinkles shall be sealed and any portion where the overlap is inadequate shall then be patched with an oval or round patch of the same geomembrane extending a minimum of 150 mm beyond the cut in all directions. All corners of the patch shall be rounded with a 25 mm minimum radius
- All repair seams shall be made in accordance with the requirements of Section 5.10.5
- Each repair shall be required to pass non-destructive tests (refer Section 5.12.3). Large cap strips may require destructive testing (refer Section 5.12.2), as directed by the Superintendent.

The Contractor shall submit to the Superintendent for review a log containing details of any defects identified and repairs carried out.

5.14 Acceptance

The Contractor shall retain all ownership and responsibility for all PE geomembrane until final acceptance of all work under this Contract by the Principal.

PE geomembrane shall be accepted by the Principal when all of the following conditions are met:

- Required submittals are provided by the Contractor to the Superintendent and approved
- Adequacy of all field seams, penetrations and repairs is verified by the Superintendent
- The electrical leak location survey has been completed and all required repairs have been completed by the Contractor
- Details of all defects identified and repairs performed have been provided by the Contractor to the Superintendent and approved
- The CQA Engineer has provided the Superintendent with a recommendation that the conditions of final acceptance have been met
- The Superintendent has inspected and approved the finished surface/s.

6. Geotextile

6.1 General

This section contains the technical requirements for geotextile.

The Superintendent may reject any geotextile that does not meet or exceed the requirements of this section.

Any geotextile rejected by the Superintendent shall be removed from the site and replaced at the expense of the Contractor.

6.2 Standards

6.2.1 Australian Standards

Relevant Australian standards are as follows:

- 2001.2.3 Methods of test for textiles - Physical tests - Determination of breaking force and extension of textile fabrics
- 3704 Geosynthetics-Glossary of Terms
- 3705 Geotextiles-Identification, marking and general data
- 3706.3 Determination of tearing strength - Trapezoidal method
- 3706.4 Determination of burst strength - California bearing ratio (CBR) - Plunger method
- 3706.7 Determination of pore-size distribution - Dry-sieving method
- 3706.9 Determination of permittivity, permeability and flow rate

6.2.2 American Society for Testing and Materials Standards

Relevant American Society for Testing and Material (ASTM) standards are as follows:

- D4354 Standard Practice for Sampling of Geosynthetics and Rolled Erosion Control Products (RECPs) for Testing
- D4355 Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water
- D4439 Standard Terminology for Geosynthetics
- D4491 Standard Test Methods for Water Permeability of Geotextiles by Permittivity
- D4533 Standard Test Method for Trapezoid Tearing Strength of Geotextiles
- D4632 Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
- D4751 Standard Test Method for Determining Apparent Opening Size of a Geotextile
- D4833 Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products
- D4873 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples
- D5199 Standard Test Method for Measuring the Nominal Thickness of Geosynthetics
- D5514 Standard Test Method for Large Scale Hydrostatic Puncture Testing of Geosynthetics

- D6767 Standard Test Method for Pore Size Characteristics of Geotextiles by Capillary Flow Test

6.2.3 Geosynthetic Research Institute Standards

Relevant Geosynthetic Research Institute (GRI) standards are as follows:

- GT12(a) Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials
- GT13(a) Test Methods and Properties for Geotextiles Used as Separation Between Subgrade Soil and Aggregate

6.3 Submittals

6.3.1 Prior to selection of the geotextile manufacturer

The Contractor shall submit the following to the Superintendent for review and approval prior to selection of a geotextile manufacturer (per manufacturer and product):

- Product manufacturer
- Product name
- Material data sheet showing the material properties of the proposed geotextile
- Manufacturer's quality control and assurance procedures.

6.3.2 Prior to delivery of geotextile to site

The Contractor shall submit the following to the Superintendent for review and approval prior to delivery of geotextile to site (per geotextile product):

- Manufacturer's certificate of compliance outlining conformance with the requirements of this Specification
- Manufacturer's quality control and assurance test results
- Certification that the geotextile supplied for this work was manufactured as consecutive rolls from a single lot or from consecutive lots. If geotextile is not manufactured from consecutive lots, the manufacturer shall provide certification of quality and consistency of the product characteristics
- Statement on the origin and identification of the fibres and polymers, including the supplier's name and production plant
- Complete description of the manufacturer's shipping, handling and storage procedures
- Manufacturer's installation procedures and requirements
- Work method statement for geotextile delivery, storage, handling and installation. This shall include seaming and jointing, procedures for testing and repairing, proposed handling equipment and restraining methods, and other information that shall promote proper use
- For protection geotextiles, the results of compression testing (refer Section 6.7)
- Relevant results of interface strength testing (refer Section 13).

6.3.3 Prior to installation of geotextile

The Contractor shall submit the following to the Superintendent for review and approval prior to installation of the geotextile:

- Delivery, storage and handling log for all geotextile rolls to be used in the Works, including delivery dockets, roll number and identification, delivery inspection checklist, details of storage and handling
- Proposed panel placement drawing, showing the location and reference number of all panels and expected seams, connections and penetrations, panel dimensions and layout, and the order of panel installation
- Results of independent material conformance testing as provided by the CQA Engineer.

6.3.4 Following installation of geotextile

The Contractor shall submit the following to the Superintendent for review and approval following installation of the geotextile:

- Panel placement log, providing details on panel number and associated roll number, date and time placed, condition of receiving surface, weather conditions and precipitation events, QA checks performed, and all other relevant information
- Finalised panel placement drawing showing the as-built location of all panels, seams, connections and penetrations
- Defects and repairs log, showing details of all defects identified and repairs completed.

6.4 Manufacturer's quality control

The manufacturer shall follow a quality control program, approved by the Superintendent, throughout the manufacturing of all geotextile for the Works.

Manufacturer's quality control submissions shall include:

- Date of manufacture
- Lot number, roll number, length and width
- Polymer quality control documentation used in the production of the rolls delivered
- Fibre quality control documentation used in the production of the rolls delivered
- Geotextile manufacturer quality control documentation for the particular lots of geotextiles used in the production of the rolls delivered
- Quality control program laboratory-certified reports
- The manufacturer's approved quality assurance stamp and the technician's signature.

The frequency of sampling and testing shall be in accordance with Table 10.

The Superintendent may reject any geotextile rolls that have not been sampled and/or tested in accordance with this section.

All geotextile rolls rejected by the Superintendent shall be removed from the site and replaced at the expense of the Contractor.

6.5 Manufacturer's quality assurance

The manufacturer shall follow a quality assurance program, approved by the Superintendent, throughout the manufacturing of all geotextile for the Works.

The frequency of sampling and testing shall be in accordance with ASTM D4354.

The Superintendent may reject any geotextile rolls that have not been sampled and/or tested in accordance with this section.

All geotextile rolls rejected by the Superintendent shall be removed from the site and replaced at the expense of the Contractor.

6.6 Material

The geotextile shall:

- Be manufactured of new, first-quality products manufactured for the Works
- Certified as needle-free by the manufacturer
- Comply with the acceptance criteria specified in Table 10.

The Contractor shall supply manufacturer's quality control and assurance testing results in accordance with the testing frequencies identified in Table 10 showing that the proposed material meets the requirements of this table. Samples taken shall be representative of the whole material source and shall be evenly distributed across the roll lots.

If required by the Superintendent, a sample of the geotextile shall be provided (per product) and the Superintendent and/or CQA Engineer may undertake an inspection of the manufacturer's facility. The Contractor shall cooperate fully with the Superintendent and CQA Engineer to allow this inspection to occur.

Table 14 Acceptance criteria – geotextile

Property	Test method	Acceptance criteria		Minimum testing frequency
		Separation geotextile	Protection geotextile ⁽²⁰⁾	
Woven/Non-woven	-	Non-woven	Non-woven	-
Polymer	-	Polyester	Polyester	-
Formation	-	Needle punched	Needle punched	-
Mass per unit area (MARV)	AS 3706.1	-	1,080 g/m ²	every 2,500 m ²
Grab tensile strength (MARV)	AS 3706.2b	1,100 N	2,250 N	every 5,000 m ²
Grab elongation (MARV)	AS 3706.2b	50%	50%	every 5,000 m ²
Trapezoidal tear strength (MARV)	AS 3706.3	400 N	960 N	every 5,000 m ²
CBR burst strength (MARV)	AS 3706.4	2,250 N	7,560 N	every 5,000 m ²
Permittivity (MARV)	AS 3706.9	0.5 s ⁻¹	-	every 5,000 m ²
Pore size (MaxARV)	ASTM D6767	120 µm	-	every 5,000 m ²
UV stability (typical) ⁽²¹⁾	ASTM D4355	70%	70%	per each formulation

6.7 Compression testing

The protection geotextile shall be capable of limiting strain within the underlying PE geomembrane to less than 6%.

²⁰ Preliminary specification only. Refer Section 6.7

²¹ Strength retained after 500 hours

The proposed protection geotextile shall be assessed by the Contractor by undertaking compression testing in accordance ASTM D5514 at 250 kPa, with the proposed overlying drainage aggregate and proposed underlying PE geomembrane(s). The results of the compression testing shall be provided to the Superintendent to verify the proposed protection geotextile can meet the PE geomembrane strain acceptance criteria.

The Contractor shall provide manufacturer's quality control and assurance test results for the protection geotextile material used in compression testing (tested for all the parameters identified in Table 10) to confirm the material properties of the geotextile. In addition to this requirement, the Superintendent may organise independent testing of this protection geotextile to verify the material properties of the geotextile. The Contractor shall provide sufficient samples of the material to allow this testing to occur.

If requested by the Contractor, alternate protection arrangements may be considered at the discretion of the Superintendent.

A preliminary specification for the protection geotextile is included in Table 10 for undertaking bidding purposes only.

6.8 Roll and sample identification

All geotextile rolls and samples shall be identified in accordance with AS 3705.

Each roll or panel shall carry a label which identifies, as a minimum:

- Product name, grade and name of manufacturer
- Date of manufacture, batch number
- Material thickness
- Roll number
- Roll length
- Roll weight
- Roll width
- Handling guidelines
- Reference numbers to raw material batch and laboratory certified reports
- The manufacturer's approved quality assurance stamp and the technician's signature.

The Superintendent may reject any geotextile rolls or samples that have not been identified in accordance with this section.

All geotextile rolls rejected by the Superintendent shall be removed from the site and replaced at the expense of the Contractor.

6.9 Delivery, storage and handling

The Contractor shall prepare a work method statement for delivery, storage, handling and installation of geotextile, including repair methods (refer Appendix A). The work method statement shall be submitted to the Superintendent for review and comment prior to delivery of the geotextile to site.

The delivery, storage and handling components of the work method statement shall be developed in accordance with the guidance provided below:

- Delivery, storage and handling of all geotextile rolls and samples shall be undertaken in accordance with the manufacturer's instructions and ASTM D4873 as a minimum

- Rolls shall be delivered to site, handled and stored in such a manner that no damage occurs to the rolls
- Rolls shall be wrapped with weather and moisture-proof wrapping to prevent any contact with water prior to installation. In the event that it is suspected that roll/s may have come into contact with water, the Superintendent shall inspect the moisture content of the effected roll/s and reject the roll/s if they are damaged beyond use. All geotextile rolls rejected by the Superintendent shall be removed from the site and replaced at the expense of the Contractor
- Roll cores shall be sufficiently strong to ensure that they do not deflect by more than half their diameter during delivery, storage and handling
- Rolls shall be stored in a location away from construction traffic but sufficiently close to the installation area to minimise handling. The storage area shall be level, dry, well-drained and stable, and shall protect the product from precipitation, chemicals, excessive heat, UV radiation, standing water, vandalism and animals
- Geotextile roll stacks shall be limited to the height at which installation personnel can safely manoeuvre the handling equipment. The recommended maximum stack height is three rolls
- Rolls shall be handled using a spreader stinger bar. The bar shall be capable of supporting the full weight of the rolls without significant bending. Under no circumstances shall the rolls be dragged, lifted from one end, lifted in the middle of the roll, lifted with the forks of a forklift or pushed to the ground from the delivery vehicle. The Contractor may nominate alternate handling equipment and plant for approval by the Superintendent as part of their work method statement
- The Contractor shall inspect all geotextile rolls for defects and damage upon delivery.

The Superintendent may reject any geotextile rolls that have not been delivered, stored or handled in accordance with this section.

All geotextile rolls rejected by the Superintendent shall be removed from the site and replaced at the expense of the Contractor.

6.10 Preparation of receiving surface

Prior to placement of geotextile, the receiving surface shall exhibit the following characteristics:

- The surface shall be smooth, flat, firm and unyielding to the satisfaction of the Superintendent
- The surface shall not exhibit visible deformation, rutting, yielding and/or show signs of distress or instability during final proof rolling (if required)
- The surface shall be free of debris, roots, angular material (such as sharp rocks), desiccation cracks, abrupt breaks, indentations, sudden changes in grade, defects and/or imperfections that may result in damage to the overlying materials
- No loose, coarse-grained material shall remain on the surface. If required, the surface shall be raked or graded to remove any material penetrating out of the surface greater than 10 mm
- The surface shall promote drainage and excessive water shall not be allowed to pond on the surface

- The surface shall not be pebbly, tracked, rutted or otherwise disturbed by the equipment deploying overlying materials or other traffic. Pockets, holes, or discontinuities shall be repaired
- All construction stakes, hubs, or other items used for grade control shall be removed and any voids filled. Any unsuitable material shall be over-excavated to a depth of 100 mm and replaced with approved material
- The surface shall be maintained at sufficient moisture content to prevent desiccation during the Works.

Where geotextile is being placed over a geosynthetic material, the underlying geosynthetic shall be free of excessive wrinkles preventing intimate contact between the underlying geosynthetics and/or foundation materials.

The receiving surface shall be surveyed as per the requirements of Section 1.10.

Placement of geotextile shall not proceed until the receiving surface has been inspected and approved by the Superintendent.

The Superintendent may reject any underlying geosynthetic or underlying foundation material which does not meet these requirements. Any geosynthetic rejected by the Superintendent shall be removed from the site at the expense of the Contractor. Any rejected foundation material shall be removed and/or remediated to the satisfaction of the Superintendent.

6.11 Installation

6.11.1 General

The Contractor shall prepare a work method statement for delivery, storage, handling and installation of geotextile (refer Appendix A). The work method statement shall be submitted to the Superintendent for review and comment prior to delivery of the geotextile to site.

The installation component of the work method statement shall be developed in accordance with the guidance provided below.

The Superintendent may reject any geotextile rolls that have not been installed in accordance with this section.

All geotextile rolls rejected by the Superintendent shall be removed from the site and replaced at the expense of the Contractor.

6.11.2 Weather conditions

The Contractor shall consider the weather conditions on a daily basis to confirm they are suitable for placement of geotextile.

Geotextile shall not be placed or seamed:

- If moisture prevents proper subgrade preparation, panel placement and/or panel seaming
- During precipitation, during hail, during periods of excessive fog, during periods of excessive dust, in standing water, on excessively wet surfaces, in the presence of excess moisture (such as dew and/or ponded water)
- During periods of excessive winds (>30 kph) or when gusting wind conditions interfere with handling operations.

6.11.3 Traffic

Equipment used shall not damage the geotextile by handling, trafficking, leakage of hydrocarbons, or by other means.

No vehicle shall be allowed to travel directly on the geotextile unless approved by the Superintendent. Prior to approval, the Contractor shall provide the Superintendent the following information:

- Guidance from the manufacturer on suitable plant for trafficking for the proposed geotextile and confirmation that the Contractor shall only use this plant
- Guidance from the manufacturer on suitable trafficking method for the proposed geotextile and confirmation that the Contractor shall only use this trafficking method
- Certification from the manufacturer that the above trafficking method and plant shall not void the warranty for the proposed geotextile.

6.11.4 Placement

Geotextile shall be placed in accordance with the following:

- The geotextile shall be placed and seamed in accordance with this Specification, the Contract Drawings, the approved work method statement and the manufacturer's instructions. Any contradictions shall be clarified with the Superintendent
- Prior to placement, each roll shall be inspected by the Contractor for damage and/or defects, including tears, abrasion, indentation, cracks, thin spots or any other faults or defects. If damage or defects are identified, the roll shall be inspected by the Superintendent and approved or rejected
- Geotextile shall be protected from damage due to exposure to sunlight, dirt, dust and other hazards
- Geotextile shall be placed such that the panels are anchored at the crest of the slope and form a continuous layer down the side walls and slopes and across the base
- The arrangement of the geotextile panels shall be in accordance with the approved panel placement drawing and any changes approved by the Superintendent
- Installation shall progress from the highest elevations to the lowest
- Geotextile rolls shall be placed in an orderly fashion which shall minimise or prevent surface water from flowing below previously installed geotextile
- Geotextile shall not be allowed to 'bridge over' voids or low areas. The geotextile shall be placed to allow intimate contact with the subgrade or underlying geosynthetic
- Geotextile shall be installed without undergoing excessive buckling, wrinkling or tensioning
- Geotextile shall not be dragged across an unprepared surface. If the geotextile is dragged across an unprepared surface, it shall be inspected for defects and repaired or rejected if necessary
- Where there is a geosynthetic layer below, the installation of the geotextile shall be undertaken in a manner so as not to damage the underlying layer
- Sandbags or equivalent ballast shall be used as necessary to hold the geotextile in position and prevent uplift by wind. In case of high winds, continuous loading shall be placed along edges of panels to minimise wind flow under the panels. Sandbag material

shall be sufficiently close-knit to prevent soil fines from working through the bags and discharging on the geotextile

- Only those geotextile rolls which can be seamed or permanently anchored on at least two sides on the same day shall be placed on a daily basis. All other sides shall be temporarily anchored
- Geotextile installed on slopes shall be fixed in anchor trenches as shown on the Contract Drawings and Section 2.15. Geotextile panels shall be anchored as soon as possible
- Personnel working on the geotextile shall not smoke, wear damaging shoes, excessively traffic or engage in other activities which may damage the geotextile. Geotextile in heavy traffic areas shall be protected by a geosynthetic overlay
- Geotextile rolls shall be freely suspended during placement
- The method used to unroll the geotextile shall not cause bridging, excessive wrinkles, scores, scratches and/or crimps
- After placement, the geotextile shall be free of excessive buckles, wrinkles, ripples, creases, folds and irregular stressing.

6.11.5 Seaming

Geotextile shall be seamed in accordance with the following:

- Geotextile seams shall be formed by overlapping the edges of the geotextile panels by a minimum of 200 mm and thermally bonding the seam or sewing the seam together with continuous stitches located a minimum of 100 mm from the overlapped edges. A two-thread, double-locked stitch shall be used. The proposed seaming method shall be in accordance with the manufacturer's instructions
- Equipment used for thermal bonding and/or sewing shall be inspected and approved by the Superintendent prior to use. If requested by the Superintendent, the Geosynthetic Installer shall prepare a trial seam for inspection and/or testing prior to approval
- The Contractor shall ensure that the seaming method does not result in damage to the underlying geosynthetics
- Sewing procedures shall conform to the manufacturer's instructions. Spot sewing shall not be allowed
- Thread used to sew panels of geotextile together shall be polymeric thread with physical and chemical-resistance properties that equal or exceed those of the geotextile. The thread colour shall contrast with the geotextile colour and shall be approved for use by the manufacturer
- Adhesive may be used to seam the geotextile subject to approval from the Superintendent. The adhesive shall be approved by the manufacturer for use in seaming their product. If requested by the Superintendent, the Geosynthetic Installer shall prepare a trial seam for inspection and/or testing prior to approval
- Seams shall provide seam strength which equals or exceeds 75% of parent material strength when tested in accordance with AS 3706.2 (parent material strength) and AS 3706.6 (seam strength). The Superintendent may organise independent testing of the completed seams to verify conformance with this requirement. The Geosynthetic Installer shall repair any locations where samples are taken in accordance with Section 6.13.

6.12 Protection and covering

The protection geotextile shall be protected from damage due to overexposure to UV radiation. Covering activities shall be coordinated to ensure the following:

- The overlying confinement layer (e.g. 300 mm thick drainage aggregate within landfill cell) shall be placed as soon as practicable, in accordance with the protection geotextile instructions or as approved by the Superintendent. Notwithstanding these requirements, the overlying confinement layer shall be placed no longer than 2 weeks following protection geotextile placement. The 300 mm thick drainage aggregate shall be installed in accordance with the approved work method statement (refer Section Appendix A)
- No vehicle shall be allowed to traffic directly on the protection geotextile during placement of the overlying confining layer unless approved by the Superintendent (refer Section 5.10.3). The overlying confinement layer shall not be pushed or graded in a direction that may cause damage to the protection geotextile seams.

In the opinion of the Superintendent, if the placed protection geotextile panels are damaged extensively due to overexposure to UV radiation, then the effected protection geotextile panels shall be removed and replaced by the Contractor at their own expense.

6.13 Defects and repairs

The Contractor shall be responsible for inspecting the placed geotextile to identify any damage or faults in the material. The Superintendent and/or CQA Engineer may also undertake inspections of the placed geotextile to identify any damage or faults in the material. Any areas of geotextile damaged during installation shall be repaired by the Contractor. All repairs shall be verified by the Superintendent.

Any geotextile that has been damaged (by tears, holes or otherwise) during installation shall be repaired by patching a new piece of geotextile of the same material type and thickness with a minimum 300 mm overlap beyond the repair area in each direction. Any soil or other foreign material that may have penetrated the damaged geotextile onto the surface of the underlying layer or within the underlying layer shall first be removed to the satisfaction of the Superintendent before any repair work is undertaken.

Seaming of geotextile repair patches shall be undertaken in accordance with Section 5.10.5.

The Contractor shall submit to the Superintendent for review a log containing details of any defects identified and repairs carried out.

6.14 Acceptance

The Contractor shall retain all ownership and responsibility for all geotextile until final acceptance of all work under this Contract by the Principal.

Geotextile shall be accepted by the Principal when all of the following conditions are met:

- Required submittals are provided by the Contractor to the Superintendent and approved
- Adequacy of all field seams, penetrations and repairs is verified by the Superintendent
- The Superintendent is satisfied that sufficient sandbags or equivalent ballast have been placed across the surface of any geotextile to be left exposed at the completion of the Works
- Details of all defects identified and repairs performed have been provided by the Contractor to the Superintendent and approved

- The CQA Engineer has provided the Superintendent with a recommendation that the conditions of final acceptance have been met
- The Superintendent has inspected and approved the finished surface/s.

7. Drainage aggregate

7.1 General

This section contains the technical requirements for the drainage aggregate. The relevant requirements for the drainage aggregate in Section 2 shall be considered alongside guidance provided in this section.

The Superintendent may reject any component of the drainage aggregate that do not meet or exceed the requirements of this section.

Any component of the drainage aggregate rejected by the Superintendent shall be remediated at the expense of the Contractor.

7.2 Standards

7.2.1 Australian standards

Relevant Australian standards are as follows:

- 1141.3.1 Methods for Sampling and Testing Aggregates – Sampling of aggregates and rock
- 1141.11 Methods for Sampling and Testing Aggregates – Particle size distribution/dry sieve
- 1289.6.7.1 Methods for Testing Soils for Engineering Purposes – Determination of the permeability of a soil

7.3 Submittals

7.3.1 Prior to delivery of drainage aggregate to site

The Contractor shall submit the following to the Superintendent for review and approval prior to delivery of the drainage aggregate to site (per material source):

- Material source
- Certification that the material is VENM or ENM
- Pre-qualification test results/reports demonstrating that the proposed material complies with the material property requirements of this section of the Specification (refer Section 7.4)
- Estimated quantity of material which is represented by the pre-qualification test results/reports
- Information on the parent geology of the material.

7.3.2 Prior to placement of drainage aggregate

The Contractor shall submit the following to the Superintendent for review and approval prior to placement of the drainage aggregate:

- Survey of the underlying surface in accordance with Section 1.10
- Work method statement for placement of the drainage aggregate, including testing and repair procedures (refer Appendix A).

7.3.3 Following placement of drainage aggregate

The Contractor shall submit the following to the Superintendent for review and approval following placement of drainage aggregate:

- As-built survey of the completed surface showing conforming layer thickness within the allowable tolerances
- CQC testing results/reports showing compliance with the requirements of this Specification
- Defect and repairs log, showing details of all defects identified and any repairs completed.

7.4 Material

Leachate drainage aggregate shall:

- Be selectively sourced material from on-site or imported from an approved source. Imported material shall be classed as VENM or ENM
- Not contain any unsuitable materials identified in Section 2.4.1 unless approved by the Superintendent
- Be rounded to sub-rounded
- Be clean, hard, sound and durable material that will maintain the required performance under the maximum loads likely to be imposed on it in service
- Be non-reactive in mildly acidic conditions
- Have a calcium carbonate content of less than 8.5% by mass
- Have an effective angle of internal friction of greater than 35 degrees
- Be relatively uniform in grain size
- Comply with the acceptance criteria specified in Table 15.

The Contractor shall supply pre-qualification testing results in accordance with the testing frequencies identified in Table 15 showing that the proposed material meets the requirements of this table. Samples taken shall be representative of the whole material source and shall be evenly distributed across the material source.

If required by the Superintendent, a sample of the material shall be provided (per source) and the Superintendent and/or CQA Engineer may undertake an inspection of the material source. The Contractor shall cooperate fully with the Superintendent and CQA Engineer to allow this inspection to occur.

The Superintendent may organise independent testing of the material to verify conformance with the requirements of this section.

Table 15 Acceptance criteria – drainage aggregate

Property	Test method	Acceptance criteria	Minimum test frequency
Constant head permeability	AS 1289.6.7.1 ⁽²²⁾	$> 10^{-3}$ m/s	Greater of: 1 per 10,000 m ³ of material or 3 per source

²² The intrinsic permeability of the testing apparatus shall be established prior to testing the drainage aggregate and reported with the test results to verify the testing apparatus is suitable for this test

Property	Test method	Acceptance criteria	Minimum test frequency
Particle size distribution: - Passing 50 mm - Passing 19 mm - Passing 0.075 mm	AS 1141.11,12,13 or AS 1289.3.6.1, 3.6.3	100% ≤ 10% ≤ 3%	Greater of: 1 per 1,000 m ³ of material or 3 per source

7.5 Preparation of receiving surface

Prior to placement of drainage aggregate, the underlying geosynthetic shall be free of:

- Any of debris, roots, angular material (such as sharp rocks), or loose, coarse-grained material on or immediately below the geosynthetic
- Excessive wrinkles preventing intimate contact between the underlying geosynthetics and/or foundation materials.

The foundation material underlying the geosynthetic shall:

- Be smooth, flat, firm and unyielding to the satisfaction of the Superintendent
- Be free of abrupt breaks, indentations and/or sudden changes in grade
- Promote drainage and excessive water shall not be allowed to pond on the surface of the geosynthetic.

Placement of drainage aggregate shall not proceed until the underlying geosynthetic has been inspected and approved by the Superintendent.

The Superintendent may reject any underlying geosynthetic or underlying foundation material which does not meet these requirements. Any geosynthetic rejected by the Superintendent shall be removed from the site at the expense of the Contractor. Any rejected foundation material shall be removed and/or remediated to the satisfaction of the Superintendent.

7.6 Installation

The Contractor shall prepare a work method statement for placement of the drainage aggregate outlining the placement methodology and proposed construction plant to be used (refer Appendix A). The work method statement shall be submitted to the Superintendent for review and approval prior to commencement of the required field trial.

A field trial shall be undertaken by the Contractor to verify the Contractor's proposed construction methodology for the drainage aggregate, in accordance with Section 8. The Contractor shall adjust the placement method as necessary based on the results of the field trial.

The work method statement and construction methodology for the drainage aggregate shall be developed in accordance with the guidance provided below:

- The drainage aggregate shall be placed with a uniform particle size distribution to prevent concentration of fines. This can be achieved through conditioning of the material prior to placement
- The drainage aggregate shall be constructed in one lift with a minimum thickness of 300 mm. Plant shall not be allowed to traffic the underlying surface unless a minimum 300 mm thick drainage aggregate layer is present. Drainage aggregate shall be placed in areas without placed drainage aggregate by unloading the material from a pad of previously placed drainage aggregate

- The maximum allowable ground pressure for plant trafficking the minimum 300 mm thick drainage aggregate layer is 35 kPa
- Plant exceeding the allowable ground pressure requirements shall be allowed providing they work from elevated pads with a minimum thickness from the underlying surface of 1 m. These elevated pads shall be removed following completion of drainage aggregate placement
- Aggregate shall be placed directly on the underlying geosynthetic rather than pushing in place to avoid the formation of excessive wrinkles or 'waves'
- Drainage aggregate shall be placed in a manner which does not result in excessive particle breakdown or crushing
- Drainage aggregate shall be placed carefully around any pipework to ensure the pipework has sufficient and uniform support
- No aggregate shall be placed in areas where the underlying geosynthetic is not in contact with the supporting subgrade
- Drainage aggregate shall not be placed closer than 2 m from the edge of geosynthetic panels where seaming of additional geosynthetics to the edge is yet to be performed. Temporary access across such edges shall be subject to approval by the Superintendent.

7.7 Construction quality control testing

The Contractor shall undertake CQC testing of the drainage aggregate in accordance with Table 16 as a minimum and the relevant requirements of Section 2.13. Sampling locations for testing shall be agreed with the Superintendent and CQA Engineer.

Table 16 Construction quality control testing – drainage aggregate

Property	Test method	Minimum test frequency
Particle size distribution	AS 1141.11,12,13 or AS 1289.3.6.1, 3.6.3	1 per 1,000 m ³

7.8 Tolerances

The Contractor shall place the drainage aggregate within the tolerances provided in Section 2.14.

7.9 Defects and repairs

The Superintendent may direct the Contractor to remove a section of the aggregate to inspect underlying materials for damage. The Contractor shall repair any damage that occurs to the underlying materials as a consequence of the placement of drainage aggregate in accordance with this Specification.

Any areas of placed drainage aggregate that do not conform to the required CQC testing criteria shall be repaired by the Contractor to the satisfaction of the Superintendent. This includes non-conformances resulting from independent testing commissioned by the Superintendent or CQA Engineer.

The Contractor shall submit to the Superintendent for review details of any defects identified and repairs carried out.

7.10 Acceptance

The Contractor shall retain ownership and responsibility for the drainage aggregate until final acceptance of the drainage aggregate by the Principal.

The drainage aggregate shall be accepted by the Principal when all of the following conditions are met:

- Required submittals are provided by the Contractor to the Superintendent and approved
- The Contractor has submitted the required as-built surveys of the completed drainage aggregate showing conformance with the Contract Drawings within the allowable tolerances, and this has been approved by the Superintendent
- CQC test results showing compliance with the requirements of this Specification have been provided by the Contractor to the Superintendent and approved
- Details of all defects identified and repairs performed have been provided by the Contractor to the Superintendent and approved
- The CQA Engineer has provided the Superintendent with a recommendation that the conditions of final acceptance have been met
- The Superintendent has inspected and approved the finished surface/s.

8. Field trial – drainage aggregate

8.1 General

This section contains the technical requirements for undertaking the field trial for the drainage aggregate. The relevant requirements for the field trial in Section 2 shall be considered alongside guidance provided in this section.

All materials used for test sections shall be removed upon completion of the field trial and disposed of by the Contractor unless otherwise approved by the Superintendent.

8.2 Submittals

8.2.1 Prior to conducting the field trial

The Contractor shall submit the following to the Superintendent for review and approval prior to conducting the field trial:

- Work method statement for field trial methodology, including proposed location of the field trial
- Work method statement for installation of the drainage aggregate.

8.2.2 Following completion of the field trial

The Contractor shall submit the following to the Superintendent for review and approval following completion of the field trial:

- A report containing the methods, details and results of the field trial
- Updated work method statement for installation of the drainage aggregate based on the results of the field trial.

8.3 Method

The Contractor shall conduct a field trial of the drainage aggregate for each source of drainage aggregate material and protection geotextile arrangement. The purpose of the field trial is to evaluate the Contractor's proposed drainage aggregate placement method and performance of the protection geotextile.

8.3.1 Proposed placement method

The Contractor shall submit a work method statement outlining the proposed placement method of the drainage aggregate to the Superintendent prior to undertaking the field trial.

The work method statement shall include details of the following as a minimum:

- Method of transportation of drainage aggregate to placement location
- Method of spreading drainage aggregate
- Method of lift thickness control
- Details of plant and equipment to be used during placement, including calculation of ground pressure and proposed drainage aggregate thickness limits during trafficking
- Details of temporary pads or access tracks for plant exceeding allowable ground pressure limits
- Approximate number of passes for each item of plant on the drainage aggregate layer.

8.3.2 Field trial of placement method

The field trial shall be supervised by the following personnel as a minimum:

- Contractor
- Geosynthetic Installer
- Superintendent
- CQA Engineer.

The field trial may be constructed within the proposed layer area, or in an area approved by the Superintendent. The Contractor shall nominate the proposed location of the field trial for approval prior to undertaking the trial.

The field trial shall measure approximately 10 m by 20 m, unless otherwise approved by the Superintendent. Should the Superintendent approve construction of the field trial outside of the proposed drainage aggregate layer area, the Contractor shall construct the field trial on an area consistent with those represented on the Contract Drawings, and the areas of drainage aggregate shall be constructed using the methods, materials and equipment to be used during construction of the permanent drainage aggregate layer.

The complete underlying material profile shall be installed for the field trial to provide meaningful and complete results. The underlying materials for the field trial shall be installed as per the methods used to install the permanent underlying materials.

The drainage aggregate shall be placed as per the work method statement outlined in Section 8.3.1. The field trial shall mimic the actual placement method and real-world conditions. Any variations from this work method statement shall result in a non-conforming field trial unless approved by the Superintendent.

The Superintendent may direct additional passes or turning manoeuvres to be performed at their discretion to fully test the effectiveness of the protection geotextile.

8.3.3 Exhumation and inspection of the underlying geosynthetics

Prior to removal of the drainage aggregate, the layer thickness shall be recorded in order to compare the degree of damage to the thickness of the drainage aggregate.

Following completion of the field trial, the underlying PE geomembrane shall be exposed.

Most of the material may be removed using an excavator; however, care shall be taken to avoid doing any further damage to the underlying geosynthetics. Within 100 mm of the PE geomembrane, the material shall be removed by hand excavation to avoid damage to the PE geomembrane.

Once the material has been removed, the PE geomembrane shall be inspected for damage. The PE geomembrane shall be inspected over the length of the field trial test area.

Damage to the PE geomembrane shall include any holes, creases, indentations or scratches. Undamaged geomembrane shall be unblemished.

The location of the damage shall be recorded and compared to the drainage aggregate thickness at that point.

Where it is clear that there is no damage to any layers of the underlying geosynthetics as agreed with the Superintendent, the thickness of the drainage aggregate and associated plant and equipment used at that point shall be recorded.

8.3.4 Reporting and update of the proposed placement method

The Contractor shall submit a report to the Superintendent outlining the major findings from the field trial. The Contractor shall update the proposed placement method to reflect the findings of the field trial.

The Superintendent shall review and approve the updated placement method prior to placement of the permanent drainage aggregate layer. The report and updated placement method shall be provided to the Superintendent 10 working days prior to placement of the drainage aggregate.

9. Waste excavation and placement

9.1 General

This section contains the technical requirements for waste excavation and placement.

9.2 Submittals

Prior to waste placement, the Contractor shall submit a work method statement for waste excavation and placement with consideration to the requirements outlined in this Specification.

9.3 Excavation

The Contractor shall excavate designated waste materials to achieve the final lines and levels as shown on the Contract Drawings.

The Contractor shall separate any clean cover material from waste material, taking care not to contaminate the clean cover material or imported materials with waste material. The separated clean cover material shall be transported to the approved stockpile area and stockpiled separate from other materials. The clean cover material may be reused as part of the Works, subject to approval by the Superintendent. The Superintendent shall inspect and approve any clean cover material stockpiles prior to reuse.

All excavated waste material shall be transported as a priority to a nominated location as directed by Superintendent. All excavated waste materials will be immediately relocated to the nominated locations.

Stockpiling of waste materials is prohibited.

All exposed waste materials or waste materials used as select waste (fill) are to be covered with a minimum of 150 mm of suitable fill material by the end of each working day. This includes waste materials relocated to locations nominated by the Superintendent. A suitable alternative approach may be used for covering subject to approval by the Superintendent.

9.4 Placement

9.4.1 General

Only waste permitted under the Contract shall be placed within cells approved for disposal.

Waste shall be placed to minimise the entrainment of leachate or surface water within the waste and the formation of void spaces. The placement of waste shall be undertaken to ensure ponding is minimised.

The amount of waste exposed during operations shall be minimised.

Waste placement shall be undertaken such that pre-capping contours are suitable for placement of the final capping layer.

9.4.2 Protection of lining system

Waste shall be placed in near horizontal layers across the entire area of the cell in horizontal lifts over the entire footprint.

Placement of the waste against the basal and sidewall liner system shall be undertaken so as to avoid damage to the lining systems. Specifically, no landfill compactor shall be allowed within 6 horizontal metres of the sidewall lining system at any time.

Waste placed against the sidewall shall be placed on existing waste and pushed against the sidewall. All pushing shall be towards the slope. No waste or other materials shall be pushed down the slope of the sidewall.

The liner protection layer across the sidewall lining system shall be maintained through operations. Inspections of the protection layer shall be undertaken following any rainfall event and any scouring or other damage to the layer shall be rectified.

No traffic is permitted on the separation geotextile over the leachate collection system, with the first layer of waste to be end tipped from the previously placed waste layer.

9.4.3 Compaction and lift thickness

Compaction of the waste shall be undertaken to ensure a minimum in-situ waste density of 0.8 tonnes per cubic metre. Based on the equipment utilised, the moisture condition and type of waste the maximum uncompacted waste layer shall be adjusted by the operator to ensure this requirement is met.

Notwithstanding the requirement to achieve a minimum in-situ waste density of 0.8 tonnes per cubic metre at all times, waste shall not be spread in uncompacted layers exceeding 450 vertical millimetres (0.45 vertical metres) prior to compaction. The maximum depth of any waste lift across the cell shall not exceed 3 vertical metres.

9.4.4 Initial waste lift requirements

The initial lift of waste (the 'fluffy layer') shall be:

- Mixed with dry construction and demolition waste (ideally fines or other non-protruding materials) to provide a suitable protective layer
- Placed by tracked plant, such as a bulldozer, to avoid high point loads that could potentially damage the base liner
- A minimum of 1.5 metre for a Cat 826 Series Compactor (or similar) and 2 metres for an Cat 836 Series Compactor (or similar) to allow for placement of subsequent lifts by a landfill compactor
- Free from protruding objects that can pierce the liner
- Placed in a manner to ensure the separation geotextile overlying the drainage aggregate remains fit for purpose.

As soon as is feasible, a working platform should be established with or on top of the first waste lift, sufficient in size to allow for truck and plant manoeuvring.

9.4.5 Covering

Daily cover shall be placed progressively over areas of exposed waste. All waste shall be covered at the end of the working day. Intermediate cover shall be placed in areas where waste is to be exposed for periods of generally 90 days or longer.

Where possible daily and intermediate cover shall be stripped back for reuse before the waste is placed over the previously filled areas. Recovered cover material that is contaminated with waste may only be used for internal bunds to delineate the working face, or other engineering purposes where it is not exposed.

9.4.6 Leachate collection system

The operation depth of leachate in the cell shall be limited to no more than 300 mm.

9.5 Access ramp

To allow for access of plant and trucks into the active waste cell, at least during the initial stages, an access ramp shall be constructed across the perimeter bund. The location of the ramp shall be selected such that it can provide cell access for the longest possible period.

The gradient of the ramp shall be suitable for truck access, under consideration of vehicle traction under full load. If the required space and construction materials are available, it is advisable to construct the ramp with a shallow gradient to avoid regular disturbance of the ramp surface.

At the crest of the perimeter bund the depth of the ramp shall be no less than 1 metre, preferably deeper to allow for future wear and compaction of the ramp.

Prior to placement of the construction material, the use of a geogrid layer shall be considered. Geogrid not only stabilises the road-base materials placed on top, but also provides for a reduction in point loads that could lead to liner damage.

If used, a layer of fines or fine rounded pebble shall be placed and compacted on top of the geogrid layer before applying the typical road-base materials used for construction of the access ramp.

Under consideration of the direction of approaching or departing trucks, a sufficiently large truck turning are shall be allowed for. Trucks approaching the ramp at an angle cause significantly greater disturbance to the ramp surface, which could lead to gradual reduction of the ramp depth over time.

10. Seal bearing layer

10.1 General

This section contains the technical requirements for the seal bearing layer. The relevant requirements for the seal bearing layer in Section 2 shall be considered alongside guidance provided in this section.

The Superintendent may reject any component of the seal bearing layer that do not meet or exceed the requirements of this section.

Any component of the seal bearing layer rejected by the Superintendent shall be remediated at the expense of the Contractor.

10.2 Standards

10.2.1 Australian standards

Relevant Australian standards are as follows:

- 1152 Specification for test sieves
- 1289 Methods of testing soils for engineering purposes
- 1289.2.1.1 Determination of the moisture content of a soil - oven drying method
- 1289.3.1.1 Soil classification tests - Calculation of the plasticity index of a soil
- 1289.3.6.1 Soil classification tests - Determination of the particle size distribution of a soil - Standard method of analysis by sieving
- 1289.3.6.3 Soil classification tests - Determination of the particle size distribution of a soil - Standard method of fine analysis using a hydrometer
- 1289.3.8.1 Soil classification tests - Dispersion - Determination of emerson class number of a soil
- 1289.5.1.1 Soil compaction and density tests - Determination of the dry density/moisture content relation of a soil using standard compactive effort
- 1289.5.6.1 Soil compaction and density tests - Compaction control test - Density index method for a cohesionless material
- 1289.5.7.1 Soil compaction and density tests - Compaction control test - Hilf density ratio and Hilf moisture variation (rapid method)
- 1289.5.8.1 Soil compaction and density tests - Determination of field density and field moisture content of a soil using a nuclear surface moisture density gauge
- 1289.6.7.3 Methods of testing soils for engineering purposes - Soil strength and consolidation tests - Determination of permeability of a soil - Constant head method using a flexible wall permeameter
- 1726 Geotechnical site investigations
- 2868 Classification of machinery for earthmoving, construction, surface mining and agricultural purposes
- 3798 Guidelines on earthworks for commercial and residential developments
- 4419 Soil for landscaping and garden use

10.3 Submittals

10.3.1 Prior to placement of seal bearing layer

The Contractor shall submit the following to the Superintendent for review and approval prior to placement of the seal bearing layer:

- Survey of the underlying surface in accordance with Section 1.10
- Work method statement for placement of the seal bearing layer, including testing and repair procedures (refer Appendix A).

10.3.2 Following placement of seal bearing layer

The Contractor shall submit the following to the Superintendent for review and approval following placement of seal bearing layer:

- As-built survey of the completed surface showing conforming layer thickness within the allowable tolerances
- CQC testing results/reports showing compliance with the requirements of this Specification
- Defect and repairs log, showing details of all defects identified and any repairs completed.

10.4 Material

Seal bearing material shall:

- Be selectively sourced material from on-site material
- Not contain any unsuitable materials identified in Section 2.4.1 unless approved by the Superintendent
- Be well graded in accordance with AS 1726
- Comply with the acceptance criteria specified in Table 17.

The Contractor shall supply pre-qualification testing results in accordance with the testing frequencies identified in Table 17 showing that the proposed material meets the requirements of this table. Samples taken shall be representative of the whole material source and shall be evenly distributed across the material source.

If required by the Superintendent, a sample of the material shall be provided (per source) and the Superintendent and/or CQA Engineer may undertake an inspection of the material source. The Contractor shall cooperate fully with the Superintendent and CQA Engineer to allow this inspection to occur.

Table 17 Acceptance criteria – seal bearing material

Property	Test method	Acceptance criteria	Minimum test frequency
Particle size distribution: - Passing 19 mm - Passing 0.075 mm	AS 1141.11,12,13 or AS 1289.3.6.1, 3.6.3	100% > 25%	Greater of: 1 per 5,000 m ³ of material or 3 per source
Atterberg limits: - Plasticity index - Liquid limit	AS 1289.3.1.1, 3.2.1 & 3.3.1	8 – 35 ≤ 50	Greater of: 1 per 5,000 m ³ of material or 3 per source
California Bearing Ratio (CBR)	AS1289.5.7.1	≥ 5	Greater of: 1 per 5,000 m ³ of material or 3 per source

Emerson class	AS 1289.3.8.1	> 3	Greater of: 1 per 5,000 m ³ of material or 3 per source
% Organic content	AS 1289.4.1.1 or Walkley Black method	< 2%	1 per source
pH	AS 1289.4.3.1 or USEPA 9045 (1:5 solution)	4.5 – 8.5	1 per source

10.5 Preparation of receiving surface

Prior to placement of the seal bearing layer, the receiving surface shall exhibit the following characteristics:

- The surface shall be smooth, flat, firm and unyielding to the satisfaction of the Superintendent
- The surface shall not exhibit visible deformation, rutting, yielding and/or show signs of distress or instability during final proof rolling (if required)
- The surface shall be free of debris, roots, angular material (such as sharp rocks), desiccation cracks, abrupt breaks, indentations, sudden changes in grade, defects and/or imperfections that may result in damage to the overlying materials
- No loose, coarse-grained material shall remain on the surface. If required, the surface shall be raked or graded to remove any material penetrating out of the surface greater than 10 mm
- The surface shall promote drainage and excessive water shall not be allowed to pond on the surface
- The surface shall not be pebbly, tracked, rutted or otherwise disturbed by the equipment deploying overlying materials or other traffic. Pockets, holes, or discontinuities shall be repaired
- All construction stakes, hubs, or other items used for grade control shall be removed and any voids filled. Any unsuitable material shall be over-excavated to a depth of 100 mm and replaced with approved material
- The surface shall be maintained at sufficient moisture content to prevent desiccation during the Works.

The receiving surface shall be surveyed as per the requirements of Section 1.10.

Placement of the seal bearing layer shall not proceed until the receiving surface has been inspected and approved by the Superintendent.

10.6 Installation

The Contractor shall prepare a work method statement for placement of the seal bearing layer outlining the measures taken to moisture condition the seal bearing material prior to placement, placement methodology and proposed construction plant to be used (refer Appendix A). The work method statement shall be submitted to the Superintendent for review and approval prior to placement.

The work method statement and construction methodology for the seal bearing layer shall be developed in accordance with the guidance provided below:

- The seal bearing material shall be moisture conditioned uniformly throughout the material prior to placement
- If the seal bearing material requires significant moisture content adjustment, the Contractor shall use a moisture conditioning area to allow hydration or dehydration of material to meet moisture content requirements
- Should the seal bearing material be too wet to permit proper compaction, all work on the portions of the seal bearing material affected shall be delayed until the material has dried to the required moisture content
- The material shall be constructed in one layer or 300 mm maximum lifts where the depth is insufficient, to the lines and grades indicated
- The surface of the seal bearing material lifts shall be maintained as necessary prior to placement of the overlying lifts or overlying materials to prevent any moisture variations outside the requirements of the Specification. The Contractor shall be required to rework areas which do not meet this requirement
- The Contractor shall seal surfaces (by smooth drum rolling) at the end of each day to minimise the penetration of water, provide erosion protection measures and ensure drainage systems (permanent and temporary) are maintained.

10.7 Compaction

All seal bearing material shall be placed and compacted to the requirements of Section 2.12.

10.8 Construction quality control testing

The Contractor shall undertake CQC testing for the seal bearing layer in accordance with Section 2.13.

10.9 Tolerances

The Contractor shall place the seal bearing layer within the tolerances provided in Section 2.14.

10.10 Finished surface

The finished surface of the seal bearing layer shall exhibit the following characteristics:

- The surface shall be smooth, flat, firm and unyielding to the satisfaction of the Superintendent. The surface shall be proof rolled by the Contractor using a mechanical self-propelled smooth drum roller (or equivalent) in the presence of the Superintendent to assess the soundness and suitability of the finished surface. The surface shall not exhibit visible deformation, rutting, yielding and/or show signs of distress or instability during final proof rolling
- The surface shall be free of debris, roots, angular material (such as sharp rocks), desiccation cracks and sudden changes in grade. If required, the surface shall be raked or graded to remove any material penetrating out of the surface greater than 10 mm
- The surface shall promote drainage and excessive water shall not be allowed to pond on the surface
- The surface shall not be rutted or otherwise disturbed by the equipment deploying overlying materials or other traffic
- The surface shall be maintained at sufficient moisture content to prevent desiccation during the Works.

10.11 Defects and repairs

Any areas of placed seal bearing layer that do not conform to the required compaction and moisture content testing criteria shall be repaired by the Contractor in accordance with Section 2.17. This includes non-conformances resulting from independent testing commissioned by the Superintendent or CQA Engineer.

The Contractor shall submit to the Superintendent for review details of any defects identified and repairs carried out.

10.12 Acceptance

The Contractor shall retain ownership and responsibility for the seal bearing layer until final acceptance of the seal bearing layer by the Principal.

The seal bearing layer shall be accepted by the Principal when all of the following conditions are met:

- Required submittals are provided by the Contractor to the Superintendent and approved
- The Contractor has submitted the required as-built surveys of the completed seal bearing layer showing conformance with the Contract Drawings within the allowable tolerances, and this has been approved by the Superintendent
- CQC test results showing compliance with the requirements of this Specification have been provided by the Contractor to the Superintendent and approved
- Details of all defects identified and repairs performed have been provided by the Contractor to the Superintendent and approved
- The CQA Engineer has provided the Superintendent with a recommendation that the conditions of final acceptance have been met
- The Superintendent has inspected and approved the finished surface/s.

11. Geonet drainage composite

11.1 General

This section contains the technical requirements for geonet drainage composite.

The Superintendent may reject any geonet or geonet drainage composite that does not meet or exceed the requirements of this section.

All geonet drainage composite rejected by the Superintendent shall be removed from the site at the Contractors expense.

11.2 Standards

11.2.1 American Society for Testing and Materials Standards

Relevant American Society for Testing and Material (ASTM) standards are as follows:

- D1505 Standard Test Method for Density of Plastics by the Density-Gradient Technique
- D1603 Standard Test Method for Carbon Black in Olefin Plastics
- D4218 Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique.
- D4354 Standard Practice for Sampling of Geosynthetics and Rolled Erosion Control Products (RECPs) for Testing
- D4355 Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus
- D4439 Standard Terminology for Geosynthetics
- D4491 Standard Test Methods for Water Permeability of Geotextiles by Permittivity
- D4533 Standard Test Method for Trapezoid Tearing Strength of Geotextiles
- D4632 Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
- D4716 Standard Test Method for Determining the (In-Plane) Flow Rate Per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head
- D4751 Standard Test Method for Determining Apparent Opening Size of a Geotextile
- D4833 Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products
- D4873 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples
- D5199 Standard Test Method for Measuring the Nominal Thickness of Geosynthetics
- D7005 Determining The Bond Strength (Ply-Adhesion) of Composites
- D7179 Standard Test Method for Determining Geonet Bearing Force.

11.2.2 Geosynthetic Research Institute Standards

Relevant Geosynthetic Research Institute (GRI) standards are as follows:

- GC8 Standard Guide for Determination of the Allowable Flow Rate of a Drainage Composite

- GN2 and GC13 Standard Guide for Jointing and Attaching Geonets and Drainage Composites.

11.3 Submittals

The Contractor shall be responsible for the submission of all submittals required for geonet drainage composite by this Specification.

11.3.1 Prior to delivery of geonet drainage composite to site

The Contractor shall submit the following to the Superintendent for review and approval prior to delivery of geonet drainage composite to site:

- Material properties of the proposed drainage composite
- Manufacturer's certificate of compliance stating conformance with the requirements of this Specification
- Manufacturer's quality control and assurance procedures
- Manufacturer's quality control and assurance test results
- Complete description of the manufacturer's shipping, handling and storage procedures
- Manufacturer's installation procedures and requirements

11.3.2 Prior to installation of geonet drainage composite

The Contractor shall submit the following to the Superintendent for review and approval prior to installation of the geonet drainage composite:

- Delivery, storage and handling log for all composite rolls to be used in the Works, including delivery dockets, roll number and identification, delivery inspection checklist, details of storage and handling and quality control and assurance certificates
- Work method statement for geonet drainage composite installation, including seaming and jointing, procedures for testing and repairing and other information that shall promote proper use
- Proposed panel placement drawing, showing the location and reference number of all panels, expected seams, connections and penetrations, and panel dimensions and layout and the order of panel installation
- Results of independent material conformance testing as provided by the CQA Engineer.

11.3.3 Following installation of geonet drainage composite

The Contractor shall submit the following to the Superintendent for review and approval following installation of the geonet drainage composite:

- Panel placement and seaming log, providing details on date and time placed, date and time seamed, condition of receiving surface, weather conditions and precipitation events, quality assurance (QA) checks performed, and all other relevant information
- Finalised panel placement drawing showing the as-built location of all panels, seams, connections and penetrations
- Defect and repairs log, showing details of all defects identified and any repairs completed.

11.4 Manufacturers quality control

The manufacturer shall follow a quality control program throughout the manufacturing of all geonet drainage composite approved by the Superintendent.

The frequency of sampling and testing shall be in accordance with Table 18.

The Superintendent may reject any geonet drainage composite rolls that have not been sampled and/or tested in accordance with this section.

All geonet drainage composite rolls rejected by the Superintendent shall be removed from the site at the Contractors expense.

11.5 Manufacturers quality assurance

The manufacturer shall follow a QA program throughout the manufacturing of all geonet drainage composite approved by the Superintendent.

The frequency of sampling and testing shall be in accordance with ASTM D4354.

The Superintendent may reject any geonet drainage composite rolls that have not been sampled and/or tested in accordance with this section.

All geonet drainage composite rolls rejected by the Superintendent shall be removed from the site at the Contractors expense.

11.6 Material

All geonet drainage composite shall be new, first quality products manufactured for the Works.

The geotextile component shall be a non-woven, needle-punched, polypropylene geotextile factory bonded to the geonet. The bonding shall be uniform across the full extent of the geonet with no unbonded areas except for edges and overlaps.

The maximum unbounded area at edges and overlaps shall be 300 mm from the edge of the geonet.

The geonet resin shall be new, first quality, compounded polyethylene resin.

Geonet drainage composite shall meet or exceed the acceptance criteria specified in Table 18.

Table 18 Acceptance criteria – geonet drainage composite

Property (qualifier)	Test Method (ASTM)	Acceptance Criteria	Minimum Testing Frequency
Geotextile (before lamination)			
Mass per unit area (MARV)	D5261	270 g/m ²	every 10,000 m ²
Grab tensile strength (MARV)	D4632	900 N	every 10,000 m ²
Grab elongation (MARV)	D4632	50%	every 10,000 m ²
CBR puncture strength (MARV)	D6241	2,000 N	every 10,000 m ²
Trapezoidal tear strength (MARV)	D4533	350 N	every 10,000 m ²
Pore size	ASTM D6767	120 µm	every 5,000 m ²
Permittivity (MARV)	AS 3706.9	0.5 s ⁻¹	every 50,000 m ²

Apparent opening size (MaxARV)	D4751	430 µm	every 50,000 m ²
UV stability (typical) ⁽²³⁾	D4355	50%	per formulation
Geonet (before lamination)			
Thickness at 200 kPa (min.)	AS 3706.1	4.8 mm	every 5,000 m ²
Density ⁽²⁴⁾ (min.)	D1505 or D792	0.94 g/cm ³	every 5,000 m ²
Melt flow index (max.)	D1238	1.0 g/10 min	every 5,000 m ²
Carbon black content (range)	D4218 ⁽²⁵⁾	2.0 to 3.0%	every 5,000 m ²
Tensile strength (machine direction) (MARV)	AS 3706.2	7.5 kN/m	every 5,000 m ²
In plane flow rate	D4716	4.3 x 10 ⁻⁵ m ² /s	every 5,000 m ²
Transmissivity ⁽²⁶⁾ (MARV)	D4716	1.36 x 10 ⁻⁴ m ² /s	every 50,000 m ²
Compressive strength (MARV)	D1621	460 kPa	every 10,000 m ²
Geonet drainage composite			
Configuration (top to bottom)		Geotextile - geonet - geotextile	
Ply adhesion (MARV)	D7005	360 N/m	every 5,000 m ²

11.7 Roll and sample identification

All geonet drainage composite rolls and samples shall be identified in accordance with ASTM D4873.

The Superintendent may reject any geonet drainage composite roll or sample that has not been identified in accordance with this section.

Any geonet drainage composite roll or sample rejected by the Superintendent shall be removed from the site at the Contractors expense.

11.8 Delivery, storage and handling

The delivery, storage and handling of all geonet drainage composite rolls and samples shall be undertaken in accordance with the manufacturer's instructions and ASTM D4873 as a minimum.

The Contractor shall inspect all geonet drainage composite rolls for defects and damage upon delivery.

The Superintendent may reject any geonet drainage composite roll or sample that has not been stored or handled in accordance with this section.

Any geonet drainage composite roll or sample rejected by the Superintendent shall be removed from the site at the Contractors expense.

²³ strength retained after 500 hours

²⁴ Base resin density without carbon black added

²⁵ 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.

²⁶ Hydraulic gradient (1 m/m), Confining stress (>20 kPa), Seating time (100 hours)

11.9 Preparation of surface to receive geonet drainage composite

The surface to receive the geonet drainage composite shall provide a dry, smooth, uniform surface that is free of defects or imperfections that may result in damage to the geonet drainage composite. The surface shall be free from abrupt breaks, sharp objects, or other foreign material that may inhibit placement of the geonet drainage composite.

All construction stakes, hubs, or other items used for grade control shall be removed and any void filled with processed material.

The surface shall not be pebbly, or tracked and rutted by equipment. Pockets, holes, or discontinuities shall be repaired. No loose, coarse-grained material shall remain on the surface.

Placement shall not proceed until the surface has been approved by the Superintendent.

11.10 Installation

The Contractor shall undertake installation in accordance with the manufacturer's instructions, the approved work method statement, GRI-GN2 and GRI-GC13, this Specification and the Contract Drawings. Any contradictions shall be clarified with the Superintendent.

The work method statement shall be developed based on the guidance provided below:

- Prior to incorporation into the works, each roll shall be inspected for damage and/or defects. If damage or defects are identified, the roll shall be inspected by the Superintendent and approved or rejected
- The protective wrapping on geonet drainage composite rolls shall be maintained at all times prior to installation
- The Contractor shall verify that the material is free from dust and dirt immediately prior to installation. Washing operations may be implemented at the discretion of the Superintendent
- Geonet drainage composite shall not be placed or seamed:
 - If moisture prevents proper subgrade preparation, panel placement or panel seaming
 - During precipitation, during periods of fog, or in the presence of excess moisture (e.g. dew, ponded water)
 - During periods of excessive winds (>30 kph) or when gusting wind conditions interfere with handling operations
- Geonet drainage composite shall be protected from damage due to exposure to sunlight, dirt, dust and other hazards
- Equipment used shall not damage the geonet drainage composite by handling, trafficking, leakage of hydrocarbons, or by other means
- No vehicle shall be allowed to travel directly on the geonet drainage composite unless approved by the Superintendent. Prior to approval, the Contractor shall provide the Superintendent the following information:
 - Guidance from the manufacturer on suitable plant for trafficking for the proposed geonet drainage composite and confirmation that the Contractor shall only use this plant
 - Guidance from the manufacturer on suitable trafficking method for the proposed geonet drainage composite and confirmation that the Contractor shall only use this trafficking method

- Certification from the manufacturer that the above trafficking method and plant shall not void the warranty for the proposed geonet drainage composite
- Geonet drainage composite shall not be allowed to 'bridge over' voids or low areas in the subgrade. The geonet drainage composite shall be placed to allow intimate contact with the subgrade or underlying geosynthetic
- Geonet drainage composite shall not be dragged across an unprepared surface. If the geonet drainage composite is dragged across an unprepared surface, it shall be inspected by the Superintendent and repaired or rejected if necessary
- Geonet drainage composite rolls shall be freely suspended during placement
- Where there is a geosynthetic layer below, the installation of the geonet drainage composite shall be undertaken in a manner so as not to damage the underlying layer
- Metallic ties shall not be used
- Geonet drainage composite shall not be welded to the geomembrane.
- The machine direction of materials shall be placed parallel to the slope
- Strands of one layer shall not penetrate the channels of another layer
- The geotextiles above and below the geonet drainage composite shall be continuously inspected for broken needles remaining from needle-punching operations
- Sandbags or equivalent ballast shall be used as necessary to temporarily hold the geonet drainage composite in position under the foreseeable and reasonably expected wind conditions. Sandbag material shall be sufficiently close-knit to prevent soil fines from working through the bags and discharging on the geonet drainage composite
- After placement, the geonet drainage composite shall be free of irregular stressing, folds and wrinkles
- The geonet drainage composite shall be covered after installation within a 10 day period.

11.11 Defects and repairs

All repairs shall be undertaken in accordance with the manufacturer's instructions and the approved work method statement. All repairs shall be verified by the Superintendent.

11.12 Acceptance

The Contractor shall retain all ownership and responsibility for all geotextile until final acceptance of all work under this Contract by the Principal.

Geotextile shall be accepted by the Principal when all of the following conditions are met:

- Required submittals are provided by the Contractor to the Superintendent and approved
- Adequacy of all field seams, penetrations and repairs is verified by the Superintendent
- Details of all defects identified and repairs performed have been provided by the Contractor to the Superintendent and approved
- The CQA Engineer has provided the Superintendent with a recommendation that the conditions of final acceptance have been met
- The Superintendent has inspected and approved the finished surface/s.

12. Revegetation layer

12.1 General

This section contains the technical requirements for the revegetation layer. The relevant requirements for the earthworks in Section 2 shall be considered alongside guidance provided in this section.

The Superintendent may reject any component of the revegetation layer that do not meet or exceed the requirements of this section.

Any component of the revegetation layer rejected by the Superintendent shall be remediated at the expense of the Contractor.

12.2 Standards

12.2.1 Australian standards

Relevant Australian standards are as follows:

- 1289 Methods of Testing Soils for Engineering Purposes
- 4419 Soils for Landscaping and Garden Use

12.3 Submittals

12.3.1 Prior to delivery of materials to site

The Contractor shall submit the following to the Superintendent for review and approval prior to delivery of materials to site (per material per source):

- Material source
- Certification that the material is VENM or ENM
- Pre-qualification test results/reports demonstrating that the proposed material complies with the material property requirements of this section of the Specification (refer Section 12.4)
- Estimated quantity of material which is represented by the pre-qualification test results/reports
- Certification of the proposed vegetation showing the species, variety and weight.

12.3.2 Prior to placement of subsoil and topsoil

The Contractor shall submit the following to the Superintendent for review and approval prior to placement of the subsoil and topsoil materials:

- Survey of the underlying surface in accordance with Section 1.10
- Work method statement for placement of the revegetation layer, including testing and repair procedures (refer Appendix A).

12.3.3 Prior to seeding and sowing

The Contractor shall submit the following to the Superintendent for review and approval following placement of revegetation layer:

- Proposed seed mix for hydroseeding

- As-built survey of the completed soil layers showing conforming layer thickness within the allowable tolerances
- CQC testing results/reports for the completed soil layers showing compliance with the requirements of this Specification
- Defect and repairs log for the soil layers, showing details of all defects identified and any repairs completed
- Statement from the supplier/s showing conformance of the seed mixes with the requirements of the Technical Specification.

12.4 Material

12.4.1 Subsoil

Subsoil material shall:

- Be selectively sourced material from on-site or imported from an approved source. Imported material shall be classed as VENM or ENM
- Not contain any unsuitable materials identified in Section 2.4.1 unless approved by the Superintendent
- Be well graded in accordance with AS 1726
- Comply with the acceptance criteria specified in Table 19.

Subsoil shall be a low organic matter material that is well balanced chemically and is not saline, sodic, excessively acidic, calcium deficient or dispersive. The subsoil material is intended to provide improved rooting depth and reduce the likelihood of water logging.

The Contractor shall supply pre-qualification testing results in accordance with the testing frequencies identified in Table 19 showing that the proposed material meets the requirements of this table. Samples taken shall be representative of the whole material source and shall be evenly distributed across the material source.

If required by the Superintendent, a sample of the material shall be provided (per source) and the Superintendent and/or CQA Engineer may undertake an inspection of the material source.

Table 19 Acceptance criteria – subsoil

Property	Test method	Acceptance criteria	Minimum testing frequency
Particle size distribution: - Passing 37.5 mm - Passing 13.2 mm - Passing 2.36 mm - Passing 0.075 mm - Passing 0.002 mm	AS1141.11,12,13 or AS1289.3.6.1, 3.6.3	100% 95 – 100% 80 – 100% 20 – 50% 10 – 30%	Greater of: 1 per 5,000 m ³ of material or 3 per source
Atterberg limits: - Plasticity index - Liquid limit	AS1289.3.1.1, 3.2.1 & 3.3.1	8 – 35 < 50	Greater of: 1 per 5,000 m ³ of material or 3 per source
Emerson class	AS1289.3.8.1	> 4	Greater of: 1 per 5,000 m ³ of material or 3 per source
% Organic content	AS 1289.4.1.1 or Walkley Black method	2-3%	Greater of: 1 per 10,000 m ³ of material or 3 per source

Property	Test method	Acceptance criteria	Minimum testing frequency
pH	AS 1289.4.3.1 or USEPA 9045 (1:5 solution)	5.5 – 6.8	Greater of: 1 per 10,000 m ³ of material or 1 per source

12.4.2 Topsoil

Topsoil shall be a 'natural soil or soil blend' in accordance with Table 1 of AS 4419. The Contractor shall provide certified pre-qualification test results from a NATA Accredited Laboratory to show the proposed material meets these requirements.

If required by the Superintendent, a sample of the material shall be provided (per source) and the Superintendent and/or CQA Engineer may undertake an inspection of the material source.

12.4.3 Seed mix

The Contractor shall submit their proposed seed mix to the Superintendent for approval prior to use.

12.5 Preparation of surface to receive revegetation layer

Prior to placement of the revegetation layer, the receiving surface shall be cleared of any debris and/or foreign material.

The receiving surface shall be surveyed as per the requirements of Section 1.10.

Placement of the revegetation layer shall not proceed until the receiving surface has been approved by the Superintendent.

12.6 Installation

12.6.1 Subsoil

The Contractor shall prepare a work method statement for placement of the topsoil layer outlining the placement methodology and proposed construction plant to be used (refer Appendix A). The work method statement shall be submitted to the Superintendent for review and comment prior to placement.

The work method statement and construction methodology for the topsoil layer shall be developed in accordance with the guidance provided below:

- Subsoil shall be spread evenly in lifts with a maximum compacted layer thickness of 400 mm and compacted lightly and uniformly so that the finished surface is smooth and free of stones or other lumps, weeds, rubbish and other deleterious material brought to the surface. Excessive compaction shall be avoided
- The equipment used for placing and spreading of materials shall be suitable for the purpose. Low pressure tyred vehicles shall be used. Graders and other high pressure tyred vehicles equipment shall not be used. The Contractor shall vary the routes of vehicles and other plant passing over completed areas of each soil profile layer to avoid areas of excess compaction
- The compaction and moisture content requirements identified in Section 12.8 shall be met. A field trial shall be undertaken prior to construction of this layer to confirm the Contractor's proposed placement methodology meets these requirements
- Each layer shall be spread evenly and thoroughly mixed to obtain a near uniform condition in each layer

- Where subsoil is placed on batters with grades of 1(V):5(H) or greater, subsoil shall be placed from the bottom of the batter upwards and perpendicular to the contour lines.

12.6.2 Topsoil

The Contractor shall prepare a work method statement for placement of the topsoil layer outlining the placement methodology and proposed construction plant to be used (refer Appendix A). The work method statement shall be submitted to the Superintendent for review and comment prior to placement.

The work method statement and construction methodology for the topsoil layer shall be developed in accordance with the guidance provided below:

- The Contractor shall cover trucks transporting the topsoil material to prevent loss of material during transport. The Contractor shall ensure trucks do not allow loss of material through tailgates or other parts of the truck body
- Prior to placement of the topsoil layer, the receiving surface of the subsoil layer shall be ripped to a minimum depth of 100 mm. Once ripped no vehicles or machinery shall traverse these areas unless they are low pressure tyred vehicles approved by the Superintendent
- Topsoil shall be spread evenly in one layer over the designated areas and compacted lightly and uniformly so that the finished surface is smooth and free of stones or other lumps, weeds, rubbish and other deleterious material brought to the surface. Excessive compaction shall be avoided
- Once placed, the topsoil surface shall be thoroughly watered. Regular watering shall be conducted by the Contractor to minimise establishment time for the vegetation and mitigate any erosion risks. Watering shall continue to be conducted until the vegetation has been established to the satisfaction of the Superintendent
- The equipment used for placing and spreading of materials shall be suitable for the purpose. Low pressure tyred vehicles shall be used. Graders and other high pressure tyred vehicles equipment shall not be used. The Contractor shall vary the routes of vehicles and other plant passing over completed areas of each soil profile layer to avoid areas of excess compaction
- Where topsoil is placed on batters with grades of 1(V):5(H) or greater, topsoil shall be placed from the bottom of the batter upwards and perpendicular to the contour lines.

12.7 Seeding and sowing

Seeding and sowing shall be completed based on the following guidance (as a minimum):

- Grass seed will be sown in accordance with the supplier's requirements and/or achieve a minimum 70% cover per square meter (whichever is greater)
- Seeding outside of the specified areas must be prevented
- After sowing the topsoil surface will be lightly raked to cover the surface and the area watered immediately
- Watering will continue throughout the establishment period in accordance with the supplier's requirements
- This area shall be protected from pedestrians or animals until the grass has established, and from vehicles or heavy plant at all times.

12.8 Compaction

All subsoil and topsoil shall be placed at a moisture content of -2 to 0% of the optimum moisture content, to a density ratio of 70-85% standard.

12.9 Construction quality control testing

The Contractor shall undertake CQC testing for the revegetation layer in accordance with Section 2.13.

12.10 Tolerances

The Contractor shall place the revegetation layer within the tolerances provided in Section 2.14.

12.11 Finished surface

The finished surface of the revegetation layer shall exhibit the following characteristics:

- The surface shall promote drainage and excessive water shall not be allowed to pond on the surface
- The finished revegetation layer shall not be rutted or otherwise disturbed by the equipment deploying overlying materials or other traffic
- The Contractor shall provide erosion protection measures and ensure drainage systems (permanent and temporary) are maintained

12.12 Defects and repairs

Any areas of placed revegetation layer that do not conform to the required compaction and moisture content testing criteria shall be repaired by the Contractor in accordance with Section 2.17.

The Contractor shall submit to the Superintendent for review details of any defects identified and repairs carried out.

12.13 Acceptance

The Contractor shall retain ownership and responsibility for the revegetation layer until final acceptance of all work under this Contract by the Principal.

The revegetation layer shall be accepted by the Principal when all of the following conditions are met:

- Required lines, levels and thickness of the revegetation layer has been achieved within the allowable tolerances as confirmed by survey data
- Required submittals are provided by the Contractor to the Superintendent and approved
- CQC test results have been received and show compliance with the requirements of this Specification
- Details of all defects identified and repairs performed have been submitted to the Superintendent and approved
- The CQA Engineer has provided the Superintendent with a recommendation that the conditions of final acceptance have been met
- The Superintendent has inspected and approved the finished surface.

13. Interface friction testing

13.1 General

This section contains the technical requirements for determining the interface strength characteristics.

13.2 Standards

- ASTM D248.7 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
- ASTM D3080 Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions.
- ASTM D5321 Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method.
- Alternate test methods may be considered by the Superintendent when requested in writing by the Contractor if the maximum particle size of the materials being tested prevents the use of standard direct shear methods.
- GRI White Paper #11 - Interpretation(s) of Laboratory Generated Interface Shear Strength Data for Geosynthetic Materials with Emphasis on the Adhesion Value

13.3 Definitions

- Interface – Shall refer to any soil-geosynthetic or geosynthetic-geosynthetic surfaces which are in contact with one another.
- Interface strength – Shall be defined as the effective adhesion and effective friction angle of a given interface when tested by direct shear methods.

13.4 Submittals

Calibration data of the shear testing device for accuracy of normal stress and shearing force shall have been undertaken within the last 2 years.

Interface strength testing results. Interface strength testing results shall consist, at a minimum, of:

- Description of all specimen sampling and trimming procedures
- Description of all soils used in the testing including:
- Description of all testing equipment used
- Description of specimen configuration and preparation conditions including (where appropriate):
 - Preparation
 - Compaction (soils only)
 - Moisture content (soils only)
 - Soil gradation (soils only)
 - Soil classification in accordance with ASTM D2487 (soils only)
- Description of all test conditions including:
 - Test method employed

- Hydration information
- Consolidation information
- Strain rate utilised during shearing
- Vertical displacement data during hydration, consolidation and shearing
- Peak and large displacement:
 - Shear stress-strain plots
 - Normal stress-shear stress plots
 - Failure envelope plots.
- Interface efficiency (for soil-geosynthetic interfaces only)
- Location and condition of the failure plane(s) within the test specimen

13.5 Execution

- Retain an independent qualified testing contractor to perform interface strength testing of the interfaces. The quantity and quality of materials required for testing shall be requested by the independent certified testing contractor within 1 week of engagement based on the required interfaces.
- Provide materials in sufficient quantity and quality for testing as requested by the testing contractor.
- Testing at low normal stresses (<25 kPa) may be performed in either tilt-table or direct shear-type apparatuses. Testing at higher normal stresses shall be performed in a direct shear-type apparatus.
- Normal stresses applied to the sample shall begin at 10 kPa and shall extend to 50 kPa. Tests shall be performed at a minimum of three different normal stresses (nominally 10, 25, 50 kPa).
- Whenever possible, the soil or geosynthetic material above and below the interface materials shall also be incorporated into the testing apparatus and procedures.
- All tests shall be performed under saturated conditions.
- All geosynthetics shall be orientated in machine direction.
- Soil samples shall be compacted to 95% standard proctor with a moisture content of 2% above optimum moisture content and then incrementally loaded in the shear box and allowed to consolidate.
- Incremental loading rates shall not exceed 12.5 kPa/hr increments up to 50 kPa;
- Vertical displacement shall be monitored during all incremental loading. Shearing shall not take place until the change in vertical displacement is less than 5% over a 12 hour period.
- Interfaces strain rates shall not exceed 0.1 mm/min for soil-geosynthetic interfaces.
- Geosynthetic materials shall not be affixed to a substrate for the entire area of the sample and shall be allowed to strain during shearing.
- The interfaces included in Table 20 shall be tested:

Table 20 Testing interfaces and notes

Interface: Top / Bottom	Test Method (ASTM)	Tests (minimum) ⁽²⁷⁾	Notes
Double Textured HDPE Geomembrane / Seal Bearing Layer	D2487 D3080 D6482	3	Saturated condition Seal Bearing Layer to 95% standard, +2% OMC Incremental loading
Geonet Drainage Geocomposite / Subsoil Materials	D6482	3	Saturated condition Subsoil fill to 95% standard, +2% OMC Incremental loading

13.6 Interpretation

The proposed materials are to meet or exceed with the properties of the critical interfaces set out in Table 21 and be approved by the Designer (GHD) ⁽²⁸⁾.

The Designer (GHD) will assess interface friction strength requirements with consideration to GRI White Paper #11.

Table 21 Interface strength critical parameters

Interface	Friction angle – peak	Cohesion (adhesion) - peak	Friction angle – residual	Cohesion (adhesion) – residual
Subsoil over Drainage geocomposite	26 degrees	1 kPa	21 degrees	0 kPa
Drainage geocomposite over PEgeomembrane	26 degrees	1 kPa	21 degrees	0 kPa
PE geomembrane over seal bearing layer	26 degrees	1 kPa	21 degrees	0 kPa

13.7 Acceptance

The Contractor shall retain all ownership and responsibility for the interface friction testing until final acceptance of all work under this Contract by the Superintendent. The interface friction results shall be accepted by the Superintendent when all of the following conditions are met:

- Required submittals are provided by the Contractor to the Superintendent and approved.
- The Designer (GHD) has provided the Superintendent with a recommendation that the required critical interface friction strength requirements have been met

²⁷ Each test shall consist of three different normal stresses (nominally 10, 25, 50 kPa).

²⁸ The required interface friction parameters were determined with respect to Koerner and Soong, 1998 – *Analysis and Design of Veneer Cover Soils*, Sixth International Conference on Geosynthetics for cover soil (gravitational forces) as well as considerations for seepage build-up, construction loading, seismic forces.

14. Drainage

14.1 General

This section contains the technical requirements for drainage elements including open drainage channels and underground culverts.

All drainage provided is to maintain the cross-sectional flow areas, slopes and lining types indicated in the design drawings to allow for the design flow conveyance and resistance to scour.

14.2 Standards

- AS3500 – Plumbing and Drainage
- AS3725 – Design and Installation of buried concrete pipes
- AS3725 Supplement 1
- AS2758.1 – Concrete aggregates
- AS1141 – Methods for Sampling and Testing Aggregates
- Australian Rainfall and Runoff A Guide to Flood Estimation

14.3 Submittals

14.3.1 Prior to delivery of materials

The Contractor shall submit the following to the Superintendent for review and approval prior to delivery of drainage materials to site:

- Product details, information and certificates for any culverts to be installed
- Details of any bedding and haunch material for stormwater drainage
- Details including particle size distribution curve and specific gravity for placed rock

14.4 Materials and Installation

14.4.1 Erosion control matting

Erosion control matting is to be provided in locations specified in design drawings. Matting to be “Grassroots” product supplied by Geofabrics Australasia or equivalent. Hydroseeding to be provided underneath matting in accordance with Sections 12.4.3 and 12.7. Erosion control matting to be installed in accordance with manufacturers guidelines including Matting Installation Guide available from the supplier.

14.4.2 Topsoil

Topsoil in drainage channels is to be supplied and installed in accordance with general topsoil requirements detailed in Sections 12.3.2 and 12.4.2.

14.4.3 Placed rock and rip rap

Rock is to be provided in channels as specified in the design drawings. Rock selection and installation is to maximise stability of channel under high velocities and must include the following:

- Selection of rock sizing, mass and grading as specified in design drawings

- Selection of rocks with an angular shape (not round) to maximise interlocking
- Selection of hard, dense and durable rocks with a specific gravity of approximately 2.65
- Placement of rocks in layers with large rocks placed first and smaller rocks fitted tightly in-between larger rocks to maximise interlocking

14.4.4 Culverts

Delivery & Handling

Pipes shall be delivered, stacked and handled in accordance with the manufacturer's recommendations. Any box culvert which is damaged during installation or during compaction of fill shall be replaced by the Contractor at the Contractor's cost.

Jointing & Assembly

Pipes and fittings shall be installed and joined in accordance with the manufacturer's recommendations. Pipes shall be laid with the female end placed upstream.

Joints in box culvert segments shall be made using cement mortar to provide as thin a joint as possible. The external faces of the units shall be bandaged with 'Denso Tape 600' or approved equivalent 200 mm wide lapped by at least 100 mm.

Lifting holes in pipes and culverts shall be plugged with mortar, precast tapered plugs mortar or tape surrounded, or other approved means prior to backfill material being placed.

Cutting operations for concrete pipe and box culverts shall provide neat end surfaces. The cut surfaces shall be given two coats of a tar epoxy paint.

Joints shall not be made under water. The trench shall be de-watered to facilitate joint making and inspection. Precautions shall be taken to prevent erosion of joint material by moving currents of water.

Completed cement mortar joints shall be kept damp and protected from the direct rays of the sun until backfilling takes place.

Installation Condition and Support

Installation shall be in accordance with AS 3725 and AS 3725 Supplement 1 with Type HS3 support. Unless specifically noted otherwise, all pipes shall be installed in trench condition (either negative projection or induced trench). For trench installation condition in an embankment, the embankment must be completed to the underside of the sub-grade prior to the commencement of the excavation for the pipe unless the Principal's Representative directs a change to embankment installation condition and the pipe class is amended accordingly.

Where the prior placement of embankment fill is required to provide for Type HS3 Support, the fill shall be placed and compacted as part of earthworks construction specified in Section 2.3.

In water charged soil or made up ground, drainage shall be bedded on reinforced concrete lintels at least 150mm thick supported on piers or piles as specified and located at intervals not exceeding 3m or suspended from slabs.

Minimum cover to box culverts shall be 500mm under trafficable areas and 450mm elsewhere UNO.

Precast components

Pre-cast concrete headwalls to box culverts shall be supplied and installed in accordance with the manufacturer's specification. Quality certification to the appropriate Australian Standards must be supplied by the manufacturer and submitted to the Principal's Representative prior to incorporation into the works.

Fill Construction

Lifting holes on all units shall be sealed by the Contractor to a standard of full structural integrity and durability before commencement of backfilling.

All box culvers shall be bedded on a continuous underlay of sand, not less than 75 mm thick in other than rock and 200 mm thick in rock after compaction. The sand shall be graded in accordance with AS3500 (latest edition) and compacted to at least 90% of the maximum dry density and shall be graded evenly to the required gradient of the pipeline.

In wet or unstable ground conditions where the trench bottom requires further stabilising, additional bedding of 20 mm and/or 30 mm nominal size aggregate (as directed by the Principal's Representative), shall be placed below the standard bedding to a depth determined by the Principal's Representative. Where ordered by the Principal's Representative an approved filter fabric shall be used in conjunction with the additional bedding.

The bed material shall be compacted for the full width of the trench by a minimum of two passes of a vibrating plate or hand tamping method to the satisfaction of the Principal's Representative.

Chases shall be formed where necessary to prevent sockets, flanges or the like from bearing on the trench bottom or the underlay.

Fill construction includes all operations associated with the preparation of the foundation areas on which fill material is to be placed, the placing and compacting of approved material within areas from which Unsuitable Material has been removed, the placing and compacting of fill material and of materials of specified quality in nominated zones and all other activities required to produce filled areas as specified to the alignment, grading, levels and dimensions shown on the Contract drawings. The Principal's Representative may order the removal of any Unsuitable Material prior to commencing construction operations.

General Fill Material

General fill material shall be inorganic, non-perishable well graded material with a maximum particle size of 75 mm and particle size not exceeding two-thirds of the compacted layer thickness, plasticity index \leq 55%. General fill excludes material containing a sulphur content exceeding 0.5%.

Where excavated material is to be used for filling, the material shall be tested according to this Section 5. Test results must be approved by the Principal's Representative, following a visual inspection, prior to use of fill material.

Select/Engineered Fill:

Select/Engineered fill shall be granular material complying with the following:

- Particle size: 75 mm maximum.
- Proportion passing 0.075 mm sieve: 25% maximum.
- Plasticity index: \leq 2%, \leq 15%.
- Hardcore: Graded hard material capable of being compacted to an even stable surface.
- Particle size: 120 mm maximum.
- Proportion exceeding particle size of 50 mm: 75% minimum.

Selected/Engineered filling materials shall be free from:

- Organic soils
- Materials contaminated through past site usage

- Materials which contain substances which can be dissolved or leached out, or which undergo volume change or loss of strength when disturbed and exposed to moisture
- Silts or silt-like materials
- Fill containing wood, metal, plastic, boulders or other deleterious material
- Clays of high plasticity
- Material containing large particles after compaction
- Overwet materials
- Gravels or rock fill which leave voids
- Saline soils
- Carbonate soils
- Demolition rubble

Unsuitable Material

Unsuitable Material, defined as material below sub-grade in excavations, below structures in excavations and below natural surface under embankments with fill liable to subsidence, ground containing cavities, faults or fissures, ground contaminated by harmful substances or ground which is or becomes soft, wet or unstable, might be encountered beneath proposed structures such as footings, slabs and roads which the Principal's Representative considers to be unsuitable for embankment or pavement support in its present position and likely to remain so despite dewatering or drying out of the subject area.

Unsuitable Material can be identified visually or through proof rolling.

It shall be the responsibility of the Contractor to notify the Principal's Representative, of areas where treatment of Unsuitable Material may be required and to demonstrate to the satisfaction of the Principal's Representative the unsuitability of that material.

Unsuitable Material does not include that which:

- Has become saturated due to the Contractor having neglected to protect the work by providing adequate drainage; or
- Otherwise suitable material in a wet condition which can be removed, dried out and reused.

Material, which is deemed to be unsuitable shall be excavated and disposed of in suitable areas onsite or removed from site. Seek the Principal's Representatives instruction.

Material deemed unsuitable for pavement construction may include:

- Alluvium (soft silts with some organics)
- Organic soils, severely root-affected subsoils and peat
- Material with a particle size greater than 300mm
- Fill which contains wood, metal, plastics, boulders or other deleterious material.

After removal of the Unsuitable Material, the floor of the excavation shall be inspected by the Principal's Representative to determine whether a sufficient depth of Unsuitable Material has been removed, prior to backfilling with replacement material.

14.5 Maintenance

The Contractor shall be responsible for monitoring and maintaining the drainage network for a period of 12 months, in particular with relation to revegetation of channels, scour and the condition of the network after significant rainfall events. A maintenance program shall be undertaken by the Contractor and should be submitted to the Superintendent for approval.

14.6 Defects and Repairs

All repairs shall be undertaken in accordance with the manufacturer's instructions and the approved work method statement. All repairs shall be verified by the Superintendent. The drainage system was designed to convey a minimum of the 20-year ARI peak flow rate, with the exception of the rock lined channels where rock sizing was sized based on the 10-year ARI peak flow rate. For storm events in excess of these erosion or other related damage may result to channels and surrounding areas. An inspection of all drainage lines is to be undertaken during major events which could have possibly exceeded design storm events. The inspection should include observation for any signs of overflow from the system and any resulting damage. Repairs should be undertaken as required.

14.7 Acceptance

The Contractor shall retain all ownership and responsibility for the drainage network until final acceptance of all work under this Contract by the Principal.

15. Appurtenances

15.1 Concrete

15.1.1 General

The supply of concrete and concrete construction shall be in accordance with this Specification and the applicable referenced standards listed below.

The Contractor shall construct the concrete gas vent base as shown on the Drawings, including fixing the gas vent structure to the concrete base. All concrete works shall be as shown on the Drawings. The Contractor shall take care constructing the concrete base and shall not damage the underlying geosynthetic materials. All damage to the geosynthetic materials shall be repaired.

15.1.2 Standards

- AS 1012 Methods of testing concrete
- AS 1275 Metal screw threads for fasteners
- AS 1379 Specification and supply of concrete
- AS 1478 Chemical admixtures for concrete, mortar and grout – Admixtures for concrete
- AS/NZS 1554.3 Structural steel welding – Welding of reinforcing steel
- AS 2350 Methods of Testing Portland and Blended Cements
- AS 2758.1 Aggregates and rock for engineering purposes – Concrete aggregates
- AS 3582.1 Supplementary cementitious materials for use with Portland and blended cement - Fly-ash
- AS 3582.2 Supplementary cementitious materials for use with Portland and blended cement - Slag - Ground granulated iron blast-furnace
- AS 3583 Methods of test for supplementary cementitious materials for use with Portland and blended cement
- AS 3600 Concrete structures
- AS 3610 Formwork for concrete
- AS 3725 Design for installation of buried concrete pipes
- AS 3735 Concrete structures retaining liquids
- AS 3799 Liquid membrane-forming curing compounds for concrete
- AS 4100 Steel Structures
- AS/NZS 4671 Steel reinforcing materials
- AS/NZS 4680 Hot-dip galvanised (zinc) coatings on fabricated ferrous articles

15.2 Unclassified aggregate

15.2.1 Characteristics and supply

Unclassified aggregate shall comply with the acceptance criteria specified in and the following performance criteria:

- Consist of clean, sound, rock or crushed/broken brick and tile of nominally 50-100 mm in size
- Be free from metals, organic material and other contaminants
- Be free flowing and achieve a hydraulic conductivity of greater than 1×10^{-4} m/s

If required by the Superintendent, a sample of the material shall be provided (per source) and the Superintendent and/or CQA Engineer may undertake an inspection of the material source. The Contractor shall cooperate fully with the Superintendent and CQA Engineer to allow this inspection to occur.

15.2.2 Installation of unclassified aggregate

Unclassified aggregate shall be placed to the limits and minimum depths indicated on the Contract Drawings.

The unclassified aggregate shall be placed in a manner and with appropriate equipment such that damage does not occur to the underlying geosynthetics or pipework.

The Contractor, at no additional cost to the Principal and in accordance with the relevant provisions of this Specification, shall repair any damage that occurs to the geosynthetics as a consequence of the unclassified aggregate placing operation.

The Superintendent may direct removal of a layer of unclassified aggregate (at the Contractor's cost) to inspect underlying geosynthetics for damage. Any damaged geosynthetics shall be removed and replaced at the Contractor's cost.

15.3 Bentonite fill

Bentonite fill shall consist of nominal 6 mm bentonite pellets. Pellets shall be adequately hydrated during installation to provide a suitable seal around the installed pipe.

The Contractor shall submit manufacturer documentation for the bentonite fill to the Superintendent for approval prior to installation.

15.4 PE pipework

The materials used for the PE pipework and fittings shall be in accordance with the Contract Drawings.

The Contractor shall prepare a work method statement for delivery, storage, handling and installation of PE pipework and fittings, including repair methods (refer Appendix A). The work method statement shall be submitted to the Superintendent for review and comment prior to delivery of the PE pipework to site.

15.5 Gas vent

Vent shaft materials and installation shall be a post type ventilation shaft with a rotating cowl as per Sydney Water Standard Specification ACP0147 Ventshaft Guidelines. The Contractor shall submit documentation for the materials and a work method statement for the works (refer Appendix A) to the Superintendent for approval prior to installation.

15.6 Decommissioning of existing stormwater pipe

The existing concrete stormwater pipe shall be decommissioned.

The Contractor shall prepare a work method statement for the decommissioning works (refer Appendix A). The work method statement shall be submitted to the Superintendent for review and comment prior to undertaking the works.

The method shall consider:

- Preventing water entering the pipe at the upstream end
- Controlling the flow of any residual liquid at the downstream end.

The decommissioning works may include the following tasks:

- Remove existing waste material from around the upstream and downstream ends of the pipe to 1 m into the surrounding waste surface
- Remove the concrete pipe from the upstream and downstream ends, so that it terminates 1 m into the surrounding waste surface
- Install a grout plug within the concrete pipe at the upstream end and backfill the area with clay rich fill to match the surrounding waste surface
- At the downstream end, excavate a trench from the end of the pipe to the leachate toe drain. Install unclassified aggregate surrounded by separation geotextile to allow any liquid to flow from the end of the pipe into the leachate toe drain.
- Install a grout plug within the concrete pipe at the downstream end, maintaining a flow path to the aggregate filled trench, and backfill the area with clay rich fill to match the surrounding waste surface

Appendices

Appendix A – Schedule of work method statements

Component	Work method statement requirements
General	<p>The Contractor shall prepare the following general work method statements for review approval by the Superintendent:</p> <ul style="list-style-type: none"> • Scheduling • Site access and traffic control • Survey control • Surface water management • Erosion and sediment control
Earthworks	<p>The Contractor shall prepare an earthworks work method statement for review approval by the Superintendent with consideration to the following:</p> <ul style="list-style-type: none"> • Scheduling • Removal of vegetation • Excavation of earthwork materials • Filling of earthwork materials • Supply and quality control • Stockpile management and control measures • Method of moisture conditioning, material placement and compaction for earthworks materials • Earthworks material layer thickness control and survey • Trimming and final surface preparation • Anchor trench excavation and backfilling • Defects and repairs • Quality control testing
Subgrade	<p>The Contractor shall prepare a subgrade surface work method statement for review and approval by the Superintendent with consideration to the following:</p> <ul style="list-style-type: none"> • Surface preparation • Trimming and final surface preparation • Defects and repairs
Clay rich fill	<p>The Contractor shall prepare a clay rich fill work method statement for review approval by the Superintendent with consideration to the following:</p> <ul style="list-style-type: none"> • Scheduling • Method of moisture conditioning, material placement and compaction • Surface preparation • Material layer thickness control and survey • Trimming and final surface preparation • Defects and repairs • Quality control testing
PE geomembrane	<p>The Contractor shall prepare a PE geomembrane work method statement for review approval by the Superintendent with consideration to the following:</p> <ul style="list-style-type: none"> • Scheduling • Supply and quality control • Method of installation • Surface preparation • Defects and repairs • Quality control testing
Geotextile	<p>The Contractor shall prepare a geotextile work method statement for review approval by the Superintendent with consideration to the following:</p> <ul style="list-style-type: none"> • Scheduling

	<ul style="list-style-type: none"> • Supply and quality control • Method of installation • Surface preparation • Defects and repairs • Quality control testing
Drainage aggregate	<p>The Contractor shall prepare a aggregate work method statement for review approval by the Superintendent with consideration to the following:</p> <ul style="list-style-type: none"> • Scheduling • Supply and quality control • Method of installation • Quality control testing
Field trial – drainage aggregate	<p>The Contractor shall prepare a field trial work method statement for review approval by the Superintendent with consideration to the following:</p> <ul style="list-style-type: none"> • Method of transportation of aggregate material to placement location • Method of spreading aggregate material • Method of lift thickness control • Details of plant and equipment to be used during placement • Details of any additional protection measures required at the entry point • Approximate number of passes for each item of plant on the aggregate
Waste excavation and placement	<p>The Contractor shall prepare a waste excavation and placement method statement for review approval by the Superintendent with consideration to the following:</p> <ul style="list-style-type: none"> • Method of excavation • Method of transportation of waste material to placement location • Method of placing, spreading and compacting waste material • Method of lift thickness control • Details of plant and equipment to be used • Environmental controls (odour, surface water, dust)
Seal bearing layer	<p>The Contractor shall prepare a seal bearing layer work method statement for review approval by the Superintendent with consideration to the following:</p> <ul style="list-style-type: none"> • Scheduling • Method of moisture conditioning, material placement and compaction • Surface preparation • Material layer thickness control and survey • Trimming and final surface preparation • Defects and repairs • Quality control testing
Geonet drainage geocomposite	<p>The Contractor shall prepare a geotextile work method statement for review approval by the Superintendent with consideration to the following:</p> <ul style="list-style-type: none"> • Scheduling • Supply and quality control • Method of installation • Surface preparation • Defects and repairs • Quality control testing
Revegetation layer	<p>The Contractor shall prepare a revegetation layer work method statement for review approval by the Superintendent with consideration to the following:</p>

	<ul style="list-style-type: none"> • Scheduling • Supply and quality control • Method of moisture conditioning, material placement and compaction • Surface preparation • Material layer thickness control and survey • Trimming and final surface preparation • Planting and sowing • Vegetation maintenance • Defects and repairs • Quality control testing
PE pipework	<p>The Contractor shall prepare a PE pipework work method statement for review and approval by the Superintendent with consideration to the following:</p> <ul style="list-style-type: none"> • Scheduling • Supply and quality control • Method of installation • Surface preparation • Defects and repairs
Gas vent	<p>The Contractor shall prepare a gas vent work method statement for review approval by the Superintendent with consideration to the following:</p> <ul style="list-style-type: none"> • Scheduling • Supply and quality control • Method of installation • Defects and repairs
Decommissioning of existing stormwater pipe	<p>The Contractor shall prepare a gas vent work method statement for review approval by the Superintendent with consideration to the following:</p> <ul style="list-style-type: none"> • Scheduling • Supply and quality control • Method of installation • Defects and repairs • Details of plant and equipment to be used • Environmental controls (odour, surface water, dust)

Appendix B – Witness and hold points

Section	Hold points
1 Introduction	<p>Submittals</p> <p>Section 1.6.1</p> <p>Section 1.6.2</p> <p>Section 1.6.3</p> <p>Section 1.6.4</p> <p>Section 1.6.5</p> <p>Section 1.10</p> <p>Section 1.12</p> <p>Section 1.13.2</p>
2 Earthworks	<p>Submittals</p> <p>Section 2.3.2</p> <p>Section 2.3.3</p> <p>Acceptance</p> <p>Section 2.18</p>
3 Subgrade	<p>Submittals</p> <p>Section 3.3.1</p> <p>Section 3.3.2</p> <p>Section 3.3.3</p> <p>Acceptance</p> <p>Section 3.11</p>
4 Clay rich fill	<p>Submittals</p> <p>Section 4.3.1</p> <p>Section 4.3.3</p> <p>Acceptance</p> <p>Section 4.12</p>

5 PE geomembrane	<p>Submittals</p> <p>Section 5.3.1</p> <p>Section 5.3.2</p> <p>Section 5.3.3</p> <p>Section 5.3.4</p> <p>Acceptance</p> <p>Section 5.14</p>
6 Geotextile	<p>Submittals</p> <p>Section 6.3.1</p> <p>Section 6.3.2</p> <p>Section 6.3.3</p> <p>Section 6.3.4</p> <p>Acceptance</p> <p>Section 6.14</p>
7 Drainage aggregate	<p>Submittals</p> <p>Section 7.3.1</p> <p>Section 7.3.2</p> <p>Section 7.3.3</p> <p>Acceptance</p> <p>Section 7.10</p>
8 Field trial – drainage aggregate	<p>Submittals</p> <p>Section 8.2.1</p> <p>Section 8.2.2</p>
9 Waste excavation and placement	<p>Submittals</p> <p>Section 9.2</p>
10 Seal bearing layer	<p>Submittals</p> <p>Section 10.3.1</p> <p>Section 10.3.2</p> <p>Acceptance</p> <p>Section 10.12</p>

11 Geonet drainage composite	<p>Submittals</p> <p>Section 11.3.1</p> <p>Section 11.3.2</p> <p>Section 11.3.3</p> <p>Acceptance</p> <p>Section 11.12</p>
12 Revegetation layer	<p>Submittals</p> <p>Section 12.3.1</p> <p>Section 12.3.2</p> <p>Section 12.3.3</p> <p>Acceptance</p> <p>Section 12.13</p>
13 Interface friction testing	<p>Submittals</p> <p>Section 13.4</p> <p>Acceptance</p> <p>Section 13.7</p>
14 Appurtenances	<p>Submittals</p> <p>Section 15.3</p> <p>Section 15.4</p> <p>Section 15.5</p> <p>Section 15.6</p>

Appendix C – Example submittal forms

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