CQA INTERNATIONAL LIMITED

Magħtab Landfill Site

Construction of Steepwall Disposal Cell

Specification and

Construction Quality Assurance Plan

Ref. No. 30499

Prepared for: Wasteserv Malta Ltd

Date: 24 January 2022

ISO 9001
Certificate No. GB2005673

Environmental Engineers

CQA INTERNATIONAL LIMITED

The Keele Centre, Three Mile Lane, Keele, ST5 5HH, UK
Phone: +44 (0)1782 338990, Web: www.cqainternational.co.uk

Quality management data

Name of Project	Magħtab Landfill Site, Construction of Steep-Wall Disposal Cell
CQA Reference No.	30499
Client details	Wasteserv Malta Ltd
Client Reference No.	
Type of document	~~Report~~ / ~~Proposal~~ / other
Title of this document	Specification and Construction Quality Assurance Plan
Status / Version	Final
Issue date and history	V1 issued 30 April 2020 V2 issued 07 October 2020 V3 issued 05 November 2020 V4 issued 09 June 2021 V5 issued 24 January 2022
Prepared by	Bob Stevens / Peter Stevens
Reviewed by	Darren Bland
Authorised to be issued as a formal document of CQA International Ltd by (name, position)	Darren Bland Director
Signature	

Contents

Tables

Appendices

Detailed design drawings

30499-WSM-SW-01 location plan
30499-WSM-SW-02 Excavation plan
30499-WSM-SW-03 Formation plan
30499-WSM-SW-04 Mineral liner plan
30499-WSM-SW-05 Landfill sections
30499-WSM-SW-06 Steepwall & Basal Liner System Construction Details
30499-WSM-SW-07 Construction sequence 1
30499-WSM-SW-08 Construction sequence 2
30499-WSM-SW-09 Construction sequence 3
30499-WSM-SW-10 Construction sequence 4
30499-WSM-SW-11 Construction sequence 5
30499-WSM-SW-12 Access ramp section
30499-WSM-SW-13 Access ramp construction sequence 1
30499-WSM-SW-14 Access ramp construction sequence 2
30499-WSM-SW-15 Section through southern bench
30499-WSM-SW-16 Support frame next to road detail
30499-WSM-SW-17 Support Frame Construction Details
30499-WSM-SW-18 Support Frame Construction
30499-WSM-SW-19 Support frame base & sub units
30499-WSM-SW-20 Support frame top unit 1 for access ramp to landfill
30499-WSM-SW-21 Support frame units and connectors
30499-WSM-SW-22 Support frame units specific to southern bench
30499-WSM-SW-23 Southern bench frame units type & locations
30499-WSM-SW-24 Support frame sloping unit
30499-WSM-SW-25 Support frame top detail
30499-WSM-SW-26 Access ramp support frame unit types & locations
30499-WSM-SW-27 Access ramp support frame units first 5 lifts
30499-WSM-SW-28 Guide to locations of specific support frame units
30499-WSM-SW-29 Leachate Collection System Plan
30499-WSM-SW-30 Leachate Collection & Monitoring Points Construction Details 1
30499-WSM-SW-31 Leachate Collection & Monitoring Points Construction Details 2
30499-WSM-SW-32 Waste surface pre settlement plan
30499-WSM-SW-33 Post settlement restoration surface plan
30499-WSM-SW-34 Landfill Capping System Details
30499-WSM-SW-35 landfill gas collection system plan
30499-WSM-SW-36 Landfill Gas Well Construction Details
30499-WSM-SW-37 Restoration Surface Sections location Plan
30499-WSM-SW-38 Restoration Surface Sections

1. Introduction

1.1 Scope of document

This document is the Specification and Construction Quality Assurance (CQA) Plan for the construction of the containment system of the new disposal cell at Magħtab landfill site, which will utilise a steepwall lining method.

This document is part of the tender package, and subsequent contract, for the execution of these works which is issued by Wasteserv Malta Ltd.

The Contractor shall follow the instructions and procedures described in this Specification and CQA Plan.

1.2 Summary of the design

The disposal cell is located on the western side of the existing Magħtab landfill site in an area that included a previously constructed but unused hazardous waste landfill.

The new landfill will utilise an excavation into bed rock to provide the below-ground void space for waste disposal.

The excavation sides are vertical and up to approximately 50m in height.

The containment system on the base of the landfill and the access ramp will be a conventional composite liner, comprising mineral liner (low permeability soil), GCL, geomembrane, protection layer and leachate drainage system. The landfill base will be split into two cells.

The containment system on the sides of the excavation will be a vertical "steepwall" construction, comprising mineral liner (bentonite-enhanced concrete), geomembrane and protection layer. The system will be initially supported by a modular steel framework.

Both containment systems comprise all elements necessary for full compliance with Subsidiary Legislation 549.29, Waste Management (Landfill) Regulations, 2002, including an enhanced geological liner, a basal sealing system, protection of the geomembrane, leachate drainage layer and a leachate collection, extraction and monitoring system.

Detailed design drawings are presented in Appendix 1. The drawings are complete and comprehensive, expect for minor works that may be necessary to adapt the design dimensions to the actual dimensions and conditions on site. This particularly applies to areas of the site where excavation to formation level was not completed when the design drawings were produced.

2. Project team

2.1 Parties and responsibilities

There will be seven main parties involved in the development works outlined in this Specification and CQA Plan, as defined below.

i) Employer	The Employer is the entity which owns and has responsibility for the site. For the works undertaken at Magħtab Landfill Site the Employer is Wasteserv Malta Ltd. The Employer shall enter into a Contract with the Contractor for the execution of the works detailed in the Specification. Personal representatives or other parties may represent the Employer on site.
ii) Contractor	The Contractor shall be responsible for the construction of the Works. This company shall be responsible for all matters relating to the site including temporary works, stockpiling, working areas and site safety. It shall appoint a Site Supervisor who shall be responsible for the full-time control of the construction works and shall liaise with the CQA Engineer as required by this CQA Plan and in order to ensure compliance and safety on site.
iii) Surveyor	The surveyor shall be either a direct employee of the Contractor or a separate subcontractor who specialises in land surveying. The Contractor shall verify the accuracy of all survey data. The Contractor shall agree original ground levels with the CQA Consultant prior to commencement of site works. The agreed original levels shall provide a basis for measurement purposes and to verify that the containment systems have been placed to the specified layout, thicknesses and gradients.
iii) Subcontractor	A Subcontractor is an entity appointed by the Contractor for the installation of the separate elements of the Works. A Subcontractor shall have specialist knowledge and experience in his field. It shall appoint a Site Agent who will be responsible for liaising with the Employer/Contractor and the CQA Engineer. If suitably qualified and experienced, the Contractor may carry out the works in their entirety.
iv) Designer	This is the company appointed by the Employer to carry out the design of the Works. For this disposal cell the Design is CQA International Ltd following design parameters previously agreed by the ERA during the development of earlier Phases at the site.

v) Supervisor	This is the entity appointed by the Employer to supervise the Contractor's works. The Supervisor and CQA Consultant may be the same company. The Supervisor will be responsible for contractual matters relating to the Works.
vi) CQA Consultant	This is the company appointed to confirm that the Works are carried out in accordance with the requirements of this CQA Plan. The CQA Consultant shall appoint a CQA Project Manager to oversee the project from a CQA perspective and a CQA Engineer to provide quality assurance of the engineering works on site. The CQA Engineer shall be present on a full-time basis during those aspects of the Works that require quality control as dictated by this document. The CQA Engineer shall be approved by the ERA.
vii) Testing Laboratory	The laboratory(s) appointed by the Employer or CQA Consultant to perform any on or off-site testing as required. The appointed laboratory(s) shall be UKAS approved for each individual test (unless otherwise approved by the ERA). The CQA Engineer shall be responsible for liaising with the Testing Laboratory with regard to the scheduling and progress of the testing. Any on site testing by the Testing Laboratory shall be carried out under the instruction of the CQA consultant.
viii) Environment and Resources Authority	The Environment and Resources Authority (ERA) licences and regulates landfill sites to ensure that their impact on the environment is minimised. ERA will approve the Specification and CQA Plan for these construction works Following the completion of the construction works, the Construction Quality Assurance Validation Report will be submitted to ERA for review. Following the review of the report, ERA may approve the completed cell for use in accordance with the site permit conditions**.**

2.2 Provision of information

At various stages of the works and prior to any stage of work being undertaken the Contractor shall provide the CQA Consultant with the information listed below:

- Summary of Contractor's experience
- Certification training and experience of geosynthetics welding personnel
- Benchmark survey levels and co-ordinates
- Survey data for the various stages of works
- Daily journal

- Method statements and layout plans
- Details of proposed geosynthetics manufacturer
- Manufacturer's quality control certificates
- Details of extrudate resin
- Certificate of sub-grade acceptance
- Geosynthetics placement, joining, testing and repair records
- Cylinder test results
- Conformance samples of geosynthetics
- Grading and strength for granular leachate drainage blanket material
- Pipework quality control data and proposals for installation
- Geophysical leak detection survey report

The Contractor shall maintain his own records for all works associated with the contract. This includes all works associated with placement and testing of the geosynthetic materials used in the works as the Contractor shall be responsible for preparing the as-built drawings and must not rely on records maintained independently by the CQA Consultant.

No works shall be deemed to have been approved by the CQA Engineer until written confirmation of the acceptance of any respective section or layer is issued by the CQA Engineer to the Contractor. Until this process has been completed all works are subject to the inspection of the CQA Engineer, which may include the removal of inclusions or overlying materials or the execution of additional works as directed by and to the satisfaction of the CQA Engineer. Final acceptance of any element of the construction works will not be given until all inspections have been completed and respective survey data and test results have been obtained for an area / layer of the construction.

The CQA Engineer shall be responsible for compiling the CQA Validation Report verifying that the Works were carried out in full accordance with this document. The report shall incorporate all site records, materials documentation, survey drawings and laboratory testing results. Any non-compliances with or deviations from this document shall be recorded in the report including any remedial measures taken to rectify non-compliances. The report shall be submitted to the ERA for approval of the Works prior to any waste placement in the cell.

2.3 General construction sequence

The main design elements and the construction sequence shall be as follows:

Verification of excavation dimensions

Rock face inspection and treatment

Prepare access ramp to formation level

Prepare formation on excavation floor

Install mineral liner on base

Install rock bolts for the initial sidewall lift

Install first lift of the steep wall liner support system

Install geotextile and steel mesh

Install vertical geological liner

Install first panel of geomembrane sealing system on sides

Install geomembrane sealing system on cell base

Install leachate drainage stone

Install leachate drainage pipes

Install leachate collection sump

Place side liner protection system

Waste placement

Phased lifts of steep wall system

2.4 Surveys and tolerances

The Contractor shall carry out construction surveys to determine ground elevations at each of the following stages of earthworks during construction and at other times as may be necessary for record purposes and to measure quantities and verify thicknesses:

- prior to commencing the earthworks
- on completion of the site clearance and general excavation to the basal formation level together with the completion of the formation level in the leachate drainage sump, leachate extraction points and recessed areas for target pads including the corners, central points and crests of recessed areas in order that cross sections of the recessed areas can be produced for the CQA Validation Report
- on completion of installation of the mineral liner
- on completion of the geomembrane installation as the as built drawing showing locations and numbers of all welds, panels, repair, sample and test locations
- on completion of installation of the sand protection layer
- on completion of placement of the leachate drainage blanket granular layer including the locations of drainage pipes, pipe welds, monitoring and extraction points and target pads

- on completion of the leak detection survey identifying any areas of remediation or repair work

The surveys shall be used as a basis for confirming technical conformance and for recording as built geomembrane panel and repair locations. Surveys of base areas shall be carried out on a calculated set out grid with maximum spacing of 10m x 10m ensuring that all features and breaks in slope are recorded to facilitate confirmation of depths by the direct comparison of survey points. The orientation of the grid shall be agreed with the CQA Consultant prior to undertaking any earthworks. Once established the grid shall be the basis of all base area surveys where confirmation of construction depths is required. In addition to the grid further points shall be surveyed round the cell boundary at spacing not greater than 15m.

The slopes of intercell bund shall be surveyed at the toe and crest of the slopes with two additional survey points on the sloped surfaces in order that cross sectional drawings can be produced to prove the thickness of the mineral liner within the bunds.

The Contractor shall give sufficient notice of the intention to carry out the formation level and top of mineral liner surveys to enable the CQA Consultant to inform The Employer to conduct a joint survey or check the Contractor's survey. The check surveys shall be undertaken by the Employer's survey department, or a third-party surveyor, who shall survey independently of the Contractor a minimum of 10% of the survey points taking in basal areas, bund slopes and recessed areas. The check survey results shall be supplied to the CQA Engineer for review and action.

The results of the check survey undertaken by the Employer, along with the Contractors survey results of the same points, are to be presented in a table. The table should show the coordinates of the points in the check survey, the elevations from both surveys and if any variation in the elevations lies within the accepted tolerances of the survey equipment (doubled) and if the check survey had passed or failed the tolerance. The check survey table shall be supplied to the CQA Engineer for review and action and included with the CQA validation report.

The Contractor shall forward a paper and an electronic copy of each survey in 3D DXF, DWG, LSS or other similar approved format within five working days of undertaking the survey. Proceeding with the installation of an overlying layer before it has been verified to the satisfaction of the CQA Consultant that the thickness of the preceding layer as calculated by survey is consistent with this Specification is at the Contractor's own risk.

The tolerance limits for the works shall be as follows:

- The heights of bunds shall be no less than those shown on design drawings and shall not exceed them by more than 100mm unless agreed with the CQA Consultant. The crests shall be sensibly plane with no obvious undulations or low areas where water may pond.

- Slopes and base grades shall be sensibly plane and within 1% of the gradient shown on the drawings.

Depths and thicknesses of any fill, mineral liner, sand protection layer, trenches and drainage materials shall not be less than the dimensions shown on the drawings.

2.5 CQA activities

The CQA Consultant will inform ERA about the start of the works, and any subsequent postponement and remobilisation, in order to allow the ERA the opportunity to inspect the works when activities are being undertaken

The CQA Project Manager shall be primarily responsible for the following tasks:

- review all designs, plans and specifications
- review other site-specific documentation including proposed layouts
- administer the CQA programme i.e. assign tasks and instruct CQA personnel, review and audit field reports and review CQA related issues
- attend CQA-related meetings as necessary
- provide quality control of the CQA personnel
- review all changes to the design, plans and specifications
- review the record drawings
- oversee preparation of the validation report

The CQA Project Manager will visit site for progress meetings and other times as deemed necessary and agreed with the Employer; and at these times will also have authority the act as the CQA Engineer.

The CQA Engineer shall be responsible for undertaking all day-to-day quality assurance monitoring and for making appropriate records as follows:

- check that all materials meet the specifications and performance criteria
- attend all CQA related meetings e.g. preconstruction and progress meetings
- prepare or oversee the ongoing drafting of the record drawings
- assign locations for testing and sampling
- prepare and review daily reports and logs
- oversee the collection and dispatch of all samples for laboratory testing
- review results of laboratory testing and make appropriate recommendations
- report any unresolved deviations from this CQA Plan to the CQA Project Manager

- provide all logs and relevant data to the CQA Project Manager for the preparation of the final report
- review all certification and documentation from the Contractor and make appropriate recommendations
- note and bring to the attention of the Contractor or Employer any on-site activities that could result in damage to the liner system components

The CQA activities may include other tasks not listed above.

2.6 Employer checks

The Employer shall implement visual checks of completed works, with both the CQA Consultant and the Contractor, undertaking a site walkover at the end of the contracted works to ascertain that the correct thickness of materials has been placed, which may include hand excavated inspection pits, if deemed necessary, during the visual check. These checks will be logged on a check sheet as shown Appendix 3

3. Earthworks

3.1 Preparation of the formation

The excavation for the landfill void has been made by the Employer.

The formation for the access ramp has been constructed by the Employer as a sloping bench in the in-situ bedrock strata on the western side of the excavation.

A bench has been formed from bedrock on the southern face of the excavation, which has a sloping access ramp from the eastern side of the base of the excavation.

The Contractor shall carry out a baseline topographic survey to confirm that the lines and levels are compliant with the design.

Any major differences shall be reported immediately to the Supervisor in order that the design can be modified, if necessary.

The excavation has been carried out by bulk excavation methods and the Contractor shall carry out final excavation and filling (locally up to 1m in depth) to produce the required gradients and levels.

It may be necessary to over-excavate the formation and construct the requisite levels using appropriate fill material installed in accordance with Highways Series 600 specifications for the compaction of such granular fill material. The new cells shall incorporate a radial fall to the leachate collection sump in the centre of the cells.

The floor of the new landfill will be divided into two cells by gradients in the cell floor.

The formation shall be compacted and prepared to a suitable condition as the foundation for constructing the basal mineral liner.

Excavated suitable and unsuitable materials shall be stockpiled at locations agreed with the CQA Engineer.

Any loose materials shall be removed from the excavation floor and be placed in the agreed stockpiles.

Filling shall utilise suitable material and shall be compacted as specified in this document.

The Contractor shall be given a benchmark on or near the site to which all levels shall be referred. The levels and coordinates of the Contractor's temporary benchmarks shall be agreed with the CQA Consultant.

If necessary, the Contractor shall remove any water from the base of the landfill during construction.

3.2 Definitions

The following definitions shall apply to this Specification wherever reference is made to the defined material.

i) Suitable fill material - shall comprise all that which is in accordance with the Contract for use in the works and deemed by the CQA Engineer to be suitable. Suitable fill material available on site can be one of the following- silty clay, sand, gravel, crushed limestone.

The use of general fill material within the works shall be in-accordance to the Manual of Contract Documents for Road Works, Transport Malta, 2003. Hand shear vane testing (calibrated) of compacted general fill material shall be in accordance with test method (BS 1377:1990) Part 9: Method 4.4 having a required value of ≥ 50 kN/m^2 at a frequency of 1 per $250m^3$ of placed material.

ii) Unsuitable material shall mean material other than suitable materials and shall include:

- Peat, material from swamps, marshes and bogs
- Logs, stumps and perishable material
- Material in a frozen condition
- Material susceptible to spontaneous combustion
- Any industrial, commercial or domestic waste
- Cobbles and boulders with a maximum dimension greater than 100mm
- Materials having a moisture content greater than the maximum or less than the minimum permitted for materials in the Specification unless otherwise permitted by the CQA Consultant
- Clay of liquid limit exceeding 90% and or plastic index exceeding 65%
- Material which cannot be compacted to the satisfaction of the CQA Engineer

In case of uncertainty, the CQA Consultant will determine which materials are unsuitable.

Material outside the permitted moisture content range shall be classified as suitable when wetted or dried sufficiently as appropriate.

The cell area shall be excavated to the formation level shown on Drawing 30374-WSM-SW-FD-02. The Contractor is required to excavate the sump and target pads from the formation layer as shown on drawings 30374-WSM-SW-FD-03 and 30374-WSM-SW-FD-14.

4. Basal mineral liner

4.1 Material source and specification

A basal mineral liner shall be constructed directly onto the prepared base of the cell, southern bench and access ramps. The material source shall be selected by exploration and sampling of potential source materials. The Contractor shall carry out a minimum of two modified Proctor compaction tests for each source to determine the acceptance envelope, which will then be used to control the earthworks. The material as used shall be characterised by classification, compaction, permeability and strength tests.

The basal mineral liner shall be placed in two lifts, which shall be spread by bulldozer and then compacted by vibrating pad-foot roller. The Contractor shall propose the details of the plant which will achieve the necessary compaction specifications. Different plant may need to be used on the southern bench and its access ramp.

The thickness of the two lifts be equal and shall achieve a minimum thickness of 500mm after finishing with a smooth roller. The basal mineral liner will abut against the base of the excavation faces.

The Contractor shall provide to the CQA Consultant before works commence a method statement detailing how it intends to place and compact the basal mineral liner. This statement shall be reviewed by the CQA Consultant for approval and amended as necessary once works are underway.

4.2 Compaction trial

Prior to the commencement of basal mineral liner construction, a compaction trial shall be carried out to prove that the proposed construction methodology will achieve the required specification. The trial shall prove compaction for basal liner construction and acceptable compaction regime for sloped areas of basal mineral liner. The general methodology for construction of the compaction trial is set out below:

a) The work shall be carried out in general accordance with Manual of Contract Documents for Road Works, Transport Malta, 2003.

b) The material shall be spread over a minimum area of 50m^2 (or a minimum of 3 machines widths wide) to achieve a nominal compacted layer thickness of 250mm using a pad foot roller in general accordance with Table 6/4 of the Manual of Contract Documents for Road Works, Transport Malta, 2003.

c) The layer shall be compacted with a range of passes of the compaction plant, as necessary, and tested for each compaction regime by the CQA Engineer (or Testing Laboratory) to determine the most effective method of achieving the required specification

d) On completion of testing and sampling of the first layer, a second layer shall be placed, compacted and tested in accordance with a), b) and c) above

e) The testing/sampling shall comprise, for each layer
   - Three core tests per compaction regime for density/ moisture content
   - One core sample for laboratory permeability testing
   - One bulk sample for laboratory classification testing

f) Upon completion of the trial, the adequacy of the bonding between the individual layers shall be investigated by careful stripping of the upper layer to verify that no definable interface is present between the layers

The Contractor may adopt alternative methods of compaction subject to the approval of the CQA Consultant. A compaction trial shall be carried out for each alternative method proposed.

Where the results demonstrate that the methodology and plant used for the compaction trial achieve the required specification (i.e. compliance with Table 1), works may proceed with placement of the basal mineral liner. If the results of the trial prove unsuccessful, the placement methodology and/or compaction plant shall be changed, and a further trial carried out to assess the revisions. This process shall continue until the CQA Engineer is satisfied that the proposed plant and methodology will produce satisfactory results. If the compaction trial is carried out within the liner area, any non-conforming material shall be removed prior to liner construction.

If an alternative or additional pad-foot roller is proposed for use in liner construction subsequent to the compaction trial, the Contractor shall submit details for the approval of the CQA Consultant prior to its use confirming that the roller has a compaction effort equivalent to or exceeding that of the roller used in the trial. If the compaction effort is less, an additional compaction trial shall be carried out in accordance with the details above.

The CQA Consultant will inform ERA at least 48 hours prior to the compaction trial taking place to allow inspection of the trial if required. The results of the trial will be provided to ERA immediately upon completion.

4.3 Basal mineral liner construction

On completion of the compaction trial, the basal mineral liner shall be constructed using the plant and methodology determined by the trial. The compaction methodology shall not be changed without further trials to demonstrate the suitability of any revision.

The basal mineral liner shall be constructed to a minimum thickness of 0.5m.

Any unsuitable materials within the liner shall be removed including any stones larger than 100mm or excessively softened or wetted material. The Contractor shall ensure that the

matrix of the basal mineral liner is of uniform consistency and finely graded. Large (≥100mm) clods shall be broken or removed before compaction and any remaining fragments (≤100mm) shall be dispersed throughout the layer. The reduction and removal of oversized elements within the basal mineral liner reduces the risk of narrow fissures being created adjacent to these oversized elements hence creating preferential pathways for liquids through the basal mineral liner. The CQA Engineer shall identify and ensure the removal of oversized elements within the basal mineral liner.

Joints between sections of placed basal mineral liner shall be constructed with a stepped connection between successive layers to assure the continuity. This shall also apply to the connection detail between the adjacent cells.

If a smooth-drum roller is used to seal an intermediate layer surface against rainfall or desiccation, or if the material surface becomes smooth from trafficking, the layer surface shall be scarified to a minimum depth of 25mm prior to the placement of any subsequent layer to ensure a competent key between layers. Any material that becomes excessively wet or dry shall have the moisture content modified or be removed from the Works, to the satisfaction of the CQA Engineer.

The required final profile and construction details for the lining system are shown on the drawings

The thickness of the completed liner shall be determined by level survey in accordance with the specified survey requirements. If the results of the surveys indicate that the basal mineral liner does not achieve the requisite thickness, additional material shall be placed and compacted, and the area(s) re-surveyed until the requisite thickness is achieved. Any additional material shall also be tested in accordance with Table 1.

The surface of the completed liner shall be prepared to a smooth, even profile using a smooth-drum roller or other suitable approved method to provide a suitable subgrade to the overlying geomembrane.

The CQA Engineer shall verify that all aspects of liner construction are carried out in accordance with this document including compliance testing as detailed below following the results of the basal mineral liner as built survey from the Contractor.

4.4 Compliance testing

The Contractor shall carry out a regime of field compliance testing and sampling for laboratory testing in accordance with Table 1, under the supervision of the CQA Engineer, to verify that the liner meets the required specification and placement criteria. The testing shall be carried out on each layer placed and the test location and result shall be recorded by the CQA Engineer. Cores shall be taken from the base of each layer such that compaction is verified at full layer depth. Subsequent layers of material shall not be placed until the CQA Engineer has verified that the tested layer has achieved the requisite density / moisture

content criteria. Any remedial works shall be carried out as determined by and to the satisfaction of the CQA Engineer.

All perforations made in the liner for testing or sampling purposes shall be backfilled with compacted material to the satisfaction of the CQA Engineer.

Samples for testing on site shall be tested the same day as they are taken. Samples for dispatch to the laboratory shall be immediately sealed in plastic bags, with chain of custody forms included within. Samples shall be stored in the site cabin until collection by the laboratory (typically within 4 working days) if the courier fails to collect the samples on the given day and the 4 working days storage on site is to be exceeded, then the following action plan shall be implemented whilst awaiting collection.

Samples that the courier had failed to collect and that can be susceptible to moisture change these samples shall be kept in a refrigerator prior to collection. The courier shall be contacted to rearrange collection of the samples at the earliest available time.

The CQA Engineer shall check the results of all laboratory compliance testing to verify that the basal mineral liner meets the required specification and hence grant approval of each layer.

At locations where the results of the field or laboratory testing indicate failure to achieve the required acceptance criteria, the extent of the non-compliant area shall be determined by the CQA Engineer based on surrounding locations of compliant tests.

Non-compliant areas shall be remediated by one of the following procedures:

- Additional compaction of the area
- Adjustment of the moisture content by the mixing in of water (to the full layer depth) or by scarifying and allowing drying until the required moisture content is obtained, followed by re-compaction
- Removal of the material and replacement with suitable material

The CQA Engineer shall record all locations of non-compliance together with remedial actions taken and shall not permit placement of a subsequent layer on the area until compliance is achieved.

4.5 Surface approval for installation of geosynthetics

The completed surface of the basal mineral liner shall be inspected by the CQA Engineer who shall verify its suitability for installation of the geosynthetics. The surface shall be smooth and firm, without irregularities including localised bumps, hollows or shrinkage cracks and free of oversize stones or other potentially deleterious materials. The surface shall be prepared such that there are no sharp angles exceeding +/- 10mm over a 1m lath with no large rounded irregularities exceeding +/- 50mm over a 3m lath. The CQA Engineer shall carry out these measurements at pertinent locations, at a minimum frequency of 5 per

hectare, to verify compliance and the measurements shall be included in the CQA Validation Report. Any non-compliance issues shall be remediated to the extent determined by the CQA Engineer. The maximum particle size in the subgrade surface shall be 20mm. All such particles shall be rounded in shape. Acceptance of an area may be withdrawn if its condition deteriorates prior to geomembrane installation as to be no longer acceptable.

The Contractor shall carry out any remedial works to the approval of the CQA Engineer. The surface shall be subject to final inspection and approval by the CQA Engineer immediately prior to the deployment of each panel of geomembrane, at which point additional works may be undertaken as deemed necessary to obtain the final approval of the CQA Engineer.

The specified survey data verifying basal mineral liner thickness shall be submitted to the CQA Engineer for approval before installation of the geomembrane can commence. The "top of basal mineral liner" survey should use the same survey grid as the formation level survey so that point on point comparisons can be made to ensure the thickness of the basal mineral liner. All breaks of slope are to be surveyed including the recessed areas of the basal mineral liner where the leachate monitoring and extraction points are placed. The grid of survey points should be extended onto all slopes, and points should also be taken as break lines along the toe and crest of the slopes. There should be a minimum of one survey point on the slopes on each perpendicular line between the crest and toe points.

The Contractor shall produce an isopach drawing showing the thickness of the basal mineral liner, with cross sections at 10m intervals, for the CQA Validation Report.

5. Steepwall mineral liner and support system

5.1 Summary

The steepwall mineral liner will comprise bentonite-enhanced concrete, cast as a vertical slab in a series of pours against the sides of the excavation.

The bentonite-enhanced concrete will be cast against a formwork of filter geotextile and steel mesh, supported on a modular steel framework that shall be bolted to the sides of the excavation. The framework will also be used to support the geosynthetic lining.

The steepwall mineral liner will initially be installed to a height of 3m. It will be extended upwards in stages during disposal operations, in coordination with the level of waste in the landfill.

Installation of the steepwall mineral liner shall commence after the basal mineral liner is completed. This can be phased into work areas of sensible dimensions.

5.2 Supporting modular structure - components

The supporting structure (support frame) for the modular steepwall mineral liner shall be formed from combinations of the various units that are shown in the drawings. The main frame of the structure shall comprise a grid made from 40mm x 40mm galvanised steel square box sections, with a 3mm wall thickness. The grid shall have 1.5m spacing, vertically and horizontally. It shall be formed from prefabricated units, each comprising one complete square and the stub arms of adjacent squares.

The stub arms on the top shall be 1.11m long. On the base they shall be 0.35m long, so that these shall form 1.5m squares when fixed onto the adjacent unit. The fixing shall be achieved by placing the join inside an oversized, 50mm x 50mm, galvanised steel box section, which is bolted in place.

The stub arms on the sides will be 0.35m long. An oversized, 50mm x 50mm, galvanised steel box section, shall join the two stub arms and shall be bolted in place. The shorter stub arms will allow some flexibility in the angle between units to accommodate the shape of the excavation face.

The square units shall have triangular corner bracket located on the right-hand upper quadrant of each cross point. The brackets will be 150mm x 150mm where attached to the frame and be made from 6mm galvanised plate. These shall be welded onto the rear of the intersection. There shall be holes drilled into the centre of each bracket for fixing to the rock bolts.

All frames and connectors will be galvanised only after fabrication in accordance with the specification is complete. Any cut faces or locations where alterations may be required on site shall be primed to reduce the risk of corrosion.

The modular steel structure will be assembled from the following units, which are shown on Drawing 30499-WSM-SW-21 and referenced drawings.

Unit	Description	Locations used
SF 01	Main unit	All, except first (basal) row
SF 02	Sub unit 1	Above access ramps
SF 03	Sub unit 2	Below access ramps
SF 04	Main base unit	All, first (basal) row only
SF 05	Subbase unit 4	Above southern bench
SF 06	Subbase unit 1, horizontal	Below access ramps
SF 07	Subbase unit 2, angled	Above main access ramp
SF 08	Subbase unit 3, angled	Above ramp to southern bench
SF 09	Top unit 1	Main access ramp
SF 10	Top unit 2	Access ramp to southern bench
SF 11	Top unit 3	Southern bench
SF 12	T-connector	Above and below access ramps
SF 13	Horizontal connector	All
SF 14	Vertical connector	All
SF 15	Horizontal bar	Sloping units
SF 16	Horizontal bar	Sloping units
SF 17	Vertical bar	Sloping units
SF 18	Connecting bracket	Sloping units
SF 19	Connecting bracket	All, top units
SF 20	Top rail	All, top units

All modular units will be connected using the indicated horizontal and vertical connectors, which are sleeves made from a larger box section, that fit over the unit arms and which are fixed with M10 bolts.

The Contractor shall provide a sufficient quantity of M10 steel nuts, washers and bolts.

Some bolt holes can be prefabricated (prior to galvanizing). Bolt holes on unit arms and sections that need to be adjusted to site conditions will need to be drilled on site.

5.3 Supporting modular structure - fixing

The supporting structure (support frame) shall be fixed to the sides of the excavation by rock bolts.

The rock bolts shall be installed in a grid at 1.5m centres, to match the locations of the holes in the connecting plates on the steel frame units. The elevation of the first row of the grid will be approximately 50mm above the top of the basal mineral liner.

The rock bolts will comprise textured steel bars with a nominal diameter of 20mm and will be threaded as necessary for fixing. The rock bolts will be installed horizontally into drilled holes with a depth of 1.5m. The hole size shall be selected to allow the rock bolts to be inserted but will allow effective adhesion of grout.

The rock bolts will be secured with a strong epoxy grout, which will be required to cure for at least 24 hours before any tensile force is applied (i.e. fixing the support frame units).

The support frames shall be positioned so that the rock bolts protrude through the holes in each corner bracket. The washer and nut combinations shall be tightened to fix each support frame unit in a vertical orientation, with a minimum distance of 0.6m from the rock face. Any surplus rock bolt rod that extends past the nuts shall be cut off and the end ground smooth, to ensure that the fixing does not protrude beyond the front face of the frame assembly.

The Contractor shall inform the Supervisor if they are concerned by potential instability in any areas of the excavation face.

5.4 Installation of formwork

The steepwall mineral liner shall be contained within a formwork of filter geotextile, held in placed by a steel mesh fixed onto the outer face of the supporting steel framework.

The filter geotextile shall be as specified in Table 7.

The galvanised steel mesh shall be rectangular grid of galvanised 3mm steel wire. The mesh spacing will be 75mm horizontally and 25mm vertically. The mesh shall be spot welded at each intersection of the steel wires.

The mesh will be cut so that there are no protruding wires. The joins will be located over the box sections, with minimal overlap.

The mesh shall be fixed to the support frame units with cable ties. These shall be inserted through the mesh, either side of the box sections, so that the clip fasteners are on the inside of the structure. These shall be tightened by a technician working inside the framework.

The cable ties shall be stainless steel with a minimum tensile strength of 160kg and a nominal width of 7.9mm. The cable ties shall be installed at the corners of each square and at 0.3m centres, amounting to a minimum quantity of 20 for each 1.5m x 1.5m frame section.

The filter textile shall then be placed over the inside face of the support from and fixed in place along the top box section of the support frame units with plastic cables ties, again with the fastener on the inside.

The Contractor shall install temporary formwork between the steel grid and the excavation face at the end of each completed section of support structure, prior to the installation of the steepwall mineral liner.

5.5 Vertical lining system adjacent to perimeter road

The lining system in some upper parts of the excavation will not be fixed to the excavated rock face. These sections are adjacent to the perimeter road where it is supported by a block retaining wall, and at the northern end of the landfill near to the underground water storage tanks, where there is neither a cliff face or block retaining wall.

In areas where the block walls are within 1m horizontally of the location of the support frame, the standard fixing procedure will be employed. In sections were the distance is greater from the block walls or the formation surface, an artificial 'cliff' will be constructed as shown in drawing 30499-WSM-SW-FD-35 and other relevant drawings.

A vertical wall constructed from bulk bags (flexible intermediate bulk containers - FIBCs) filled with 6F2 (or equivalent) will provide the rear face against which the bentonite enhanced concrete liner will be cast. After each layer of bulk bags is placed the void between the bulk bags and the existing block retaining wall will be filled with 6F2 (or equivalent). This will be placed and compacted in layers.

The ground anchors required to fix the support frame units will be installed in the backfill and passing between the bulk bags, as this material is placed in stages. The ground anchors will be constructed from 3m x 20mm rebar with a 300mm x 300mm x 6mm steel plate attached to one end. The vertical wall of bulk bags will only be constructed to a height to enable the next lift of support frame to be installed. The Contractor shall ensure that the works do not affect the perimeter road structure, which is outside the battery limit of the landfill construction.

5.6 Lining system on sloping fill slope

In areas where the top of the excavation is a sloping surface, rather than a 90 degree crest, the upper part of the lining system shall be constructed as shown in drawing 30499-WSM-SW-24 and other relevant drawings. The ground anchors (excluding end plate) shall be used to provide temporary support to the framework while the lining system is installed.

5.7 Installation of steepwall mineral liner

The steepwall mineral liner shall be formed from bentonite-enhanced concrete, with the following mix, with proportions by weight:

Coarse aggregate	40%
Fine aggregate	45%
Cement	10%
Bentonite	5%

Mix certificates from the batching plant shall be provided for each delivery of bentonite-enhanced concrete. The CQA Engineer may require samples to be taken for laboratory testing to confirm the mix proportions. One samples shall be taken for permeability testing at the frequency specified in Table 1. The samples shall be taken by tamping a representative amount of the material into a 100mm plastic "U100" sample tube. These shall be numbered and cured on site prior to delivery to the testing laboratory.

The bentonite-enhanced concrete shall be installed into the void between the rock face and formwork by a mobile concrete pump. The water-cement ratio will be adjusted to provide a slurry that will flow easily into all parts of the formwork, without excessive separation and bleeding of water or fines. A sonic vibrator will be used as necessary to ensure a consistent density and lack of air bubbles.

The top surface of each layer in a single lift shall be wetted as necessary with fresh water prior to installing the next lift. Layers which were cast more than 1 week prior to the next lift shall be wetted with a bentonite slurry.

5.8 Construction sequence

Initially, the first two rows of the support frame shall be installed in order to support installation of the mineral liner and geosynthetics to a height of 4.1m.

The grid shall be increased as the height of waste approaches the height of the sidewall liner. The subsequent lifts will involve two rows of frame units. This is for information only because the Employer may install the second and subsequent lifts under a different contract.

6. Lining system on ramps and bench

6.1 Main access ramp - construction sequence

The Construction of the main access ramp is shown in the Drawings. This shall be as follows:

Support frame above access ramp

Install the safety barrier along the edge of the access ramp.

Install engineered mineral liner on access ramp surface. Leaving 2m standoff from inside edge to minimise the risk of causing damage from the vibrating compactor.

Place a 2m wide strip of GCL along the edge of the access ramp surface where it meets the excavation face before installing any support frames.

Place first support frame basal units in position to locate rock bolt locations.

Drill holes for rock bolts

Install rock bolts

Fit support frame basal units and connectors

Place next support frame units

Repeat the last 5 steps

Place filter geotextile over outside face of support frame

Fix steel mesh over support frame

Place wedge of mineral liner at toe of support frame

Install bentonite enhanced concrete behind support frame in 1m lifts

Install protection geotextile over support frame

Install HDPE over support frame

Install GCL over mineral liner of access ramp

Install double textured HDPE over GCL

Install protection geotextile over HDPE

Place 1m thick protection layer over geotextile

Install second safety barrier along edge of protection layer

Install waste bales against support frame

Support frame below access ramp

Install support frame units to top of excavation face below access road

Remove safety barrier

Install geogrid

Place engineered mineral liner over geogrid using thin layers and small compactor

Install 12mm wide polymer ties from top support frame unit to geogrid

Place filter geotextile over outside face of support frame

Fix steel mesh over support frame

Install bentonite enhanced concrete behind support frame in 1m lifts

Install GCL over mineral liner of access ramp to edge of top support frame

Install double textured HDPE over GCL

Install protection geotextile over support frame

Install smooth HDPE over support frame

Install waste bales against support frame

Install protection geotextile over HDPE on access ramp and over the top of the waste bales to stop the protection layer material migrating behind the waste bales

Place minimum 300mm protection layer over geotextile

6.2 Main access ramp - Liner installation

The formation for the access ramp has been created by the Employer. This shall be prepared as described in Section 3.1.

A safety barrier shall be placed 1m from the edge of the access ramp. This shall be formed from large limestone blocks, concrete blocks or an earth bund, as available.

The basal mineral liner and protection layer shall be installed over the entire length of the access ramp, as specified in 4 and as shown in Drawing 30499-WSM-SW-12.

The steepwall liner and support frame shall be installed on the face of the excavation above the access ramp, as shown in Drawing 303499-WSM-SW-27, over the entire length of the access ramp. The installation shall be as specified in Section 5.

The steepwall liner and support frame shall be installed on the initial lift only below the access ramp, as shown in Drawing 30499-WSM-SW-27. The installation shall be as specified in Section 5.

6.3 Southern bench

The "horizontal" liner on the southern bench shall be formed as specified for the basal mineral liner. The Contractor shall take precautions to avoid causing instability or accidents when working close to the edge of the bench.

The "vertical" liner and support frame installation and connections to the "horizontal" mineral liner shall be formed as described for the main access ramp, except that horizontal units and connectors will be utilised.

Refer to drawing 30499-WSM-SW-15 and other relevant drawings.

6.4 Access ramp to southern bench

The lining system on the access ramp to the southern bench shall be formed as specified for the main access ramp, except that the unbound road is not required The Contractor shall take precautions to avoid causing instability or accidents when working close to the edge of the ramp.

The support frame installation shall be as described for the main access ramp.

Refer to drawings 30499-WSM-SW-12 to 15 and other relevant drawings.

7. Access road pavement

7.1 Summary

The road pavement will extend the total length of the main access ramp, then continue onto the 10m wide bench of the cell and then down the access ramp into the cell base. A turning area will be formed at the lower end of the main access ramp so vehicles can reverse down the ramp into the cell during placement of the first waste into the cell. See drawings 30499-WSM-SW-29, 13 & 14.

7.2 Road pavement - specification

The road pavement for the access ramp shall be formed from 1000mm of a well-graded, angular sub-base material and 250mm of a suitable wearing course material.

The sub-base material shall have the following grading characteristics:

Sieve size	Weight passing, %
63	100
31.5	75 – 99
16	43 – 81
8	23 – 66
4	12 – 53
2	6 – 42
1	3 – 32
0.063	0 – 9

The sub-base shall be placed and compacted in layers no more than 250mm thick (after compaction).

The wearing course material shall be a dry-bound macadam. This will comprise a coarse aggregate, with a grading as follows, and a fine aggregate.

Sieve size	Weight passing, %
75	100
50	55 – 100
37.5	0-30
28	0-5

This coarse aggregate shall be spread and compacted in two layers, each 150mm thick. After each layer is spread and compacted, fine aggregate (sand and grit) shall be spread onto the surface and compacted into the coarse aggregate by vibrating smooth roller to produce a dense layer. Any loose material shall be brushed off before the next layer is placed or before use of the road.

7.3 Road pavement – safety barriers

A safety barrier shall be placed 1m from the edge of the access ramp, and the ramp into the cell base. This shall be formed from large limestone blocks, concrete blocks or an earth bund, as available.

8. Geosynthetic clay liner (GCL)

8.1 Material specification

A continuous Geosynthetic Clay Liner (GCL) shall be installed on the base of the cell and under the access ramps. The GCL shall be a manufactured product consisting of a sodium bentonite clay layer evenly distributed between two geotextiles. The GCL shall conform to the property requirements listed in the table below and shall be free of tears, holes or other defects that may affect its serviceability. Encapsulating geotextiles shall be mechanically bonded together using a needle punch or stitch bonding process. The GCL shall during manufacture be continuously inspected for broken needles using an in-line metal detector and broken needles shall be removed. Minimum dimensions of the manufactured GCL panels shall be 4.10m width and 30m length.

The properties of the GCL shall comply with the requirements of Table 2. This shall be demonstrated by the Contractor submitting the manufacturer's certified raw and roll material data sheets containing certified test results to the Engineer at least 30 working days prior to delivery of the GCL.

Quantity measurements shall be made of the total surface area covered by GCL in m^2. Final quantities shall be based on as-build conditions. Allowance shall be made for GCL in anchor and drainage trenches; however, no allowance will be made for waste, overlap, repairs or material used for the convenience of the Contractor. GCL installed and accepted will be paid for at the respective contract unit price stated in the BOQ.

The Contractor shall ensure that the manufacturer's warranty states that the GCL materials meet all the requirements of the contract documents and that for the intended use, the GCL is warranted for 30 years against deterioration. The Contractor shall likewise ensure that the installer's warranty states that the GCL shall not fail due to improper installation within 1 year.

8.2 Delivery and storage

Delivery, storage and handling of GCL shall be in accordance with ASTM D 5888. The Contractor together with the Engineer (or his authorised representative) shall be present during unloading of the GCL. Rolls shall be packaged in an opaque, waterproof, protective covering and wrapped around a central core. Tears in the packaging shall be repaired to restore a waterproof protective barrier around the GCL. Unloading of rolls from the delivery vehicles shall be done in a manner so that it prevents damage to the GCL and its packaging.

Storage of GCL rolls at the site shall take place in a flat and dry, where water cannot accumulate and the GCL rolls can be protected from damage. Storage of the rolls on blocks or pallets will not be allowed unless the GCL rolls are fully supported as approved by the

Engineer. Stacks of GCL rolls shall be not greater than three high. Rolls shall be covered with a waterproof tarpaulin or plastic sheet when stored outdoors.

8.3 Installation

Placement of the GCL shall be done by use of construction equipment. During handling, rolls shall not be dragged, lifted by one end, dropped to the ground or otherwise manipulated involving risk of damage. A pipe or solid bar of sufficient strength to support the full weight of the roll without significant bending shall be used for all unloading and handling activities. If recommended by the manufacturer, a sling handling method utilising appropriate loading straps may be used.

Five working days before any GCL is deployed the Contractor shall provide to the Engineer a proposed panel layout plan which shall be designed to minimise, as far as is practicable, the amount of welds and panels laid out within the works. This plan shall form the broad plan for the GCL layout. It will be subject to amendment during works at approval of the Engineer.

The GCL shall be installed as soon as possible after completion and approval of the subgrade. GCL rolls shall be delivered to the work area in their original packaging. Immediately prior to placement, the packaging shall be carefully removed without damaging the GCL. GCL which is found to have been hydrated prior to being covered by a minimum of 0.30m of cover material shall be removed and replaced. Hydrated GCL is defined as having become soft as determined by squeezing the material with finger pressure or GCL which has exhibited swelling.

The GCL panels shall be positioned with the overlap recommended by the manufacturer, but not less than 0.15m for panel sides and 0.45m for panel ends. Soil or other foreign matter shall be removed from the overlap area immediately prior to seaming. If recommended by the manufacturer, granular bentonite of the same type as the bentonite used for the GCL shall be placed along the entire overlap width at a minimum rate of 0.37 kg/linear meter or as recommended by the manufacturer. Construction adhesive or other approved seaming methods recommended by the manufacturer shall be used for horizontal seams on slopes. Overlaps which occur on slopes shall be constructed with the up slope GCL placed over the down slope GCL (identical to placement of roof tiles). Alternative seaming methods may be approved by the Engineer if it is recommended by the manufacturer.

Only the GCL panels which can be covered in the same day by geomembrane shall be unpackaged and installed. If exposed GCL cannot be permanently covered before the end of a working day, it shall be temporarily covered with plastic or other waterproof material to prevent hydration (see also below).

The installed GCL shall not be covered prior to inspection and approval by the Engineer. Immediately after approval has been obtained, the installed GCL shall be covered. Covering shall take place inside the same working day as installation of the GCL has been made. If this

for some reason is impossible to accomplish, the exposed GCL shall be temporarily covered with plastic or other waterproof material to prevent hydration. The Engineer shall immediately be informed in case if the above situation arises, the reasons for it, and how the Contractor intents to mitigate the situation.

8.4 Repair procedure

Holes or tears in the GCL shall be repaired by placing a patch of GCL extending a minimum of 0.30m beyond the edges of the hole or tear on all sides. If recommended by the manufacturer, powdered bentonite or bentonite paste shall be applied in the overlap area. Patches shall be secured with a construction adhesive or other approved method as recommended by the manufacturer.

Passing pieces shall be as recommended by the GCL manufacturer. As a minimum, pipe passing piece shall incorporate a collar of GCL wrapped around the pipe and securely fastened. Dry bentonite powder or bentonite paste shall be placed around the penetration as recommended by the manufacturer.

9. HDPE geomembrane liner

9.1 General description

The geomembrane shall be 2.0mm thick HDPE, smooth/smooth on the base and against steepwall and textured/textured on access ramps. The HDPE shall be fully welded in line with GRI methodology to provide a continuous leak-proof membrane.

HDPE installation shall be carried out only by skilled and experienced operators using methods outlined in this document. The installer shall provide a supervisor accredited to at least Level 1 of the BGA/TW1/CSWIP Welding Standard. The lead technician (if different) shall also be accredited to at least Level 1. All additional welding operatives shall be accredited to at least Level 2. The qualification and experience details of the proposed personnel shall be provided to the CQA Engineer prior to the commencement of any installation works in the form of photographic ID cards and the individual welder's certificates. The details of any subsequent personnel shall be provided to the CQA Engineer prior to them being accepted for participation in the works.

The CQA Engineer shall maintain detailed records of the delivery, installation and testing of the geomembrane which shall be incorporated into the CQA Validation Report.

The suitability of the geomembrane subgrade and installation shall be subject to inspection by the CQA Engineer until such a time as final written approval is given by the CQA Engineer and until which time additional work may be undertaken as directed by and to the satisfaction of the CQA Engineer. The CQA Engineer shall only sign off areas for geomembrane deployment in discrete sections in advance of geomembrane deployment. The CQA Engineer shall not pass of as acceptable large areas (areas equal to or more than one day's panel deployment) of sub-grade.

The CQA Engineer shall, when satisfied as to the suitability of areas of sub-grade, issue a Sub-grade Acceptance Certificate for that area of deployment which will be signed by both the Lead Technician of the geomembrane installation Subcontractor.

Unless a suitable procedure is agreed, deployment and installation of HDPE shall not take place during any period of precipitation, high relative humidity, high wind speed or when air temperature is outside the range 5C to 35C.

9.2 Material specification

The Contractor shall provide to the CQA Engineer details of the proposed HDPE for use within the works at least five days before lining works commence. All geomembrane material shall be new and manufactured using pure (non-recycled) resin, entirely free of plasticizer or other filler materials and without prefabrication. The geomembrane shall fully comply with the requirements of Table 3.

The Contractor shall submit a copy of the manufacturer's quality control documentation and CE registration certificates for each roll of geomembrane delivered to site to the CQA Engineer, who shall verify that it meets the requirements of Table 3. No geomembrane shall be installed until all documentation has been received and approved by the CQA Engineer. Any non-conforming material will be rejected.

9.3 Delivery, storage and handling

The geomembrane material shall be delivered, stored and handled strictly in accordance with the manufacturer's instructions, a copy of which will be provided to the CQA Engineer prior to delivery. The handling equipment and storage method employed shall ensure no damage to the geomembrane. Each geomembrane roll shall be equipped with suitable slings to enable appropriate handling. Other handling methods may be considered appropriate subject to the approval of appropriate method statements by the CQA Engineer. Stacking of rolls shall not exceed three rolls in height.

The storage area shall be prepared in such a way as to avoid damage to the geomembrane. The installer shall provide adequate and acceptable measures for protecting the materials at all stages of the work from all sources of potential damage, including adverse weather conditions until completion of the Works.

Upon delivery, the CQA Engineer shall visually examine all rolls for damage. Any damage shall be marked for further investigation, as necessary. The CQA Engineer shall record the relevant reference numbers of each roll.

9.4 Conformance testing

Upon delivery, samples shall be taken from selected rolls of geomembrane as determined by the CQA Engineer at the frequency detailed in Table 3 and submitted for conformance testing to confirm that the properties of the material meet the requirements detailed in the table. Samples shall generally be 1m long by the roll width and shall not include the first linear metre of the roll. The Contractor shall programme delivery of the material such that the testing can be achieved, and the compliance of the material confirmed prior to installation. No geomembrane installation shall be permitted prior to receipt of satisfactory conformance testing results.

Any non-conforming roll will be rejected and removed from the Works. In the event of failure, the two rolls with adjacent sequential reference numbers to the failed roll shall be conformance tested. Any additional testing required as a result of non-conforming material shall be carried out at the expense of the Contractor.

In addition to the above conformance testing procedure if, during the installation works, any material appears to be visually defective, the installer shall be obliged to replace the material

or undertake additional conformance testing as determined by the CQA Engineer. This additional testing shall be carried out at the expense of the geomembrane supplier.

9.5 Subgrade

Prior to the deployment of each panel of geomembrane, the CQA Engineer shall inspect the surface of the regulating layer to verify its compliance with the requirements of this CQA Plan. Final approval of the geomembrane subgrade will not be given until all inspections have been satisfactorily completed and the CQA Engineer has received satisfactory test results and survey data for the specific section of subgrade.

9.6 Deployment - general

Five working days before any geomembrane is deployed the Contractor shall provide to the CQA Engineer a proposed panel layout plan which shall be designed to minimise as far as is practicable the amount of welds and panels laid out within the works. This plan shall form the broad plan for the geomembrane layout. It will be subject to amendment during works at the discretion of the CQA Engineer.

The geomembrane shall be installed in accordance with the manufacturer's recommendations, either by hand or by approved suitable plant, so as not to cause damage to the geomembrane or deterioration of the basal mineral liner. The deployment methodology shall endeavour to minimise disturbance to adjacent subgrade, which will be subject to any subsequent remedial work necessary and the approval of the CQA Engineer in accordance with the requirements of this CQA Plan. Plant shall not run directly over installed geomembrane.

9.7 Deployment on the steepwall

The first lift of geomembrane panels shall be installed on the steepwall before any geosynthetics are installed on the base of the landfill (apart from the strip of GCL below the support frame).

The geomembrane panels will be deployed using a vertical deployment bar attached to a tracked excavator. This will be free to rotate and incorporate a wheel and tyre at the base which is of a larger diameter than the roll of geomembrane and deployment equipment. As this is a bespoke installation tool fabrication details will be provided to the contractor prior to commencement.

The geomembrane shall be unrolled by driving the excavator alongside the support framework, with the start of the panel being fixed to the frame. The top of each panel shall be fixed to the frame as it is unrolled. A protection geotextile shall have previously been fixed to the frame.

Circular holes shall be cut in the top edge of the geomembrane panels using a 10-20mm hole cutter drill attachment at 1.5m centres no more than 150mm from the edge of the HDPE panels. Ropes shall be used to temporarily secure the panels to the upper part of the support framework. A hole cutter is essential to avoid tear propagation cuts potentially causing the panels to tear at the attachment point. The edge of the panels with the holes will be cut away and removed before welding to the next panel.

As soon as a panel or geomembrane is fixed to the framework, it will be welded to the previous panel below, using twin-track fusion.

The first lift of the geomembrane liner will require panels that are wide enough to extend both vertically 4.5m and extend onto the base by a minimum 1m.

The first panel shall extend onto the base of the new cell for subsequent connection to the basal liner. In curved sections, the lower edge of the sheet may need to be adapted to the shape by cutting fillets from wrinkles in concave curves or welding fillets into stretched membrane on convex curves. Twin-track fusion welds shall be used where possible.

For information, subsequent lifts shall be 3.5-3.75m wide.

This is based upon the following deployment:

3.0m lift +

0.2m overlap for welding +

0.2m removed from temporary anchor points

If the Contractor is unable to order rolls with the required widths, it may be necessary to cut 7.5m rolls of geomembrane in half (at the factory or on site) to achieve the required width.

If necessary, more than one sheet shall be used, and these shall be joined by twin-track fusion welds.

After installation of the steepwall geomembrane panels, the basal mineral on the base of the cell shall be dampened, as necessary, and smooth rolled to repair any damage.

9.8 Deployment on base and access ramp

Individual panels of geomembrane shall be positioned with a minimum overlap as stipulated by the geomembrane manufacturer but no less than 100mm between the adjacent panels. On the side slopes the panels shall be installed parallel to the direction of slope (i.e. downslope). The first linear metre of each roll shall be removed and shall not be used in the Works.

The method of installation of the geomembrane shall ensure that:

- panels are deployed and welded one at a time
- scratches or crimps as a result of deployment are minimised

- undulations in the installed geomembrane are minimised as far as practicable and do not exceed 75mm in height. Excessive undulations which cannot be pulled out or distributed shall be remediated by cutting and welding in accordance with following procedures
- equipment does not cause excessive heat or leak hydrocarbons on the geomembrane
- adequate and suitable temporary weighting (e.g. sandbags or other means deemed acceptable by the CQA Engineer) is provided to ensure no movement occurs during deployment or welding or at any subsequent time prior to approval by the CQA Engineer of the completed geomembrane installation

To minimise potential damage to the geomembrane all personnel working on the geomembrane shall wear suitable footwear and shall not smoke.

The CQA Engineer shall visually inspect each panel of geomembrane deployed for defects or damage and shall clearly mark and record any locations for repair or removal.

9.9 Welding

Individual panels shall be joined generally by means of dual track fusion welding. The overall weld width shall not be less than 100mm. Where necessary in certain areas, which shall be agreed with the CQA Engineer, extrusion welding may be used but the use of this technique should be limited. The width of extrusion welds shall not be less than 30mm. Prior to forming welds, all surfaces to be welded shall be completely clean, dry and free from imperfections. Welds shall extend to the back of all anchor trenches. Where three or more individual panels meet, the resulting 'T' joint shall be extrusion welded or, if deemed necessary by the CQA Engineer, patched.

Panels shall be aligned in accordance with the Panel Layout Plan provided to the CQA Engineer prior to the commencement of the works and without significant wrinkles and shall be temporarily anchored using sandbags or other suitable means deemed suitable by the CQA Engineer to minimise the potential for slippage or wind disturbance.

Prior to forming an extrusion weld, adjacent panels shall be temporarily secured by heat bonding and the panel joint roughened by grinding to provide a key and to remove surface oxidation. Grinding shall not remove more than 10% of the nominal sheet thickness, shall not extend outside the completed extrusion weld and shall not be carried out more than 30 minutes prior to welding. To enable spark testing of the completed weld, copper wire shall be incorporated into the fillet of the weld prior to welding and shall extend the full length of the weld. The extrusion welding equipment shall pre-heat the sheet material by hot air at controlled temperature during the welding process.

The extrudate material used for extrusion welding shall be identical in composition to that of the geomembrane sheet. Prior to its use in the works the Contractor shall submit to the CQA Engineer respective documentation confirming the suitability and compatibility of the

proposed extrudate material with all proposed sheet material types or demonstrate this by laboratory destructive weld testing. The costs for this testing shall be borne by the Contractor.

The procedure used to temporarily bond adjacent panels, together with any pre-heating during welding, shall not cause any damage or overheating to the geomembrane. Temporary bonding using adhesives shall not be permitted.

9.10 Trial welds

Prior to welding of the geomembrane each day, trial welds shall be carried out to confirm the set-up of the welding equipment for the ambient conditions and that the equipment is working satisfactorily. Trial welds shall be produced under the same conditions as the installation welds and shall be performed with the geomembrane in contact with the same subgrade type.

A trial weld of minimum length 3m shall be carried out for each piece of welding equipment proposed for use at the beginning of each welding period or every 4hrs (whichever is greater), following a period of shut down greater than one hour, if the prevailing weather conditions change from the start of the welding period or if the operator is changed. All trial welds shall be carried out in the presence of the CQA Engineer.

From each trial weld, six tab samples of length 105mm by 25mm shall be extracted at random from the length of the weld. The tabs shall be examined by the CQA Engineer to confirm that the weld exhibits a homogenous fusing of the two sheets with no definable boundary or layer. The tabs shall be tested by the installer in the presence of the CQA Engineer, three for peel failure and three for shear failure. The mode of failure shall be yield of the sheet material outside the weld. No samples shall fail within the weld. For fusion welds, both tracks of the weld shall be tested in peel.

If the field testing of the trial welds proves unsatisfactory, further trial welds shall be performed and the procedure repeated until the CQA Engineer is satisfied with the setup of the particular item of welding equipment. Welding operations shall not commence until successful trial welds are achieved.

Under no circumstances shall the cutting of test specimens, sheet material or any other materials be permitted directly above installed geomembrane.

9.11 Non-destructive weld testing

The CQA Engineer shall verify that each weld undergoes non-destructive testing in accordance with the following procedures and shall record the results of the testing. All welds and repairs shall be clearly marked with a sequential reference number and the test result.

For any welded weld, the CQA Engineer shall walk over the length of the weld and check the weld visually for any obvious defects (burns, track variances, wheel slippages, etc.) and ensure that they are brought to the attention of the contractor and remediated as appropriate.

9.12 Air pressure testing

All twin track fusion welds shall be pneumatically tested. The air channel formed between the twin tracks shall be sealed at its ends and inflated to a pressure between 2 bar (30psi, 200kPa) and 2.4 bar (35psi, 240kPa). Following removal of the pressure source the pressure shall be allowed to equalise for 1 minute. Thereafter the pressure shall not decrease by more than 10% (0.2bar, 3psi, 20kPa) over a 5-minute period.

To confirm that the full length of weld is pressurised the test shall be carried out by one of the following two methods:

- The pressure source and gauge are applied to opposite ends of the weld and, on completion of the test, the pressure drop is observed on the gauge following removal of the pressure source; or
- If pressure source and gauge are applied to the same end of the weld, on completion of the test, the channel is deflated from the opposite end of the weld and the pressure drop observed on the gauge.

If a weld fails air pressure testing or indicates a channel blockage, the test length shall be incrementally reduced until the failure area has been clearly identified. In the case of identifiable points of failure, the weld shall be repaired in accordance with the requirements of this CQA Plan. If specific points of failure cannot be identified or if the CQA Engineer is not satisfied with the integrity of the weld, the weld shall be repaired in accordance with the requirements of this CQA Plan by replacement or capping.

9.13 Spark testing

All extrusion welds shall be tested over their entire length using a high frequency continuous coil spark tester in accordance with ASTM D6365 "Standard Practice for the Non-destructive Testing of Geomembrane Seams using the Spark Test".

The equipment shall be adjustable in voltage between 15kV and 30 kV and shall generally be operated at a voltage of 10kV per mm of membrane thickness. The spark tester shall be passed slowly in close proximity to the weld to test all points on the weld. Any anomalies in the weld will be identified by the presence of a spark. The location of any sparks shall be marked and the weld repaired in accordance with the requirements of this CQA Plan and re-tested to the satisfaction of the CQA Engineer.

9.14 Vacuum box testing

The Vacuum Box test is a method used to non-destructively test extrusion welds and fusion welds when the geometry of the weld makes air pressure testing impossible or impracticable or when attempting to locate the precise location believed to exist after air pressure testing. The test shall be undertaken in accordance with ASTM D 56741-94 (2006) and in line with the procedures specified in clause 7.2.4 of the BGA/TWI/CSWIP British Geomembrane Association (BGA) Welding Syllabus and following techniques outlined below:

The equipment for vacuum testing consists of:

- A vacuum box assembly, consisting of a ridged housing, a transparent viewing window, a soft neoprene gasket attached to the bottom of the ridged housing to form a seal against the liner, a port hole or valve assembly and the vacuum gauge
- A vacuum pump assembly equipped with a pressure pump and a pipe connection
- A rubber pressure/vacuum hose with fitting and connections
- A soapy solution and a means of applying it to the line

The procedure for vacuum testing is as follows:

- Trim excess overlap material from the weld in the case of a fusion weld
- Turn on the vacuum pump and set it to produce approximately 0.35bar of vacuum
- Apply a generous amount of a strong soapy solution and water to the area to be tested. This helps to create a vacuum
- Place the vacuum box over the area to be tested and apply sufficient downward pressure to form a seal between the vacuum box and the liner
- Close the bleed valve and open the vacuum valve
- Apply a minimum of 0.35bar to the area as indicated by the gauge on the vacuum box
- Ensure that a leak tight seal is created
- For a period of approximately 10 to 15 seconds examine the geomembrane through the viewing window for the presence of air bubbles. If no air bubbles appear, the test is successful and the vacuum box can be removed to the next section of the weld, and the test repeated. It is important that an overlap of a minimum of 75 mm is maintained every time the vacuum box is moved along the weld

In the event of air bubbles appearing, the area should be marked and repaired by means of an extrusion bead or a patch depending on the nature and extent of the damage. The repaired area should be re-tested. Particular attention should be exercised when vacuum testing "T" welds or patch intersections with welds as these areas are at most risk of having

a defect and are also the most difficult to test by means of a vacuum box as it may be difficult to achieve a seal between the vacuum box and the liner.

If the weld fails vacuum box testing, repairs shall be undertaken in accordance with the requirements of this CQA Plan.

The installer shall maintain full records of all non-destructive testing which shall be provided to the CQA Engineer on a regular basis.

9.15 Destructive weld testing – extrusion and fusion welding

Destructive weld testing shall be carried out on samples taken from locations selected by the CQA Engineer as the welding work progresses. The samples shall be taken at a minimum frequency of one per 200m length of weld and at least one per day, whichever is greater. However, the CQA Engineer may increase this frequency if test results indicate problems or poor workmanship. A destructive test sample can be created at the end of the weld if the 200m frequency falls within a weld, so as not to create extra defects within a weld. In this case, the destructive sample should be created immediately after the weld is complete and using the same material, welding technicians and equipment as that of the weld completed.

The samples shall be a minimum of 0.3m wide by 1.0m long with the weld centred lengthways. One 25mm wide strip shall be cut from each end of the sample and shall be tested in the field for peel adhesion failure. The specimens shall not fail in the weld. If the field tests are acceptable, the sample shall be submitted for laboratory testing. The sample shall be tested for shear and peel failure on a minimum of five specimens per test. A minimum of four of the five specimens shall meet the strength requirements detailed in Table 3 and the fifth shall exceed 80% of these values. No specimens shall fail in the weld. The CQA Engineer shall review the testing results at the earliest opportunity to assess compliance.

The installer shall undertake field destructive testing of all fusion welds. On completion of each fusion weld, a tab sample shall be taken from each end of the weld and tested for peel adhesion failure. The samples shall be tested in the presence of the CQA Engineer and shall not fail in the weld.

The installer shall maintain full records of all destructive testing which shall be provided to the CQA Engineer on a regular basis.

In the event of a failed destructive test, the installer shall have the following options:

- Replace or cap the entire weld (i.e. remove the weld and re-weld or extrusion weld a strip of additional geomembrane over the weld of sufficient width as determined by the CQA Engineer) or, subject to the specific nature of the failure and the approval of the CQA Engineer, remove the exposed overlap and extrusion weld the resulting fillet joint;

- Extract further samples for destructive testing from the proximity of the failed location, a minimum of 3m from the location of the failed test in both directions (if applicable). If these samples pass destructive testing, the weld shall be reconstructed between these locations by capping as detailed in this CQA Plan.

Regardless of the selected remedial option, the CQA Engineer shall extract an additional test sample, remote from the identified failure but from a weld produced on the same day by the same item of welding equipment, to confirm that the failure was an isolated occurrence. If this sample fails destructive testing, all welds produced that day by the particular item of equipment shall be investigated and, if deemed appropriate by the CQA Engineer subject to the investigation, may be condemned and the installer shall follow the procedures detailed in this CQA Plan for all welds in question.

9.16 Repair procedure

Any locations of geomembrane damage, determined by inspection or testing, including weld failures, locations of destructive sampling and discontinuous intersections of welds, shall be marked by indelible white ink on the geomembrane surface. These areas shall be repaired by patching and/or extrusion welding to the satisfaction of the CQA Engineer, as follows:

- In the case of small faults as per international standards (to include significant scratching and crimping), the location shall be repaired by extrusion welding (beading), as determined by the CQA Engineer;
- Large faults as per international standards shall be repaired by patching with appropriately shaped pieces of the same geomembrane material, to give a minimum 150mm overlap with undamaged material, which shall then be welded by extrusion welding and tested accordingly. The size and shape of patches shall be such that re-heating of previously welded material is minimized.

The size and shape of patches shall be such that re-heating of previously welded material is minimised.

All repairs shall be subject to non-destructive testing and, if deemed necessary by the CQA Engineer, destructive testing. The installer shall provide to the CQA Engineer full written records of all repairs and re-testing undertaken. Information concerning all tests, repairs and sample locations shall be written in indelible white ink on the geomembrane surface.

9.17 Installation approval

The installed geomembrane shall be subject to the inspection and approval of the CQA Engineer immediately prior to the placement of the protective geotextile at a respective location. Approval shall be made based on the following:

- Visual inspection to confirm that all stones or any other potentially deleterious materials have been removed from the surface of the geomembrane and that there are no visible surface defects or excessive undulations in the membrane
- All necessary repairs have been made and their locations recorded
- All tests to welds, patches and repairs have been completed and recorded and the results of respective laboratory destructive weld testing have been received by the CQA Engineer
- Areas for approval have been clearly defined by suitable means. Approved areas not covered in a timely manner shall be subject to re-cleaning and re-inspection
- Completion of the panel layout survey of that particular area

The Contractor or their nominated Subcontractor for geomembrane installation shall keep daily records of installation of geosynthetic materials and provide these to the CQA Engineer upon request. Records of all panels, welds, tests and repairs are required as a minimum to be recorded by the Contractor or Subcontractor.

10. Protection and separation layers

10.1 General requirement

The geosynthetic liner on the base of the cell and the access ramp shall be protected from damage during construction and subsequent operations by either:

A suitable heavy-duty geotextile, or

A layer of sand covered by a separation geotextile

The geomembrane liner on the steepwall of the cell shall be protected from damage from the frame by a suitable geotextile fixed over the mesh prior to installation.

10.2 Basal protection geotextile specification

The basal protection geotextile shall be non-woven fabric manufactured from mechanically entangled UV stabilised fibres of polypropylene with no post-consumer fibres. The geotextile shall incorporate a minimum 1% by weight active carbon black if it is not to be covered within two weeks by the leachate drainage layer.

The necessary thickness and strength of the geotextile, usually expressed as weight per unit area, shall be determined by cylinder testing at an approved laboratory and the requirement will vary depending upon the angularity of the drainage stone proposed. The thickness of waste will be at least 54m excluding restoration soils and the access ramp will accommodate heavy trucks and construction plant. Therefore, the protection geotextile will be heavy-duty material. The Contractor shall propose the material to be used. As a guide, the weight is likely to be at least 2 kg/m^3 or greater.

The tensile strength (according to ISO 10319) shall be no less than 30 kN/m in both lengthwise and transverse directions.

The breaking elongation shall be no less than 25% kN/m in both lengthwise and transverse directions.

The Contractor shall supply to the Engineer a copy of the manufacturer's quality control documentation covering the delivered material. The Contractor's CQA Technician shall review the data to verify its suitability. Any non-conforming material will be rejected. No material shall be installed until the documentation is received and approved by the Engineer.

10.3 Steepwall geotextile specification

The steepwall protection geotextile shall conform to the specification in Table 8.

The Contractor shall supply to the CQA Engineer a copy of the manufacturer's quality control documentation covering the delivered material. The Contractor's CQA Technician shall

review the data to verify its suitability. Any non-conforming material will be rejected. No material shall be installed until the documentation is received and approved by the Engineer.

10.4 Delivery and storage of geotextiles

Geotextile shall be delivered to site in suitable protective packaging and shall be maintained in the packaging until required for use in the Works. The Contractor's CQA Technician shall examine all rolls on delivery for damage in transportation and shall record the details of any damage together with the relevant manufacturer's reference numbers for each roll. Damaged rolls shall be set aside until the extent of damage and rejection of material can be determined.

10.5 Installation of basal geotextile

The Contractor shall submit to the CQA Engineer for approval a method statement detailing how geotextile is to be deployed.

Individual panels of geotextile shall be deployed with a minimum overlap of 300mm and the overlap secured by heat bonding. On slopes the geotextile shall be installed downslope as continuous panels with no longitudinal (roll-end) joints.

Geotextile placement shall not take place during periods of excessive winds. Following installation, the geotextile shall be weighted as necessary using sandbags (filled with sand or silt, not gravel) or other suitable means to prevent wind disturbance prior to placement of the subsequent layers.

No equipment or tools shall be used which could damage the geotextile by handling, trafficking or other means. Personnel working on the geotextile shall wear suitable footwear and shall not smoke or otherwise engage in any activity that could damage the geotextile. Plant shall not run directly over installed geotextile unless there is a 1m thickness of drainage stone in the trafficked areas.

Any areas of damage shall be repaired by the placement of a suitably sized patch of the same geotextile material ensuring a minimum overlap of 300mm in all directions from the damaged area. The patch shall be securely heat bonded in place.

The Contractor shall produce for approval by the Engineer a panel layout plan for the deployment of geotextile. The Engineer shall verify that the installation of the geotextile is completed to the requirements of this document, including any repairs, prior to granting approval of the installation.

10.6 Installation of steepwall protection geotextile

The Contractor shall follow the general requirements for installation of the basal geotextile. The additional procedures for installation of protection geotextile on the steepwall are as follows.

The geotextile shall be fixed to the support frame before the geomembrane is installed.

The geotextile shall be fixed in a similar method to the geomembrane on the steepwall, using strong plastic cable ties, through holes at least 150mm from the edge of the geotextile.

10.7 Optional basal sand layer - specification

The Contractor may propose the use of a layer of sand on top of the basal protection layer, depending on the properties of the sand and the results of cylinder testing with a sand / geotextile combination.

If a protection layer of sand is used, this shall be a minimum of 150mm thick. It will be placed over the basal protection geotextile before placement of the leachate drainage layer.

The sand shall be well graded (uniformity coefficient greater than 4), rounded or sub-rounded, with a maximum particle size of 7mm, as specified in Table 10. Details of the proposed offsite sand source, including a minimum of three particle size distribution test results, shall be submitted to the CQA Engineer for prior approval. The sand protection layer shall be placed in dry conditions.

The grading, particle shape and particle size shall be verified by laboratory testing on three samples on initial delivery for the offsite source and for every 500m^3 of material placed from both sources (to test method BS1377: Part 2: 1990: Method 9.4). Particle Size Distribution Testing shall comply with the properties in Table 9.

10.8 Optional protection sand layer - placement

The sand layer shall be placed to a minimum thickness of 150mm over the entire area of the basal protection geotextile.

Placement of the protection layer shall be carried out in a manner which causes no damage, displacement or undue stress in the underlying geotextile and geomembrane.

Plant used to place the protection layer shall under no circumstance be driven directly on the geotextile and geomembrane. A minimum thickness of 1m of material shall be maintained beneath all wheeled plant and 500mm beneath tracked plant.

Placement methods shall ensure that lateral stresses induced in the geotextile and geomembrane are minimised. In general, the methods employed shall comprise the following:

i) Tipping of fresh material on previously placed material.

ii) Casting material by 360° excavator (using a bucket without teeth).

iii) Pushing of material up and over the face of the tipped load allowing it to fall vertically onto the geomembrane.

iv) Pre-loading of the geotextile and geomembrane with discrete mounds of material, to prevent the generation and accumulation of undulations, and in-filling between mounds.

Placement of material to the side slope shall only be carried out using method ii) above, commencing from the toe of the slope and proceeding upslope.

Any damage that may occur to the geotextile and geomembrane shall be reported to the CQA Engineer who will determine the extent of remedial work to be carried out.

The thickness of the layer shall be controlled by the Contractor during placement and proven by survey and shall be verified by CQA Engineer by occasional checks by careful hand-probing or excavation of inspection pits.

10.9 Separation geotextile over optional protection sand layer

The drainage layer separation geotextile shall be non-woven fabric manufactured from mechanically entangled UV stabilised fibres of polypropylene with no post-consumer fibres. The geotextile shall incorporate a minimum 1% by weight active carbon black where it is not covered within two weeks by the leachate drainage blanket granular layer. The geotextile shall comply with the properties in Table 7.

The Contractor shall supply to the CQA Engineer a copy of the manufacturer's quality control documentation covering the delivered material. The CQA Engineer shall review the data to verify its suitability. Any non-conforming material will be rejected. No material shall be installed until the documentation is received and approved by the CQA Engineer.

Geotextile shall be delivered to site in suitable protective packaging and shall be maintained in the packaging until required for use in the Works. The CQA Engineer shall examine all rolls on delivery for damage in transportation and shall record the details of any damage together with the relevant manufacturer's reference numbers for each roll. Damaged rolls shall be set aside until the extent of damage and rejection of material can be determined.

The Contractor is required to submit to the CQA Engineer for approval a method statement detailing how geotextile is to be deployed.

Individual panels of geotextile shall be deployed with a minimum overlap of 300mm and the overlap secured by heat bonding. On slopes the geotextile shall be installed downslope as continuous panels with no longitudinal (roll-end) joints.

Geotextile placement shall not take place during periods of excessive winds. Following installation, the geotextile shall be weighted as necessary using sandbags (filled with sand or silt, not gravel) or other suitable means to prevent wind disturbance prior to placement of the subsequent layers.

No equipment or tools shall be used which could damage the geotextile by handling, trafficking or other means. Personnel working on the geotextile shall wear suitable footwear and shall not smoke or otherwise engage in any activity that could damage the geotextile. Plant shall not run directly over installed geotextile unless there is a 1m thickness of drainage stone in the trafficked areas.

Any areas of damage shall be repaired by the placement of a suitably sized patch of the same geotextile material ensuring a minimum overlap of 300mm in all directions from the damaged area. The patch shall be securely heat bonded in place.

The CQA Engineer shall verify that the installation of the geotextile is completed to the requirements of this document, including any repairs, prior to granting approval of the installation. The CQA Engineer shall produce a panel layout plan for the deployment of geotextile.

11. Leachate drainage system

11.1 General

The leachate drainage systems for the cell shall be installed in accordance with the details presented on Drawings 30499-WSM-SW--6, 29 & -30 comprising heavy duty protection geotextile or sand protection layer and separator geotextile, gravel drainage blanket, collection pipework feeding a collection sump at the low point of the cells, together a monitoring points in each cell. The collection points and monitoring points will each incorporate a target pad.

The Contractor shall submit to the CQA Engineer for approval a method statement detailing how leachate drainage system is to be placed.

11.2 Leachate drainage layer

The granular drainage layer of shall be 20/40mm gravel, minimum 300mm thick, installed directly on top of the protection geotextile or the separation geotextile over the sand layer.

The gravel shall undergo Ten Percent Fines Tests, Particle Size Distribution Testing and Permeability Testing and shall comply with the properties in Table 9.

The Contractor shall provide a minimum of three grading analysis and strength test results on representative samples of the proposed source, taken within the last 6 months, for approval by the CQA Engineer prior to commencement of the importation of materials.

11.3 Leachate drainage layer placement

The Contractor shall not place any granular leachate drainage blanket material at any location until the CQA Engineer has approved the underlying separation geotextile at that location.

No tracked or wheeled plant shall run directly on the geotextile. Wheeled plant shall have a minimum haul route depth of 1000mm of material above the geotextile. The Contractor shall ensure that the geotextile is not rippled by plant driving on the geotextile and that welds are not damaged. The granular leachate drainage blanket material shall be cast from the haulage routes by a 360° excavator, using a bucket without teeth and levelled using Low Ground Pressure bulldozers.

Placement methods shall ensure that no lateral stresses are induced in the underlying geotextile. In general, the methods employed shall comprise the following:

- depositing fresh material on previously placed material
- casting material by 360° excavator, using a bucket without teeth

- pushing of material up and over the face of the deposited loads allowing it to fall vertically onto the underlying geotextile
- pre-loading the geotextile with discrete mounds of material to prevent the generation of excess wrinkles or folds and infilling between mounds.

The Contractor shall provide to the CQA Engineer for approval at the start of the works a Method Statement detailing how the gravel shall be placed to the requirements of this CQA Plan.

When installing the gravel onto a slope the gravel shall be installed from the toe of the slope working upwards using a 360° excavator.

All non-compliant material shall be rejected, removed and replaced by the Contractor with acceptable material to the satisfaction of the CQA Engineer. Any damage to the underlying layers shall be reported immediately to the CQA Engineer. Remedial works to the underlying layers shall be undertaken in accordance with the requirements of the specification to the satisfaction of the CQA Engineer.

The Contractor shall undertake an as built survey on top of the completed granular leachate drainage layer. A copy of the survey shall be forwarded to the CQA Engineer prior to placement of subsequent layers of the leachate drainage layer. If the results of the survey show that the granular leachate drainage layer does not achieve the required thickness additional gravel shall be placed and the area or areas resurveyed until the required thickness is achieved. Any subsequent works undertaken prior to approval of survey data by the CQA Engineer shall be at the Contractor's risk.

11.4 Collection pipework

The collection pipework shall comprise slotted pipes installed on top of the protection geotextile or the separation textile covering the 150mm sand protection layer (if included). The pipes shall be 160mm I.D. minimum for the main drains and 160mm I.D. minimum for the branch drains. Following installation of the pipes the surveyor shall survey co-ordinates and levels of the ends, centre lines and connections. These co-ordinates shall be shown on the final as built drawing for future reference.

The pipes shall be covered with a haunch of drainage stone of minimum thickness equivalent to twice external the pipe diameter. The stone shall comply and shall be conformance tested in accordance with this CQA Plan. The pipes shall be fitted with suitable welded endcaps.

All pipework products used in the leachate control system shall be manufactured from HDPE and shall be subject to the approval of the CQA Engineer prior to any delivery to site. Pipes shall be solid-wall with minimum SDR11 and PE80 classification and shall be joined by butt-fusion welding or using electro-fusion couplings.

The vertical pressure at the level of the top of the drainage layer is expected to reach a maximum of 560 kN/m2 after closure and restoration. At this time, the temperature at this level could exceed 50°C. The Contractor shall specify materials and installation methods that will resist damage from these anticipated conditions.

Approval shall be based on submission by the Contractor of full details of the proposed pipework products, including calculations confirming the suitability of pipes with regard to strength and deflection under the proposed loading conditions. The deflection value shall not exceed 5%.

The data shall include full details of pipe perforations including slot width and permeable area. The maximum slot width shall be 5mm and the minimum open area shall be approximately 10%. A minimum of one third of the pipe arc shall be non-perforated and the pipes shall be installed with the non-perforated section to invert. All pipe connections, junctions, bends and end caps shall use purpose made fittings and shall be installed in accordance with manufacturer's recommendations.

The CQA Engineer shall verify that the pipes are properly fusion or electro fusion jointed and that all elements of the leachate drainage system are installed in accordance with this document with no damage or disturbance to the underlying materials. Print out data from the welding boxes shall be provided to the CQA Engineer to verify all welds have been completed successfully for inclusion into the CQA Validation Report.

11.5 Leachate collection and monitoring points and target pads

The Contractor shall supply and install leachate collection and monitoring points for each of the two cells, as shown in Drawing 30499-WSM-SW-30 & 31, at the locations shown in Drawing 30499-WSM-SW-29. These shall comprise vertical shafts of precast concrete chamber rings installed on a cast in-situ reinforced concrete base slab. The slab will include a former to accommodate the flange of the initially placed concrete ring. The base slabs will also incorporate a target pad. The base slab concrete shall be C40/50 DC4 grade, sulphate resistant. The Contractor shall provide to the CQA Engineer for approval at least 24 hours prior to delivery, the mix design from the concrete supplier. The mix design shall include as a minimum the cement combination, the water to cement ratio, the proportion of cement coarse aggregate and fine aggregate, maximum aggregate size, chloride content class and consistency class.

The chloride content class shall be in the range 0.2 to 0.4.

One slump test in accordance with BS EN 12350-2 shall be performed on each delivery of concrete. The concrete supplied shall be in consistency class S3, with maximum slump range of 100 – 150mm.

Two cube samples shall be taken from each batch of concrete used for the section of slab beneath the leachate collection and monitoring points and sent to the laboratory for

crushing strength tests at 7 and 28 days. The concrete forming the target pad section of the slab does not need to be tested.

The base slabs shall be cast in-situ within a 5m by 10m depression formed in the formation and lining system and shall be reinforced with steel mesh (A393) installed at the base of the slab (minimum 75mm cover). Half of the slab shall be 500mm thick the other 250mm thick. Prior to casting, the depression shall be lined with an additional layer of HDPE geomembrane (not welded to the liner).

The part of the slab that will support the leachate shafts shall be 500mm thick. The concrete target pads shall be 250mm thick. During casting, a prefabricated former for the shaft shall be set into the 500mm thick slab, which shall be placed horizontal to a tolerance of 0.5 degree.

Prior to installation of the mineral liner in the location of the shafts, a depression shall be excavated in the formation, with dimensions 11.5m by 6.5m by 600mm deep, to ensure the mineral liner will have the required minimum thickness beneath the slab.

The shafts shall be formed from pre-cast fibre reinforced concrete chamber rings, with internal diameter of 1.3m and a length of 1m. They shall be specifically designed for the purpose and shall be connected by flanges on the ring walls. The pre-cast concrete rings shall conform to the requirements of Wasteserv Malta Ltd, as specified on drawings WSM16001-01, -02 and -03.

The first three rings shall be perforated and subsequent rings shall be non-perforated. The first ring shall be located in the recess created by the former and grouted in place.

Initially, the first four rings shall be installed, 3 perforated and 1 non perforated.

The shafts shall be surrounded with leachate drainage stone to 3m vertical height. In addition, the leachate drainage layer shall be thickened by an additional 500mm over the area of the target pad.

Two 4.5m long HDPE pipes with OD 315mm, PN80, SDR26 grade shall be installed inside the leachate shafts. These pipes shall be closed at the base with specially manufactured end caps. The pipes shall be perforated for the lower 3m (maximum 30mm diameter perforations comprising 10% open area) and non-perforated for the upper 1.5m.

The shafts shall be filled with 40mm clean drainage stone to a depth of 3.5m. Then an accurately shaped washer of filter geotextile will be placed on the gravel, followed by a 200mm layer of sand, followed by 600mm depth of concrete of the same grade as used for the target pad. A sheet of A142 mesh reinforcement shall be installed inside the fourth ring, which is bent to form a tube, at least 50mm from the inner wall of the ring. The reinforcement shall protrude from the concrete to allow fixing of subsequent mesh reinforcement.

Subsequent extension of the leachate shafts (rings, HDPE pipes, reinforcement mesh and concrete) shall be carried out by the Contractor during waste placement.

Following installation of the target pads the surveyor shall survey co-ordinates and levels of the corners and centre point of the target pad. These co-ordinates shall be shown on the final as built drawing for future reference.

12. Geomembrane leak detection survey

The Contractor shall appoint a suitable Subcontractor to undertake a Geophysical Leak Detection Survey (GLDS/Dipole Survey) of the basal geomembrane liner in each cell after the Contractor has completed the placement of the leachate drainage blanket granular layer, leachate collection pipework, leachate extraction wells and leachate monitoring points.

The Subcontractor appointed to carry out the GLDS shall submit a Method Statement to the CQA Engineer for approval at least five working days prior to the commencement of the survey. The survey shall include the base area, the internal slopes of the perimeter and inter-cell bunds together with the crests of the bunds.

The condition of the protective geotextile and leachate drainage blanket shall be damp but not saturated and have no areas of standing water. In excessively dry conditions the leachate drainage layer shall be doused before the survey is undertaken. Should the leachate drainage blanket and protective geotextile become waterlogged the Contractor shall undertake dewatering for the duration of the survey such that the materials are maintained in a condition suitable for testing.

The Contractor shall hand over the cell to the GLDS contractor for his sole use and no traffic or personnel shall enter the cell area whilst the survey is taking place.

The GLDS shall be carried out in accordance with UK Environment guidance document "LFE8 – Geophysical testing of geomembranes used in landfills (version 1)" or the latest version of this document should it have been updated since the time of writing this report.

The GLDS shall be carried out on a calculated set out grid with maximum spacing of 1m x 1m. The survey shall be undertaken in two phases. The first phase shall comprise an initial survey to identify the locations and extents of any perforations in the geomembrane. The GLDS contractor shall then provide an initial assessment to the Contractor of where any perforations are and their extents. The Contractor shall expose the areas of geomembrane suspected of being defective. The Contractor shall remove locally the leachate drainage medium and protective geotextile to expose the geomembrane liner to facilitate a visual inspection to investigate the anomaly identified at that location. The area exposed shall be sufficient to facilitate any necessary repair to the geomembrane.

Any defects identified in the geomembrane liner shall be repaired and non-destructively tested in accordance with the requirements of Section 5 to the satisfaction of the CQA Engineer. The protective geotextile and leachate drainage stone shall be reinstated in accordance with the requirements of this CQA Plan to the satisfaction of the CQA Engineer.

On completion of the repairs a retest of a ten-metre radius around the defect is then undertaken. This is to ensure that all leaks have been located and repaired successfully and that the defects found during the initial survey did not mask smaller defects. This process shall be repeated until no defects are identified during the survey.

The GLDS Contractor shall provide to the Contractor no more than five working days after the survey a report showing that no further perforations are present in the geomembrane liner. A copy of this report shall be provided to the CQA Consultant for inspection and inclusion in the validation report. The report shall contain the following elements:

- A description of the system used, including the site tested accuracy
- A copy of the Specification given to the survey team
- Scaled plans accurate to 0.1 m, of the area surveyed. Such plans should be referenced to the national grid and as minimum contain:
    - site infrastructure such as access ramp, leachate chambers
    - the survey grid
    - the extent of the liner surveyed
    - north arrow
    - site name, survey date and scale
    - all defects found, clearly marked with unique reference numbers, size, description, repair and retest dates
- Referenced and described photographs of the works and defects
- Records of the survey should be supplied in sufficient detail to allow interpretation by a third party in the case of any dispute. This should include the location and electrical potential for every measured point
- The name and experience of the operator(s) must be indicated

The report should also show a schematic of the testing equipment in context with the cell.

13. CQA validation reports

13.1 Responsibilities

The CQA Engineer shall submit to the ERA independent Validation Reports verifying the compliance of the works with this document and identifying any non-compliance issues. The Contractor shall ensure that all necessary information and assistance is provided to the CQA Engineer in order to complete these reports.

As the liner construction will continue during the operation of the disposal cell, the Validation Reports shall be issued in several volumes, as follows:

Main Report	after completion of the formation, basal liner, access ramp liner, first section of steepwall liner, protection layers, drainage layer and leachate collection system
Supplementary Reports	periodically, describing the completed steep wall lifts or sections (subject to confirmation by ERA)
Final Report	describing the capping and closure

13.2 Contents of validation reports

The reports shall include, but not be limited to, the following contents:

General contents	Scope of work carried out Description of results and compliance with requirements CQA Engineer's Daily Logs Photographs As-built drawings including construction plans and cross sections
Basal mineral liner	Field testing results, including compaction graphs Laboratory test results Formation and "top of basal mineral liner" surveys Thickness calculations
Steepwall mineral liner	Locations installed Quantities of frame elements Rock bolt records (type, depth, anchor method) Quality data for bentonite-enhanced concrete Thickness measurements for bentonite-enhanced concrete
Geosynthetics, generally	Manufacturer's quality control documentation Roll inventory Laboratory conformance test results As-constructed panel layout, including repairs

Geomembrane	Laboratory conformance test results, including cylinder test results Installation records, including panel deployment, trial weld, welding and repair records Non-destructive testing records and results Destructive testing records and results Geomembrane Leak Detection Survey report including survey operative daily diaries
Sand protection layer	Laboratory conformance test results Top of layer survey drawing and thickness values
Leachate drainage layer	Laboratory conformance test results Top of layer survey drawing and thickness values.
Leachate drainage system	Pipework specification and deflection calculations Coordinates of all concrete target pads Welding records

Table 1 Basal Mineral Liner Testing and Compliance Requirements

Property	**Test Method (BS 1377:1990)**	**Required Value**	**Testing Frequency (per m^3 placed)**
Classification Testing			
Liquid Limit	Part 2: Method 4.3	≤ 90%	500
Plastic Limit	Part 2: Method 5.3	-	
Plasticity Index	Part 2: Method 5.4	< 65%	
Particle Size Distribution	Part 2: Method 9.2	≤ 100 mm	
Clay Content	Part 2: Method 9.4	≥ 10%	
Particle Density	Part 2: Method 8.2	-	
Compaction Testing			
Density/ Moisture Content	Part 9: Method 2.4 (core cutter)	As per acceptance envelope	250
Air Voids Content	-	≤ 5%	
Shear Strength Testing			
Hand Shear Vane	Part 9: Method 4.4	≥ 50 kN/m^2	250
Permeability Testing			
Permeability (1)	Part 6: Method 6	≤ 1 x 10^{-9} m/s	4,000

(1) For standard permeability test, effective pressure 100kPa, pressure across specimen =20kPa, mean effective stress =90kPa.

Tolerance limits to be as defined in UK Environment Agency document "LFE4".

Table 2 GCL Specification and Conformance Testing Requirements

	Test method	**Required value**	**Conformance Test Frequency**
Bentonite clay material (Sodium Bentonite Powder)			
Mass per unit area	ASTM D 5993 or EN 14196	5,000 g/m^2	1 per 5,000m^2
Swell index – minimum	ASTM D 5890	24 ml/2g	
Fluid loss – maximum	ASTM D 5891	18 ml/2g	
Geosynthetic Clay Liner			
Mass per unit area	EN 14196	5,330 g/m^2	1 per 5,000m^2
Thickness	EN ISO 9863-1	7 mm	
Max. tensile strength, md/cmd**	ASTM D 6768 or EN ISO 10319	MD: 12 kN/m CD: 12 kN/m	
Elongation at break, md/cmd**	EN ISO 10319 or ASTM D6768	MD: 10.0 % CD: 6.0 %	
Peel strength – minimum	ASTM D 6496	360 N/m	
Static puncture strength	EN ISO 12236 or ASTM D6241	2,000 N	
Index flux – maximum	EN 16416 or ASTM D5887	3.5 x 10^{-9} (m^3/m^2)/s	
Permeability/hydraulic conductivity – maximum k_{10}	EN 16416 or ASTM D5887	2 x 10^{-11} m/sec	

*MD = machine direction, CD = cross machine direction

Table 3 Geomembrane Specification and Testing Requirements

Property	**Test Method**	**Required Value**		**Conformance Testing Frequency**
		Smooth	**Textured**	
Thickness	ASTM D5994 (smooth) ASTM D5199 (textured)	≥ 2.0 mm The minimum average value shall not be less than 1.9mm. The lowest individual value for 8 out of the 10 test values shall not be less than 1.8mm. The lowest individual value of the 10 test values shall not be less than 1.7mm.		1 per conformance suite (+ each roll checked on site)
Density	ASTM D1505/D792	≥ 0.94 g/ml		1 per 5,000m^2 per batch delivered
Carbon Black Content Carbon Black Dispersion	ASTM D1603 ASTM D5596	2 - 3 % (range) 1, 2 (rating)		
Tensile Strength at Yield	ASTM D6693 (Type IV)	≥ 29 kN/m		
Tensile Strength at Break		≥ 53 kN/m	≥ 21 kN/m	
Elongation at Yield		≥ 12 %		
Elongation at Break		≥ 700 %	≥ 100 %	
Puncture Resistance	ASTM D4833	≥ 640 N	≥ 534 N	
Tear Resistance	ASTM D1004	≥ 249 N		
Stress Crack Resistance	ASTM D5397	≥ 500 hrs		
Texture Asperity Height	ASTM D7466	>0.4mm		
Weld Strength		**Fusion**	**Extrusion**	
Shear Strength [4] (N/mm)	ASTM D6392 Minimum value for 4 of 5 test specimens, the 5th shall not be less than 80% of minimum value.	≥ 28.0		1 suite per 200m of weld
Elongation at break (%)		≥ 50		
Peel Strength [4] (N/mm)		≥ 21.2	≥ 18.2	
Peel separation (%)		≤ 25		

Table 4 Locus-of-Break Codes for dual hot wedge seams tested in shear mode

Types of Break	Break Code & Description		Pass / Fail
	AD	Adhesion Failure	Fail
	AD-BRK	Break after some adhesion failure (>25%incursion)	Fail
	BRK	Break in sheet	Pass
	SE1	Break at weld edge	Pass
	SE2	Break at inner edge of weld through both sheets	Pass
	SIP	Separation in the plane of the sheet	Pass

Table 5 Locus-of-Break Codes for fillet extrusion seams tested in shear & peel modes

Types of Break	Break Code & Description		Pass / Fail
	AD1	Adhesion Failure	Fail
	AD2	Adhesion Failure	Fail
	AD-WLD(1)	Break through fillet	Fail
	SE1	Break at weld edge in bottom sheet (shear only)	Pass
	SE2	Break at weld edge in Top sheet (shear only)	Pass
	SE3	Break at weld edge in bottom sheet (peel only)	Pass
	BRK1(2)	Break in bottom sheet	Pass
	BRK2(2)	Break in top sheet	Pass
	HT	Break at the edge of the hot tack, where the hot tack did not delaminate	Pass
	AD-BRK	Break in bottom sheet after some adhesion failure between the fillet and bottom sheet	Pass
	SIP	Separation in the plane of the sheet	Pass

(1) Acceptance of AD-WLD breaks may depend on whether test value meets a minimum specification value.
(2) A "B" in parentheses following the code means the specimen broke in the buffed area.

Table 6 Protective Geotextile Conformance Testing Requirements

Property	**Test**	**Acceptance**	**Conformance Test Frequency**
Polymer		Polypropylene	Meets Requirement
Geotextile Construction		Non-woven mechanically bonded	
Marked		CE	
Mass per unit area	EN ISO 9864	g/m^2	1 per 5,000m^2
Thickness	EN 964-1	>1.5 mm	
Tensile strength, md / cmd**	EN ISO 10319	12.0 / 18.0 kN/m	
Elongation at max. tensile strength, md / cmd**	EN ISO 10319	40 / 30 kN/m	
Static puncture force	EN ISO 12236	2,780 N	
Displacement at static puncture strength	EN ISO 12236	30 mm	
Resistance to weathering (UV)	EN 12224	> 1 month	Meets Requirement
Resistance to chemical ageing	EN ISO 12960, EV ISO 3438 or ENV 12447	Within manufacturers published parameters	
Resistance to microbiological degradation	EN 12225	No loss	

** Md/cmd = machine direction, cross machine direction

Note Geotextile conformance testing shall be carried out to the above test methods and testing frequencies to achieve the manufacturer's specified values for the geotextile selected as a result of cylinder testing [Ref. 1] (see Section 9)

Ref 1 "A Methodology for Cylinder testing of Protectors for Geomembranes", UK Environment Agency April 2006

Table 7 Minimum requirements for the steepwall filter and separation geotextile

Property	**Test**	**Acceptance**	**Conformance Test Frequency**
Polymer		Polypropylene	Meets Requirement
Geotextile Construction		Non-woven mechanically bonded	
Marked		CE	
Mass per unit area	EN ISO 9864	≥ 250 g/m^2	1 per 5,000m^2
Thickness	EN 964-1	>1.5 mm	
Tensile strength, md / cmd**	EN ISO 10319	12.0 / 18.0 kN/m	
Elongation at max. tensile strength, md / cmd**	EN ISO 10319	40 / 30 kN/m	
Static puncture force	EN ISO 12236	2,780 N	
Displacement at static puncture strength	EN ISO 12236	30 mm	
Characteristic opening size	EN ISO 12956	70 µm	
Water permeability - VH50-Index - Flow rate$_{H50}$	EN ISO 11058	 4.0 x 10^{-2} m/s 40 l/(m^2 s)	Meets Requirement
Water flow rate in the plane, at 2 kPa $_{(h/h,\ I=1)}$	EN ISO 12958	3 x 10^{-3} l/(ms)	
Resistance to weathering (UV)	EN 12224	> 1 month	
Resistance to chemical ageing	EN ISO 12960, EV ISO 3438 or ENV 12447	Within manufacturers published parameters	
Resistance to microbiological degradation	EN 12225	No loss	

** Md/cmd = machine direction, cross machine direction

Table 8 Requirements for the steepwall protection geotextile

Property	**Test**	**Acceptance**	**Conformance Test Frequency**
Polymer		Polypropylene	Meets Requirement
Geotextile Construction		Non-woven mechanically bonded	
Marked		CE	
Mass per unit area	EN ISO 9864	≥ 250 g/m^2	1 per 5,000m^2
Thickness	EN 964-1	>2.4 mm	
Tensile strength, md / cmd**	EN ISO 10319	32 / 40 kN/m	
Elongation at max. tensile strength, md / cmd**	EN ISO 10319	40 / 35 kN/m	
Static puncture force	EN ISO 12236	5,200 N	
Displacement at static puncture strength	EN ISO 12236	40 mm	
Characteristic opening size	EN ISO 12956	60 µm	
Resistance to weathering (UV)	EN 12224	> 1 month	Meets Requirement
Resistance to chemical ageing	EN ISO 12960, EV ISO 3438 or ENV 12447	Within manufacturers published parameters	
Resistance to microbiological degradation	EN 12225	No loss	

** Md/cmd = machine direction, cross machine direction

Table 9 Drainage Stone Specification and Testing Requirements

Property	**Test Method**	**Required Value**		**Conformance Testing Frequency**
Particle Size Distribution 20/40mm	BS EN 933: Pt 1	BS Sieve Size (mm)	% Passing by Mass	Three tests on initial delivery + 1 per 500m^3 on placement
		63	98-100	
		40	80-99	
		31.5	20-70 (+/-15)	
		20	0-20	
		14	-	
		10	0-5	
		4	-	
Crush Strength (10% Fines Value)	BS 812: Pt 111	≥ 100 kN		Three tests on delivery 1 per 500m3 during placement
Permeability	DTp. HA 41/90	> 1 x 10^{-3} m/s		One test on proposed source to be submitted by Contractor prior to any importation to site

Table 10 Sand Protection Layer Specification and Conformance Testing Requirements

Property	**Test Method**	**Required Value ***		**Conformance Testing Frequency**
Particle Size Distribution	BS EN 933: Pt 1	Sieve Size (mm)	% Passing by Mass	Three tests on initial delivery + 1 per 500m^3 on placement (estimated 16 tests in total)
		6.00	100	
		4.00	99-100	
		2.00	87-96	
		1.00	76-84	
		0.60	67-74	
		0.250	34-48	
		0.125	13-22	
		0.063	6-10	

* Based upon laboratory PSD result of sand produced from on-site road sweepings processing plant, as used for the cylinder test.

Appendix 1 DETAILED DESIGN DRAWINGS

30374-WSM-SW-FD-01	Location Plan
30374-WSM-SW-FD-02	Landfill Formation Plan
30374-WSM-SW-FD-03	Basal Mineral Liner Plan
30374-WSM-SW-FD-04	Landfill Sections
30374-WSM-SW-FD-05	Construction Sequence 1
30374-WSM-SW-FD-06	Construction Sequence 2
30374-WSM-SW-FD-07	Construction Sequence 3
30374-WSM-SW-FD-08	Construction Sequence 4
30374-WSM-SW-FD-09	Construction Sequence 5
30374-WSM-SW-FD-10	Support Frame Construction Details
30374-WSM-SW-FD-11	Support Frame Construction
30374-WSM-SW-FD-12	Steepwall & Basal Liner System Construction Details
30374-WSM-SW-FD-13	Leachate Collection System Plan
30374-WSM-SW-FD-14	Leachate Collection & Monitoring Wells Construction Details 1
30374-WSM-SW-FD-14A	Leachate Collection & Monitoring Wells Construction Details 2
30374-WSM-SW-FD-15	Waste Surface Pre-Settlement Surface Plan
30374-WSM-SW-FD-16	Landfill Capping System Details
30374-WSM-SW-FD-17	Landfill Gas Collection System Plan
30374-WSM-SW-FD-18	Landfill Gas Well Construction Details
30374-WSM-SW-FD-19	Post Settlement Restoration Surface
30374-WSM-SW-FD-20	Restoration Surface Section Locations
30374-WSM-SW-FD-21	Restoration Surface Sections
30374-WSM-SW-FD-22	Access ramp section
30374-WSM-SW-FD-23	Access ramp liner system construction sequence 1
30374-WSM-SW-FD-24	Access ramp liner system construction sequence 2
30374-WSM-SW-FD-25	Support frame base & sub units
30374-WSM-SW-FD-26	Support frame top unit 1 for access ramp to landfill
30374-WSM-SW-FD-27	Access ramp support frame first 5 lifts
30374-WSM-SW-FD-28	Access ramp support frame unit types and locations
30374-WSM-SW-FD-29	Section through southern bench
30374-WSM-SW-FD-30	Support frame units specific to southern bench
30374-WSM-SW-FD-31	Southern bench frame units type & locations
30374-WSM-SW-FD-32	Support frame units and connectors
30374-WSM-SW-FD-33	Support frame sloping units
30374-WSM-SW-FD-34	Support frame top detail
30374-WSM-SW-FD-35	Support frame adjacent to perimeter road
30374-WSM-SW-FD-36	Guide to locations of specific support frame units

Appendix 2 CLIENT'S DRAWINGS

WSM16001, Drawing 01 Proposed Reinforced Concrete Rings for the Collection of Leachate, Normal Concrete Rings

WSM16001, Drawing 02 Proposed Reinforced Concrete Rings for the Collection of Leachate, Perforated Concrete Rings

WSM16001, Drawing 03 Proposed Reinforced Concrete Rings for the Collection of Leachate, Lifting Detail

Appendix 3 PRO-FORMA CQA RECORD SHEETS

CQA Engineer's Daily Log

Sub-grade Release Record

Geomembrane Delivery Record

Geotextile Delivery Record

Geomembrane Installation and Testing Record

Geosynthetics Sample Register

Employers Inspection Check Sheet

CQA Engineers Daily Report			
Project No.		Site	Magħtab Landfill Site
Client	Wasteserv Malta Ltd	Task	Steepwall Cell

Date	
Weather Overnight a.m. p.m.	
Site Hours	
Personnel on site	
Visitors	
Plant utilised on site	
Works undertaken (with timing)	
Testing undertaken	
Meetings	
H&S issues	
Comments	

CQA Inspection Report		**Subgrade release log**	
Project No.		Site	Magħtab Landfill Site
Client	Wasteserv Malta Ltd	Task	Steepwall Cell

Date	Location	Welder's signature to confirm subgrade suitability	CQA Engineer's signature	Panels laid on the released area

CQA Inspection Report		**Geomembrane delivery log**	
Project No.		Site	Magħtab Landfill Site
Client	Wasteserv Malta Ltd	Task	Steepwall Cell

Manufacturer	
Product	
MQC datasheets provided (Y/N)	

Delivery date	**Batch No.**	**Roll No.**	**Roll width, m**	**Roll length, m**	**Comments**

CQA Inspection Report		**Geotextile delivery log**	
Project No.		Site	Magħtab Landfill Site
Client	Wasteserv Malta Ltd	Task	Steepwall Cell

Manufacturer	
Product	
MQC datasheets provided (Y/N)	

Delivery date	**Batch No.**	**Roll No.**	**Roll width, m**	**Roll length, m**	**Comments**

CQA Inspection Report		**Geomembrane installation and testing record**	
Project No.		Site	Magħtab Landfill Site
Client	Wasteserv Malta Ltd	Task	Steepwall Cell

FUSION SEAM PRODUCTION LOG											SEAM TESTING (APTs)															
Date	Locn	Panel Code 1	Panel No. 1	Panel Code 2	Panel No. 2	Seam Length	Equip ID	Time	Tech ID	QC ID	Date Tested	Panel Code 1	Panel No. 1	Panel Code 2	Panel No. 2	Section	Start Time	Bar	End Time	Bar	Pressure Drop	% Drop	Length Tested	CQA ID	Pass / Fail	Comments

CQA Inspection Report		**Geomembrane installation sample register**	
Project No.		Site	Magħtab Landfill Site
Client	Wasteserv Malta Ltd	Task	Steepwall Cell

Sample Identity No.	Sample Receipt No.	Date Sampled	Material Identity	Test Required	Sample Number	Sample Location / Description	Sampled by	Date Sent	Comments
			See Key below						

KEY

Material Identity		Tests required		
TXT	Geotextile	CF	Conformance	
GCL	Geosynthetic Clay Liner	DS	Destructive	
FML	Flexible membrane Liner (HDPE,LLDPE)	CYL	Cylinder Test	
SOIL	Regulation & Restoration Soil	PSD	Particle Size Distribution	

Group Identity		Material Identity		Tests Required
Basal mineral liner	BML	Do not need material identity		B - Bulk, P - Perm, C - Core, S - Shear Strength, M - Moisture, CP - Compaction
Geosynthetics	GEO	Flexible membrane (HDPE,LLDPE)	FML	CF - Conformance, FD / ED - Destructive, CYL - Cylinder Test If the sample is additional to the normal conformance frequency, state the reason; sample location; roll no; DS seam reference etc.
		Textile	TXT	
		Geosynthetic Clay Liner	GCL	
Aggregate (Stone or Sand)	AGG			B - Bulk**, PSD - Grading, CC - Calcareous Content, TPF - 10% Fines (** If more than one of the tests is required on the sample. For Bulk samples, denote the required tests in the "Comments" column and with the sample)

Employers Inspection Check Sheet						
Date	Name	Company	Event/Reason for visit	Items Checked	Actions required	Signed