water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

TITLE: CONSTRUCTION QUALITY ASSURANCE PLAN FOR GOVERNMENT WATERWORKS WASTE DISPOSAL FACILITY POLLUTION CONTROLWORKS

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Signatory Page signed off by the Client and the Engineer
(Providing Name, ID number, contact details and date of signature including ECSA Registration number for the Engineer)

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1. INTRODUCTION

This plan addresses the Construction Quality Assurance (CQA) procedures required during the Project WDF pollution control barrier systems at the base of the facility.

This CQA Plan establishes procedures to verify that construction is in accordance with the Construction Drawings and Construction Specifications, meets the appropriate regulatory requirements, and develops the necessary documentation for submittal to the regulatory authority.

The objective of this plan is to establish:

- Duties of parties responsible for the CQA program
- Qualification requirements of the CQA Engineer(s)
- Inspection activities
- Sampling procedures
- Document control measures
- Procedures for approving the materials used for construction
- Methods for assuring compliance to design standards and Construction Specifications during construction
- Procedures for resolving issues that may occur concerning the design and construction
- Documentation of construction and testing for submittal to the regulatory authority for their review

The intent of the CQA Plan is to provide independent third-party verification and testing, to demonstrate that the Contractors and Installers have met their obligations in the supply and installation of components and materials according to the Construction Drawings, Construction Specifications, and regulatory requirements.

Quality control is provided by the Manufacturers, Installers, and Contractors and refers only to their actions taken to ensure that materials and workmanship meet the requirements of the Construction Drawings and Construction Specifications.

2. PARTIES INVOLVED WITH CONSTRUCTION QUALITY ASSURANCE

The following section provides descriptions of the parties referred to in this CQA Plan including their responsibilities and qualifications. Specific qualified personnel will be chosen once the work has been approved and the schedule is confirmed for the selected CQA project members. (The SANS 10409 standard specification as amended has particular reference.)

2.1 Owner/Operator

For the purpose of this CQA Plan and the PROJECT Specifications, all references to the “OWNER” shall mean the party identified as such on the title and signatory page of this document and is the license holder.

2.2 Project Manager

The Project Manager is the official representative of the OWNER and is responsible for construction activities at the facility, including oversight and construction management. The Project Manager is responsible for coordinating construction and quality assurance activities for the project. The Project Manager shall be responsible for the resolution of all quality assurance issues that arise during the barrier system construction and must be involved in any decisions that may affect future operations of the impoundment.

For the purpose of this CQA Plan and the Project Specifications, all references to the "PROJECT MANAGER" shall mean the party identified as such on the title and signatory page of this document.

2.3 Design Engineer

The Design Engineer, also referred to as the "Designer" or "Engineer," is the individual or firm responsible for the design and preparation of the Construction Drawings and Construction Specifications. The Designer is responsible for approving all design and Construction Specification changes, modifications, or clarifications encountered during construction.

For the purpose of this CQA Plan and the Project Specifications, all references to the "DESIGN ENGINEER" shall mean the party identified as such on the title and signatory page of this document.

2.4 CQA Monitor(s)

The CQA Engineer and CQA Monitor(s) will be responsible for understanding this CQA Plan and shall conduct CQA testing, monitoring, documentation, and reporting as required by this CQA Plan. The CQA Engineer will be the Engineer-of-Record and will stamp the final construction report. The implementation and reporting of this CQA Plan shall be conducted under the direct supervision of an Engineering Council of South Africa registered professional engineer or technologist in the branch of civil engineering.

For the purpose of this CQA Plan and the Project Specifications, all references to the "CQA MONITOR" shall mean the party identified as such on the title and signatory page of this document.

2.5 Geosynthetics Manufacturer

The geosynthetics manufacturer(s), also referred to as the "Manufacturer," is responsible for production of the geosynthetic components outlined in this plan. The Manufacturer may not be aligned with the Geosynthetics Installer as prescribed in the Competition Act, Act 89 of 1998. Each Manufacturer must pre-qualify that they

are able to produce material that meets the requirements of the Project Specifications (listed in Appendix C and on the certified drawings).

2.6 Geosynthetic Installer

The Geosynthetics Installer (Installer), also referred to as the "Geosynthetics Installation Contractor" or the "Installer", is responsible for proper installation of the geosynthetic components in accordance with the Project Drawings and Project Specifications. The Installer may not be aligned with the Manufacturer as prescribed in the Competition Act, Act 89 of 1998.

The Installer must pre-qualify by meeting the requirements outlined in the Project Specifications. The Installer shall provide a qualified Superintendent (formally known as Foreman) who will provide full-time technical guidance to the field crew. The Superintendent will represent the Installer at all site meetings and will act as the spokesman for the Installer on the project. Welding technicians shall be certified as competent by the International Association of Geosynthetic Installers, the TRI (Austin, Texas) or equal approved independent oversight body. The CQA Engineer, through the Project Manager, reserves the right to reject any welding technician whose performance is unsatisfactory.

2.7 Earthworks Contractor

The Earthworks Contractor, also referred to as the "CONTRACTOR," is responsible for completion of the site work as defined by contract with the OWNER and in accordance with the Project Drawings and Project Specifications including materials provided by the Geosynthetics Manufacturer and work performed by the Geosynthetics Installer, but excluding materials provided by the OWNER.

The Earthworks Contractor will be responsible for retaining a surveyor to set lines and grades required for excavation, construction, and preparation of as-built drawings. Surveying shall be performed under the direction of a registered Surveyor.

2.8 Independent CQA Laboratory

The Independent CQA Laboratory (CQA Lab) is the third-party laboratory responsible for performing the quality assurance soils and/or geosynthetics laboratory testing tasks listed in this plan. The CQA Lab is directed by the CQA Monitor and may be part of the CQA Consultant firm or company. The geosynthetics testing laboratory shall be accredited by the Geosynthetics Research Institute Laboratory Accreditation Program (GRI-LAP or similar). The CQA Lab shall not be affiliated with the Earthworks Contractor nor Geosynthetics Installer nor materials suppliers.

3. MEETINGS

Meetings shall be held at inception and during the construction of the project to enhance coordination among the various parties involved. Meetings will include a pre-construction meeting, progress meetings, and resolution meetings if necessary.

3.1 Pre-Construction Meeting

A pre-construction meeting will be held at the site prior to the start of construction. The Project Manager, Design Engineer, CQA Monitor, Installer, contractor, and others designated by the Owner shall attend this meeting. The purpose of this meeting will at a minimum:

- Define lines of communication, responsibility, and authority
- Conduct a site inspection to discuss work areas, work plans, stockpiling, lay-down areas, access roads, haul roads, and related items
- Review the project schedule
- Review the Project Drawings, CQA Plan, and Project Specifications and take cognisance of the conditions in regulatory authorisations and licenses.
- Review work area security and safety protocol

This meeting will be documented by the CQA Monitor and copies of the meeting minutes will be distributed to all parties and included in the construction completion report submitted to the authorities.

3.2 Progress Meetings

Weekly progress meetings will be held. At a minimum, these meetings will be attended by the CQA Monitor, Engineer or their designee, the Project Manager, the Installer, and the Contractor. The Project Manager is responsible for organizing and conducting the progress meetings. The purpose of this meeting will be to:

- Review the previous weeks accomplishments and activities
- Review upcoming scheduled work and project milestones
- Discuss any problems or potential construction problems
- Review the results and status of CQA field and laboratory testing

This meeting will be documented by the CQA Monitor and the minutes transmitted to all in attendance.

3.3 Resolution Meetings

Special meetings will be held, as needed, to discuss and resolve potential problems or deficiencies. At a minimum, these meetings will be attended by the Project Manager, Design Engineer, CQA Monitor, and the Installer and/or Contractor. The meeting will be documented by the CQA Monitor.

When deficiencies (items that do not meet the project requirements stated in the Project Specifications) are discovered, the CQA Monitor shall immediately determine the nature and extent of the problem and notify the Design Engineer and Contractor and vice versa. If unsatisfactory test results identify a deficiency, additional tests will be performed to define the extent of the deficient material or work area.

The Installer or Contractor shall correct the deficiency to the satisfaction of the Design Engineer and CQA Monitor. If the remediation of the deficiency involves a design revision, the Project Manager shall also be contacted. Design revisions can only be made by the Design Engineer.

The corrected deficiency shall be re-tested and/or approved before any additional related work is performed by the Installer or Contractor. Retest results shall also be recorded by the CQA Monitor and included in the final report documentation.

4. EARTHWORK CONSTRUCTION QUALITY ASSURANCE

Construction of the project's NEMWA 2013 compliant containment barrier system or specified earthworks must be in accordance with the approved Project Drawings and Project Specifications. This CQA Plan establishes the CQA monitoring and testing program designed to ensure compliance with the Project Drawings and Project Specifications. The earthwork quality assurance testing program consists of testing of soil and rock materials used during the excavation and the construction of the project's NEMWA 2013 compliant containment barrier system. Quality assurance testing and observation is required during excavation of subgrade, placement of the engineered fill, and construction of the liner system components for the project's NEMWA 2013 compliant containment barrier system.

4.1 Construction Monitoring and Testing

All components of the construction shall be observed and tested as required by the CQA Monitor to verify that the construction is in accordance with the Project Specifications. The Design Engineer shall review the work performed by the CQA Monitor and identify inadequate construction methodologies or materials which may adversely impact the performance of the project's NEMWA 2013 compliant containment barrier system. Visual observations and verification of the independent survey required for specific layers throughout the construction process shall be made to evaluate whether the materials are placed to the lines and grades as shown on the Project Construction Drawings.

The CQA Monitor and Design Engineer will give the Project Manager sufficient notice of anticipated completion of the construction components so that related CQA documentation may be reviewed and accepted without delay to the Contractor. Specific CQA observation and/or testing are required for the following:

- Engineered Fill
- Subgrade Preparation including subsurface drainage
- Compacted clay liner (CCL)
- Anchor trench backfill
- Soil protection layer
- Drainage Gravel and LCS Drainage Layer
- Operations soil layer or pioneering waste layer

In addition to the above components, the CQA Monitor and Design Engineer will observe the construction of the aggregate base surfacing (geomembrane protection layer) and HDPE pipes for compliance with the Project Drawings and Project Specifications.

4.1.1 Engineered Fill And Anchor Trench Backfill

The CQA Monitor shall observe and document the subgrade preparation prior to placement of engineered fill and shall include:

- Monitoring the stripping of vegetated soil, and growth media to be stockpiled, if directed, in the area designated by the Owner.
- Monitoring that appropriate dust control measures are implemented
- Visually inspecting the excavation for moisture seeps, soft or excessively wet areas, and unstable slopes
- Monitoring subgrade preparation and confirming that the surface of the subgrade is free of soft, organic, and otherwise deleterious materials, and that the surface is firm and unyielding and in accordance with Project Specifications (e.g. compaction density or CBR)
- Verify that the subgrade is suitable for supporting any overlying geosynthetic layers as required by the Project Specifications. Borrow materials for engineered fill and anchor trench backfill will be obtained from the excavation area within the cell or the clay stockpile. CQA observation and/or testing is required during construction to verify that the materials and construction are in accordance with the Project Specifications. The tests to be performed, including testing frequency, are shown on Table 1. The testing frequencies specified in Table 1 may be increased when construction conditions warrant additional tests. Additional tests may be recommended by the CQA Monitor and approved by the Design Engineer.

Table 1: Engineered fill and anchor trench backfill construction testing

Test Designation	ASTM Designation	Frequency
Visual-Method Soil Classification	D2488	Continual during excavation and placement of soils
Moisture-Density	D1557	1 per 5000 m^3 or each material type
Sieve Analysis	D422	1 per 1,500 m^3 or each material type
Atterberg Limits	D4318	1 per 1,500 m^3 or each material type
Nuclear Moisture/Density[1]	D6938	1 Per 500 m^3, one per lift, or one per day – whichever results in a higher number of tests
Moisture Content	D2216	1 per 20 Nuclear moisture tests
Sand Cone Test, or Drive Cylinder Test	D1556 or D2937	A minimum of 1 Per 20 Nuclear Density Tests

Notes to Table 1:

1. Tests shall be performed on an even grid to provide adequate testing coverage. For large fills in small areas, the testing frequency shall be increased as necessary to ensure testing for each lift or layer of soil placed.

4.1.2 Compacted Clay Liner

4.1.2.1 Test Pad Construction

(a) Purpose and Scope

The purpose of the test pad is to establish the placement and compaction procedures to be used to construct the compacted clay liner component of the containment barrier system and to ensure conformance with the Project Specifications, and regulatory requirements. The test pad program is intended to establish methods, equipment, and procedures for attaining the specified properties, not to pre-qualify materials for the compacted clay liner. Once the methods and procedures have been verified by completing a successful test, the Contractor must use the same method and procedures to construct the compacted clay liner.

(b) Subgrade Preparation

- The test pad shall be in an area of the project site designated by the Project Manager
- The area within the limits of the test pad shall be cleared and grubbed of all trees, debris, stumps, and any other vegetation. After clearing and grubbing, the area shall be stripped of topsoil and/or organic materials
- The surface of the subgrade shall be proof-rolled with a heavy-wheeled vehicle to detect soft zones, irregularities that may require removal and replacement. The finished subgrade surface shall be sloped at a grade of 1% to 3%
- Construction of the test pad shall not commence until the condition of the subgrade has been examined and documented by the CQA Monitor

(c) Test Pad Construction

The test pad shall be constructed in a rectangular shape to a minimum plan area of 10 m by 15 m. The test pad should consist of a minimum 600mm thick compacted clay liner placed and compacted in accordance with the requirements of the Project Specifications. The compacted clay liner in the test pad shall be constructed in four lifts not exceeding 200 mm loose and 150 mm in compacted thickness. The soil material shall be compacted within the specified moisture-density window. If appropriate, the moisture-density window may be modified by the Design Engineer to improve permeability or constructability based on the results of the test pad.

The Design Engineer shall finalize the moisture-density compaction window in writing prior to full-scale construction of the compacted clay liner and inform the CQA Monitor. Only when the CQA Monitor and Design Engineer has determined that each lift meets the target dry density and moisture content requirements, shall the following lift be constructed. The completed compacted clay liner shall be sealed by rolling with appropriate equipment (e.g., rubber tired or smooth drum roller). Overbuilding the test pad and trimming back may be necessary to obtain a sufficiently smooth top of clay surface and to protect the test pad from desiccation and cracking.

(e) Monitoring and Testing

The CQA Monitor shall monitor and document the borrow material and construction of each lift of the test pad and shall ensure that construction is performed in accordance with the appropriate sections of the Project Specifications. Monitoring and documentation shall include:

- Weather conditions during construction
- Equipment used in construction
- Manner in which equipment was used
- Soil type and USCS classification
- Moisture content and dry density measurements for each lift
- Approximate thickness of each uncompacted and compacted soil lift

Field and laboratory testing shall be performed by the CQA Monitor, as a minimum, during construction of the subgrade and compacted clay liner in the test pad and shall include those tests presented in Table 2.

Table 2: Test pad construction testing

Test Designation	**ASTM Designation**	**Compacted Clay**	**Subgrade**
Visual-Method Soil Classification	D2488	Continuous	1 per Soil Type
Moisture-Density	D1557	1 Test	1 Test
Atterberg Limits	D4318	1 per Lift	NA
Nuclear Moisture/Density[1]	D6938	4 Tests Per Lift[1]	3 Tests
Moisture Content	D2216 or D 4643	4 Tests Per Lift [2]	1 Test
Sand Cone Test, or Drive Cylinder Test	D1556 D2937	1 Per 20 Nuclear Density Tests	NA
Hydraulic Conductivity	D5084 (5 psi)	2 per Lift [3,4]	NA
Field-Scale Infiltration Test & Permeability Evaluation or Alternatively Double ring Infiltrometer or Guelph Meter test	D6391-11 (2020) D3385 D5126 – 16e1	Two-Stage Borehole Permeameter[4] 1 per lift 1 per lift	NA

Notes to Table 2:

1. Nuclear gauge tests for moisture content and dry density shall be performed at evenly spaced locations in a grid pattern within the footprint of the test pad. Acceptance will be based on test

results that fall within the compaction window developed by the Design Engineer, or as modified by the Design Engineer based on pre-construction testing.

2. A correlation shall be developed between the moisture contents as determined by the nuclear gauge and conventional oven and/or microwave oven methods during construction of the test pad in order to facilitate construction testing and placement of compacted clay liner during full scale operations.
3. Upon completion of the test pad, samples shall be collected using 3-inch (76mm) outside diameter thin walled sampling tubes (Shelby tubes) in accordance with ASTM D1587 or by the block sampling technique in accordance with ASTM D4220, at the discretion of the Design Engineer. Two samples in each lift shall be collected to represent the compacted clay liner. Samples should be collected outside of the future location of the field scale infiltration test.
4. The hydraulic conductivity evaluated in the laboratory (ASTM D5084) for the 3-inch (76mm) diameter samples shall be correlated to the hydraulic conductivity evaluated in the field scale testing. Effective confining pressures of 5 psi (35 kPa) shall be applied during the test. The correlation is to provide a means for establishing criteria for laboratory and field testing of the full-scale (construction) compacted clay liner. In addition, in-situ hydraulic conductivity data is to provide information demonstrating the feasibility of constructing a compacted clay liner meeting the Project Specifications.

(f) Test Pad Data Interpretation

The interpretation of the test results shall focus on the feasibility of constructing a full-scale compacted clay liner in conformance with the project and regulatory requirements. A letter report summarizing the test results shall be issued by the Design Engineer to the CQA Monitor at the completion of the test pad testing program. This letter report shall also be included as a part of the final project CQA documentation.

4.1.2.2 Compacted Clay Liner Construction Monitoring and Testing

CQA observation and/or testing is required during construction to verify that the compacted clay liner construction is in accordance with the Project Specifications. The tests to be performed, including testing frequency, are presented in Table 3. The testing frequencies specified in Table 3 may be increased when construction conditions warrant additional tests. Additional tests shall be recommended by the CQA Monitor and approved by the Design Engineer.

Table 3: Compacted clay liner construction testing

Test Designation	ASTM Designation	Frequency[1]
Visual-Method Soil Classification	D2488	Continual during excavation and placement of soils
Moisture-Density	D1557	1 per 5000 m^3 or each material type
Sieve Analysis	D422/D1140	1 per 1,500 m^3 or each material type
Atterberg Limits	D4318	1 per 1,500 m^3 or each material type
Nuclear Moisture/Density	D6938	1 Per 250 m^3
Moisture Content	D2216	1 per 5 nuclear moisture tests
Sand Cone Test, or Drive Cylinder Test	D1556 D2937	1 Per 20 Nuclear Density Tests
Laboratory Hydraulic Conductivity on Field Collected Sample [2,3,4]	D5084	1 per 1,500 m^3

Notes to Table 3:

1. Specified frequency or one per material type and source, whichever is greater.
2. Tests shall be performed on an approximately even grid to provide adequate testing coverage.
3. Samples will be collected and transported to the laboratory using the same procedures selected by the Design Engineer for the test pad (i.e., Shelby tubes or block samples).
4. Laboratory samples will be tested at confining pressures of 15 psi (104 kPa).

Construction observation and monitoring during the compacted clay liner placement includes:

- Verify that the Contractor obtains compacted clay liner material from the approved excavation or borrow location
- Observe construction staking and/or grade control methods to verify that the compacted clay liner is placed to the lines, grades, and elevations shown on the Project Drawings without puncturing geotextile filters or geomembranes.
- Verify that fill is placed in loose lifts no more than 200mm thick that result in a nominal compacted thickness of 150mm or less
- Verify that the Contractor adequately moisture conditions the borrow soils

- Perform field testing in accordance with Table 3 to verify that the fill materials are placed to the moisture and density requirements indicated in the Project Specifications
- Perform laboratory testing in accordance with Table 3 to verify that the compacted clay liner exhibits the required material properties
- Promptly notify the Contractor of test results that affect the work. Notify the Project Manager of construction progress and of the results of all testing. In the event of failing tests, verify that the Contractor adequately reworks the areas which do not meet the Project Specifications
- Observe that the Contractor takes adequate protective measures to maintain the surface of the compacted clay liner and prevent desiccation cracking
- Verify that the CQA survey has been completed and that the Record Drawing furnished by the surveyor indicates compliance with the lines, grades, elevations, and tolerances as indicated by the Project Drawings and Specifications
- Verify that the test samples and survey stake holes are remediated to not affect the performance of the layerworks.

4.1.3 Drainage Gravel and LCS Drainage Layer Placement

Drainage gravel is used in the LCS collection system and groundwater underdrain system. On-site selected soil is used for the LCS drainage layer cushion protection to the geomembrane. Both pre-construction and construction testing are required for these materials. Pre-construction testing consists of testing proposed materials from samples obtained at the aggregate or on-site borrow source. Construction testing consists of testing performed from samples obtained during delivery of materials during the module or layer construction. The tests to be performed, including testing frequency, for each material type are presented in Table 4. The testing frequencies specified in Table 4 may be increased when construction conditions warrant additional tests. Additional testing may be performed on suspect materials as recommended by the Design Engineer.

Table 4: Drainage gravel and LCS drainage layer construction testing

Test Designation	**ASTM**	**Designation Frequency**
Sieve Analysis	D422	1 per 1,500 m^3 or each material type
Hydraulic Conductivity	D2434	1 per 1,500 m^3 or each material type
Visual-Method Soil Classification	D2488	Continual during excavation and placement of soils

Construction observation and monitoring required during the drainage gravel and LCS drainage layer includes:

- Verification that all pre-construction testing has been performed and that laboratory test results indicate compliance with the Project Specifications. The CQA Monitor shall assure that the Project Manager and the Contractor receive prompt notification of material conformance
- Verify that the material upon which the cushion/protection soil and drainage aggregate layers will be placed (HDPE geomembrane) has been installed in accordance with the Project Drawings and Specifications, and that all required testing, and as-built documentation have been completed
- Observe that care is taken when placing the soil cushion layer and LCS drainage layer on the HDPE geomembrane and that the geomembrane is not punctured or damaged during placement operations. Frequent video records should augment observations to reflect the method of placement.
- Observe and document that appropriate light ground pressure equipment is used and that such equipment avoids sharp turns.
- Observation and monitoring of hauling equipment and spreading equipment to verify that the minimum thickness is maintained for spreading and hauling equipment above the HDPE geomembrane
- Collect and transmit to the laboratory the required number of samples for testing.
- Communicate with the laboratory to verify that the materials tested comply with the Project Specifications
- Visually observe the soil cushion and drainage materials to inspect for any variability in the material including variation in gradation, excess fines or any deleterious material present
- Verify that the CQA Survey has been completed and that the Record Drawings furnished by the surveyor indicates compliance with the lines, grades, elevations, and tolerances as indicated by the Project Drawings and Specifications

If the equipment or material placement procedures do not comply with the Project Specifications, the geomembrane shall be exposed and inspected for potential damage.

4.1.4 Operations Soil Layer or Pioneering Waste Layer Placement

Construction observation and monitoring required during operations layer placement includes:

- Observation and monitoring of hauling and spreading equipment to verify that the minimum thickness is maintained between equipment and the underlying geosynthetic materials
- Verify the integrity of the geotextile layer by final inspection of all seams and geotextile panels
- Verify that the operations/pioneering waste layer fill materials meet the Project Specifications
- Observe that operations/pioneering waste layer fill materials are pushed upslope on side slope areas
- Verify that the thickness of operations/pioneering waste layer required by the Project Drawings is achieved

Table 5: Operations soil layer construction testing

Test Designation	ASTM	Designation Frequency
Visual-Method Soil Classification	D2488	Continual during excavation and placement of soils
Sieve Analysis	D422	1 per 1,500 m^3 or each material type

Note: If an operations soil layer is replaced with a pioneering waste layer above the filter protected LCS, the design engineer shall record equivalent performance specification compliance of the pioneering waste makeup, layer thickness and placement technique

4.2 Surveying

Surveying shall be conducted such that all applicable standards are followed. The Surveyor shall furnish "Record Drawings" (also referred to as "as-built" drawings) for review by the Design Engineer. The CQA Monitor shall also review and approve the drawings prior to placement of a new system component over the work. Required Record Drawings shall be as specified in the Project Specifications. All surveying shall be performed under the direction of a registered surveyor. All Record Drawings shall be signed and certified by the registered surveyor who directed the CQA survey work. Record Drawings shall be at a scale not smaller than 1:1000 scale. The accuracy of the surveying shall be sufficient to determine if the measurements are within the tolerances specified in the Project Specifications.

The required surveying of the barrier system elevations shall be carried out on a maximum 20 m square grid. Additional survey locations shall be recorded to define the following features in the barrier system: toe of slope, crest of slope, grade breaks, ridges and valleys, anchor trench, drainage system piping, perimeter drainage ditch, and position of liner penetrations and instrumentation. The thickness of the geosynthetic barrier system components on the Project Drawings shall be interpreted as negligible. Refer to the Project Specifications for details of the minimum requirements for surveys, Record Drawings, and grades, lines, and levels.

5. GEOSYNTHETICS CONSTRUCTION QUALITY ASSURANCE

Construction of the specified geosynthetics must be in accordance with the approved Project Drawings and Project Specifications. This Quality Assurance program consists of reviewing Geosynthetics Manufacturer’s and Installer's Quality Control submittals, material conformance testing, and construction monitoring and testing.

The types of geosynthetics used in the barrier system construction include geotextile, geomembrane, geosynthetic clay liner, and HDPE pipe and fittings. These geosynthetics are defined in the Project Specifications. Prior to and during construction, these geosynthetics shall be sampled and tested to determine if they conform to the Project Specifications. All geosynthetic conformance testing shall be the responsibility of the Geosynthetic Installer and CQA Monitor.

5.1 Review Quality Control Submittals

Prior to geosynthetic installation, the Design Engineer shall review the Geosynthetic Installer's Quality Control submittals to confirm that materials meet the Project Specifications. The Design Engineer shall review the following submittals for each geosynthetic material specified for the Project:

- Geosynthetic material samples, name of Manufacturer, and minimum material specifications which shall include the Manufacturer's minimum physical properties of the material, test methods (SANS and ASTM Standards) used, and factory and site seaming methods
- Manufacturer's Quality Control Manual followed during the manufacturing process
- **The origin (supplier's name and production plant), identification (brand name and number) and material properties of the resin used to manufacture the product**
- Geosynthetics Installer's Quality Control Manual, for the installation and testing of the geosynthetic
- Resume (Curriculum Vitae) of the Installer Superintendent, Master Seamer, and Seamers to be assigned to this project (geomembrane only)
- A copy of each of the Quality Control Certificates on each lot of resin issued by the resin Supplier for the specific material for this project. Geomembrane submittals shall include certification of the resin for extrusion welding rod
- The result of quality control testing conducted on the resin used in manufacturing the specific material for this project
- A listing which correlates the resin to the individual geosynthetic rolls and extruded materials
- A copy of the geosynthetic roll Quality Control Certificates which shall be supplied at a minimum frequency of one (1) per every five thousand (5 000) square metres of geosynthetic material continuously produced and supplied to the project unless otherwise presented in the Project Specifications
- A panel layout drawing for geomembrane showing the proposed installation layout identifying field seams as well as any variance or additional details which deviate from the Project Drawings
- A detailed installation schedule for the project
- Certification that the extrusion welding rod to be used is comprised of the same resin type as the geomembrane to be used (geomembrane only)

5.2 Conformance Testing

Prior to geosynthetic installation, the CQA Monitor shall obtain samples of the geosynthetics for independent conformance testing to evaluate or confirm that these materials meet the Project Specifications. The conformance testing frequency shall be at a rate of 1 per 15 000 square metres, or one sample per lot, whichever results in the greater number of conformance tests. Samples shall be taken across the entire width of the roll and shall not include the first metre. The samples shall be a minimum of 1 metre wide by the roll width. The CQA Engineer shall mark the

machine direction and roll number on the sample, and date the sample was obtained and forward the sample to the geosynthetic laboratory.

All conformance tests shall be performed in accordance with the Project Specifications. The CQA Monitor and Design Engineer shall review the test results and shall report any non-conformance to the Project Manager and the Installer.

5.3 Geosynthetics Construction Monitoring and Testing

All geosynthetic components of the construction shall be monitored and tested to verify that the construction is in accordance with the Project Specifications. The Design Engineer shall identify inadequate construction methodologies or materials which may adversely impact the performance of the facility being constructed and existing structures. Visual observations throughout the construction process shall be made to evaluate whether materials are placed to the lines, grades and orientations as shown on the Project Drawings.

The CQA Monitor shall review the following submittals provided by the Installer during the project:

- Quality control documentation recorded during installation
- Daily reports detailing arrival and departure times, the personnel present on-site, the progress of the work, the arrival of materials, and any problems encountered
- Subgrade surface acceptance certificates for each area to be covered by the liner system, signed by the Geosynthetics Installer's Superintendent

The CQA Monitor shall observe and document the geosynthetic installation including:

- Delivery and unloading of geosynthetic materials to the site to verify that the materials are not damaged and are properly labelled
- Obtaining geosynthetic packaging identification slips for verification and generation of an on-site materials inventory
- Subgrade conditions prior to liner installation and verify that any deficiencies (e.g. surface irregularities, protrusions, excessively soft areas, stones, desiccation cracks) noted are corrected
- Verification that the Design Engineer has reviewed completed surveys
- Handling of geosynthetic materials from storage to the work area
- Temporary and permanent anchoring of geosynthetics to verify that Project Specifications are met
- Verification that required overlap distances are met
- A record of all incidents such as storms and fires which may have an influence on materials properties.

5.3.1 Geomembrane

During geomembrane installation, the CQA Monitor shall observe and document deployment, trial seams, field seaming, non-destructive and destructive seam

testing, and repairs to determine whether the installation is in accordance with the Project Specifications.

Storage and Handling - Geomembrane shall be stored in accordance with the Manufacturer's recommendations, if approved by the Design Engineer, at a site selected by the Project Manager. Rolls shall be off-loaded using the appropriate equipment and straps. Rolls shall not be placed directly on the ground and shall be stacked no higher than three rolls. Only soft-sole shoes will be allowed on the deployed geomembrane and rub sheets shall be placed under equipment.

Deployment - The CQA Monitor shall verify that only approved materials are used, that each panel is given a unique panel number, that no geomembrane is placed during inclement or unsuitable weather conditions, that the geomembrane is not damaged during installation, that excessive wrinkles are not present, must confirm that the sand bags used and their contents for temporary or permanent ballast comply with Project Specifications and at least the same constraints as the soil protection layer in respect of geomembrane strain limitation, and that anchoring is performed in accordance with the Project Specifications and Project Drawings. The CQA Monitor shall record the deployment on a deployment log form including whether sand bag placement is by dragging or carrying to the point of deposition.

Trial Seams - The CQA Monitor shall verify that seaming conditions are adequate, tests are performed at required intervals, specified test procedures are followed, and that re-testing is performed in accordance with the Project Specifications. The Installer shall perform pre-weld testing at the beginning of each crew shift and immediately following any work stoppage (e.g., for lunch, weather, etc.) of 30 minutes or more. Seaming operation shall not commence until the CQA Monitor has determined that the seaming process meets the Project Specifications. Testing shall include visual observation of a trial seam a minimum of 1 m long on the geomembrane material. The Installer shall mark the trial seam with date, ambient temperature, geomembrane temperature, welding machine number, welding technician's initials, machine temperature, and speed. For extrusion welding, the Installer shall record the nozzle and extrusion settings and for fusion welding, the wedge temperature and machine speed shall be recorded. A 300 mm portion of each trial seam sample shall be archived by the CQA Monitor at the site. The CQA Monitor shall record the trial seam test results on a trial seam log form.

Field Seaming - The CQA Monitor shall verify that only approved equipment and personnel perform welding, all welding is performed under suitable conditions as specified in the Project Specifications, specified overlaps are achieved, seams are oriented in accordance with project requirements, and that grinding techniques and extrudate meet project requirements for extrusion welding. The CQA Monitor shall record all field seaming on the field seaming log forms.

Seaming shall not proceed at an ambient temperature below 5°C or above 45°C unless the Installer demonstrates the capability of achieving acceptable results through the utilization of special seaming techniques and total tensile strain limitations are not exceeded. Such cold or hot weather seaming shall be proven by an approved program presented in the Project Specifications or presented otherwise by the Design Engineer. If seaming operations are conducted at night, lighting

equipment shall be sufficient to allow the Installer and CQA Monitor to adequately and safely perform their duties.

Non-Destructive Seam Continuity Testing - The CQA Monitor shall verify that all seams are non-destructively tested in accordance with the Project Specifications. If the seam cannot be tested, the CQA Monitor shall observe cap strip operations and verify that test equipment and gauges are functioning properly and that test procedures are in accordance with the project requirements. The CQA Monitor shall verify that all failing tests are repaired and re-tested until passing results are achieved. The CQA Monitor shall record all non-destructive test locations on the vacuum test and pressure test log forms.

Destructive Seam Testing - The Installer shall obtain samples, at locations selected and marked by the CQA Monitor, of the field seamed geomembrane. The samples shall be taken centred over the seam and prioritized as follows:

- All areas identified as suspect during non-destructive testing/monitoring
- Seams that appear suspect to the CQA Monitor
- A minimum of one sample per day
- A minimum of one sample for each geomembrane seaming apparatus
- A minimum of one sample for each representative working conditions (e.g. weather condition)
- A minimum of one sample every 150 metres of seaming for each apparatus

Two types of samples shall be obtained at each location. The first sample shall consist of two specimens, each cut approximately 25 mm wide by 200 mm long, taken 1 m apart. These specimens shall be tested for peel and shear strength in the field by the Installer using a calibrated field tensiometer capable of quantitatively measuring peel and shear strengths. The CQA Monitor shall observe all field tests and record the test results.

If one or both of the specimens fail, the Installer shall take additional test samples 3m from the point of the failed test in each direction and repeat the field test procedure. If these additional tests fail, then the procedure shall be repeated until the length of the poor-quality seam is established.
If the initial field tests pass, the second type of sample shall be taken between the passing specimens. The second sample type shall be approximately 1 m along and 300 mm across.
The sample shall be divided into three equal sections and distributed and tested as follows:

- One sample - Manufacturer/Installer for their use
- One sample - CQA Monitor for destructive testing
- One sample - CQA Monitor for site archives

Each sample shall be subject to the following destructive tests at a GRI-LAP accredited CQA geosynthetics laboratory (or similar approved by CQA Monitor) or at the CQA Site Office and tested per ASTM D6392 with appropriate calibrated equipment:

- Seam shear strength (five tests)

- Seam peel strength (five tests)

For fusion seams, one peel strength test refers to testing of both sides of the seam. A passing test must have all five passing tests for the shear test and peel test.
Failed destructive tests shall be subject to additional testing until a passing area is found. The Installer shall take another test sample 3 m from the point of the failed test in each direction and repeat the field test procedure. If subsequent tests fail, then the procedure is repeated until the length of the poor-quality seam is established. Once the field tests have passed, a second sample shall be taken between the passing specimens and tested by the Independent CQA Laboratory.
Failed seams shall be tracked according to the welding apparatus and the machine operator. All failed seams shall be bounded by locations from which passing Independent CQA Laboratory tests have been taken.

The Installer shall be responsible for patching all areas cut for test samples in accordance with the Project Specifications and the Manufacturer's recommended procedures, and for non-destructive testing (e.g. vacuum box, spark testing etc.) of the patched seams. The CQA Monitor shall record all test locations, results, actions taken in conjunction with destructive test failures, and repairs.

Repairs - The CQA Monitor shall observe and document that all repair materials, techniques, and procedures used for repairs are approved in advance and meet the requirements of the Project Specifications. The CQA Monitor shall verify that all repairs are marked, recorded, repaired, tested, and that wrinkles are addressed, prior to being covered by other materials; and that repairs are performed as specified, including specified type of repair according to type of damage and proper patch size or dimension. The CQA Monitor shall record defects and repairs on repair log forms.

Acceptance - The CQA Monitor shall approve areas of the geomembrane prior to coverage of the geomembrane by other materials. Acceptance of areas shall follow these procedures:

- As-built panel layout survey
- Full documentation of all seams
- Full documentation of non-destructive testing on all seams and repairs
- Full documentation of repairs on all defects
- Full documentation of passing destructive tests
- A final “walk-over” of the area to observe any subsequent damages or non-addressed items
- All submittals required by this CQA Plan or the Project Specifications

5.3.2 GCL

During installation, the CQA Monitor shall observe and document deployment, adequate overlap, seaming, and repairs to evaluate whether the installation is in accordance with the Project Specifications.

Deployment - The CQA Monitor shall verify that the subgrade is suitable for supporting the geosynthetics, any underlying layers are clean and free of deleterious materials prior to deployment, and that anchoring is achieved as specified.

Seams and Repairs - The CQA Monitor shall verify sufficient overlap and that the specified seam procedures were followed as required in the Project Specifications. The CQA Monitor shall verify that all repairs are performed in accordance with Project Specifications.

Protection - The CQA Monitor shall observe and document that all geocomposite materials are covered with the approved material and in accordance with the time threshold in the Project Specifications and that traffic or hauling equipment does not damage the material during installation. In the presence of wind, the geosynthetic layers will be securely anchored with sandbags or equivalent. The deployed GCL may not be exposed to rainfall prior to covering.

Submittal - The Installer shall submit an as-built GCL panel layout to the CQA Monitor and records of deployment and cover placement dates and times.

Testing and Acceptance – The CQA Monitor shall take samples from the GCL material prior to deployment to evaluate conformance with the GRI GCL3 and GRI GCL5 as amended Standard specifications and the Project Specifications. As a minimum the CQA Monitor shall independently confirm the mass per unit area of bentonite at zero percent (0%) gravimetric moisture content and the swell index of the bentonite in the GCL, along with the name of GCL manufacturer, roll identification markings, type of bentonite, type of carrier geotextiles and location of manufacturing plant.

5.3.3 Geotextile

During the geotextile installation, the CQA Monitor shall observe and document deployment and repairs to determine whether the installation is in accordance with the Project Specifications.

Deployment - The CQA Monitor shall confirm that the subgrade is in conformance with Project Specifications, any underlying installations are complete, installed as designed, and as-built documentation has been obtained.

Seams and Repairs - The CQA Monitor shall verify sufficient overlap and that the specified seaming (eg. Hot-air-gun welding or stitching etc.) and patch procedures were followed as required in the Project Specifications. The CQA Monitor shall verify that all repairs are performed in accordance with Project Specifications and that the seaming method, be it by hot-air-gun or stitching does not induce detrimental impacts on adjacent materials

Protection - The CQA Monitor shall observe and document that all geosynthetics materials have no damage, no slippage of geosynthetics underlying layers and no excessive tensile stresses in the geosynthetics.

Testing and Acceptance – The CQA Monitor shall take samples from the geotextile material prior to deployment to evaluate conformance with the GRI GT12(b) and GRI GT13(b) as amended standard specifications and the Project Specifications for cushion protection geotextiles and filter separator geotextiles respectively.

As a minimum the CQA Monitor shall independently confirm the mass per unit area and CBR puncture maximum force and elongation, and 3 in-field seam strength test results for cushion protection geotextiles, along with the name of geotextile manufacturer, roll identification markings, type of polymer and filament and location of manufacturing plant. Similarly as a minimum the CQA Monitor shall independently confirm the mass per unit area, CBR puncture strength and either the Apparent Opening Size or Gradient Ratio filter compatibility for separator and filter geotextile installations as required by the Standard and Project Specifications.

5.3.4 HDPE Pipe and Fittings

During high-density polyethylene (HDPE) pipe installation, the CQA Monitor shall observe and document that the installation is in accordance with the Project Specifications.

Placement - Observation that the handling procedures used do not damage the pipe, backfill is placed in accordance with the requirements of the Project Specifications so as not to damage the pipe, any foreign material is removed from the interior of the pipe, and indentations on the pipe are within the allowable limits.

Joints and Connections - Monitoring of the jointing and connection operations to verify that the Installer follows the Project Specifications or at least the pipe Manufacturer's recommendations, verification that the pipes are clean when installed, and that perforated sections of pipe are aligned properly prior to connection.

Non-destructive Testing - Observe and document any required testing of the pipe to verify accordance with the Project Specifications. The CQA Monitor shall keep a photographic record of post installation pipe pressure tests in progress along with the field data of date, time, location and product suppliers identification markings.

6. LYSIMETERS

Soil moisture lysimeters will be installed in the compacted clay liner beneath the temporary leachate extraction point. The CQA Monitor will observe and document the following:

- The lysimeters are the make and model specified in the Project Specifications and are undamaged (no cracks)
- The lysimeter is installed as shown in the Project Drawings and per manufacturer’s recommendations
- The tubing is continuous and in good condition
- The location of the lysimeters are surveyed

7. DOCUMENTATION

An effective Quality Assurance program depends on thorough monitoring and documentation of all construction activities during all phases of construction and as a minimum shall comply with SANS 10409 as amended and the all-important inception meeting. Documentation shall consist of daily record keeping (including minutes of meetings), construction problem resolutions, design and specification changes, photographic records, weekly progress reports, chain of custody forms for test sample tracking, and a certification and summary report. During construction, all documentation shall be kept on-site and will be available for review by the Project Manager, Design Engineer, or CQA Monitor.

No section of the barrier system may be covered up until the CQA Monitor and Design Engineer (as appropriate) observes and approves the completed section of the barrier system and assures that all CQA documentation has been completed.

7.1 Daily Record Keeping

Daily records shall consist of field notes, observation and testing data sheets, summary of the daily meeting with the Installer and Contractor, and reporting of construction problems and resolutions. This information shall be submitted weekly along with a weekly summary to the CQA Monitor. Copies of all CQA documentation shall be maintained at the site and be made available for review by the Project Manager.

7.2 Soils Observation and Testing Data Sheets

Soils observation and testing data sheets generally include the following information:

- Date, project name, location, and weather data
- A reduced-scale site plan, or full-scale plots, showing work areas and test locations
- Descriptions of ongoing construction
- Summary of test results and samples taken, with locations and elevations
- Off-site materials received including quarry certificates
- Test equipment calibrations, if necessary
- Signature or initials of the CQA Monitor

7.3 Geosynthetic Observation and Testing Forms

Geosynthetic observation and testing forms generally include the following information:

- Date, project name, location, and weather data
- Identification of panel or seam number
- Numbering system identifying test or sample number
- Location and identification of repairs and date of repair
- Length and/or thickness measurements for geomembrane panels or seams
- Welding machine temperatures and settings
- Welding machine and technician identifications

- Location of tests and test results
- Identification of testing technicians and time of tests
- Signature or initials of the CQA Monitor

7.4 Construction Problem and Resolution Documentation

Any construction problem which cannot be resolved between the Installer, Contractor, and CQA Monitor may require a special meeting in order to resolve the problem. The problem should be discussed with the Project Manager, and Design Engineer if a design issue is involved. Specific written documentation of that problem should be prepared, if warranted, and will generally include the following information:

- Detailed description of the problem
- Location and cause of the problem
- How and when the situation or deficiency was identified
- How the problem was resolved
- Any measures taken to prevent similar problems in the future
- Signature of the Design Engineer and CQA Monitor

Copies of all Construction Problem and Resolution correspondence will be submitted to the Project Manager.

7.5 Photographic Documentation

All phases of construction shall be sufficiently photographed and/or audio video recorded by the CQA Monitor. Photographs shall be identified by separate photographic log by location, time, date, and name of the person taking the photograph. A camera which records the time and date shall be used. Representative photographs will be included in the certification report.

7.6 Design and Specification Changes

If it is necessary to address Project Drawings and/or Projects Specification changes, modifications, or clarifications during construction, the CQA Monitor or Design Engineer will inform the Project Manager. Project Drawing and Project Specification changes shall only be made with written agreement from the Project Manager and Design Engineer, and approval of the regulatory authorities if required.

7.7 Construction Report

At the completion of construction, a construction report shall be prepared and signed by the CQA Monitor and Design Engineer to certify that the work has been performed in compliance with the license conditions, Project Drawings and Project Specifications and will contain the following general information:

- Summary of construction activities
- Observation and test data summary sheets, inclusive of a table reflecting statistical analyses i.e. for each test method on all materials the number of

tests; minimum, maximum and mean values; standard deviation; number of non-compliances and rectification shall be included.

- Sampling, testing locations, and test results
- Confirmation of interface shear strength parameters (peak and residual) using the actual geosynthetic materials supplied and installed on site
- A description of significant construction problems and the resolution of these problems
- Changes to the Project Drawings or Project Specifications and the justification for these changes
- Record drawings
- Specific barrier performance confirmation tests, which may include amongst others:
    - Electric leak location survey according to ASTM D7007 or D8265 or similar amendment to encourage competitive procurement provided the independence and performance of the survey are not compromised as agreed with the lead authority in writing prior to implementation;
    - Differential Scanning Calorimeter (DSC) test results on the geomembrane installed for the sample identified by the regulator or agreed agent when required;
    - In-situ geomembrane tensile strain confirmation for the construction method employed (the test usually been undertaken in the trial pad or initial footprint area), or laboratory test simulating site loading conditions on site specific material or similar approved
    - The destructive test specimens of installed geomembrane welds shall be retained for visual and physical inspection by the regulator, with photographic record and weld dimensions included in the report.
- Detail of instrumentation that is provided to test, measure and confirm assumed parameters used in design and construction performance assessments e.g. settlement beacons, flow gauges, vibrating wire piezometers, strain gauges, inclinometers and similar, including co-ordinates and elevation.
- A certification statement signed and certified by the Design Engineer and CQA Monitor, by whom the CQA activities were supervised and work performed in responsible charge.

The Record Drawings shall be prepared by the Surveyor and shall accurately locate all construction items including the lines, grades, and thickness of all soil components for the barrier system.

LIST OF APPENDICES

Appendix A: Parties involved in the CQA implementation

Appendix B: Design parameters (materials strength, internal and interface shear resistance required; strain limitation; slopes; service life requirement (in years); assessed leakage rate and action leakage rate in l/ha/d).

Appendix C: Standard specifications (SANS 1200; 1526; 10409; GRI for GCLs and GT cushion layers; ASTM D series for and GC3 and GN2 for geocomposites etc.)

Appendix D: List of Design Drawings as submitted to the Regulator

Appendix E: Example of performance parameter reporting summary sheet

Compiled by Chief Directorate: Engineering Services for the Department of Water and Sanitation, Revision November 2020

Appendix A: Parties involved in the CQA implementation

Company Name	Representatives Name	Email address	Contact number
Owner/Operator			
Project Manager			
Design Engineer			
CQA Monitor			
Geosynthetics Manufacturer			
Geosynthetics Installer			
Earthworks Contractor			
Independent CQA Laboratory			

APPENDIX B: Design parameters (materials strength, internal and interface shear resistance required; strain limitation; slopes; service life requirement (in years); assessed leakage rate and action leakage rate in l/ha/d).

1. Site Conditions

1.1 Surface Water

- The nearest water course: Name of stream & distance from site km
- Shortest distance to the 1:100 year flood line: m
- Regional Rainfall: mm/annum
- Regional evaporation: mm/annum
- 1:50 year 24hr duration storm event: mm

1.2 Groundwater

- Depth to groundwater: m below NGL
- Aquifer classification: Yield and Class, including perched/fractured rock etc.

1.3 Geotechnical profile

- Depth to pebble marker: m
- Transported soil: description and parent material
- Residual soil: description and parent rock
- Depth to hard rock: m below NGL
- Foundation rock description: rock type/formation
- Collapsible structures: describe if relevant e.g. Halfwayhouse granites/wad/churt/dolomites/fault zones/under mined
- Bearing capacity and consolidation: MPa and mm under kPa
- Seismicity: g (m/s^2)

1.4 Topography

- Wall/embankment side slopes: v:h
- Minimum slope: % or degrees
- Maximum slope: % or degrees
- Minimum floor slope: v:h

2. Materials Properties

2.1 Clay for barrier systems

- PI:
- Standard proctor MDD: kN/m^3
- Optimum Moisture Content (OMC): %
- Percentage clay: %
- Maximum particle size: mm
- Permeability: cm/s
- Minimum shear strength: degrees and kPA

2.2 Geomembrane

- Indicator parameters: compliance with SANS1526 (2015), with no project specific deviations
- Performance parameters: ≤ 3% total tensile strain

2.3 Liner Protection

- Description of soil: Describe grading, uniformity, and cohesion, including CBR when marginal
- Particle size distribution: mm

2.4 Waste (industrial, municipal or mining general description)

- Waste Type assessed as: 1, 2 or 3 as per NEMWA R635 of 2013
- Material Strength Properties (density and strength):
- Degree of saturation:
- Permeability:
- Estimating pollution period (years):
- Maximum depth and rate of rise:

3. System Performance Criteria

- Predicted mechanism of failure: Describe height of waste to width ratio, and failure mechanism as sliding/slip circle/combination of mechanisms
- Minimum factor of safety: Provide the actual parameter in the design report, with ≥ 1,1 for seismic loading, ≥ 1,3 for industrial and municipal waste; and ≥ 1,5 for mining deposits
- Frequency of PCD overtopping: never or < than once in 50 years depending on waste risk assessment based on a stochastic analysis using rainfall data from name of weather station
- Action leakage rate: l/ha/d over ha of barrier system No.
- Peak total tensile strain limitation:
- Elevated temperature and duration (°C and years):
- Interface shear strength: test results
    - Interface 1: Protection/Geomembrane - Peak (shear angle and cohesion) and Residual (shear angle and cohesion)
    - Interface 2: Geomembrane/GCL or CCL - Peak (shear angle and cohesion) and Residual (shear angle and cohesion)
    - Note: For multi-layer barrier systems the graph of stress versus strain is provided in the technical report for the normal load under consideration so as to identify the critical interface
- Wrinkles
    - Maximum height
    - Maximum wrinkle length
    - No. of wrinkles per hectare
    - Zero folds

APPENDIX C: Standard specifications (SANS 1200; 1526; 10409(2020); GRI for GCLs and GT cushion layers; ASTM D series for and GC3 and GN2 for geocomposites etc.)

Standard Specification	Description
e.g. SANS 1200 DE	Small earthworks
SANS 1526 (2015)	HDPE
SANS 10409 (2020)	Design, selection and installation of geomembranes
SANS 1083 (2014)	Aggregate
BS8007	Concrete water retaining structures
GRI-GN2 and GRI-GC13 (2012)	Joining and attaching Geonets and Drainage
EPA 9090, ASTM D5747 and ASTM D5721	Durability
ASTM D7007 or D8265 as per the license with limited deviation allowed to facilitate competitive procurement of services without compromising independence and performance.	Form of electric leak location survey to be undertaken post placement of cover material

APPENDIX D: List of Design Drawings as submitted to the Regulator

Number:	Title
1.	General Layout Plan
2.	Phases of Development Layout Plan
3.	Final fill model layout plan
4.	Sections showing geotechnical profile of site
5.	Long section & Cross sections of excavations and fill
6.	Typical liner details
7.	Typical Barrier System
8.	Manhole, Subsoil Drain Pipes & Pipe Liner Details

APPENDIX E: Example of performance parameter reporting summary sheet

CONSTRUCTION QUALITY ASSURANCE PLAN: RECORD OF MATERIAL CONTROL TEST

Layers	PARAMETER	TEST METHOD	PERFOMANCE CRITERIO	MINIMUM FREQUENCY	Min	Max	MIN VALUE	NUMBER OF TESTS	STANDARD DEVIATION	NUMBER OF FAILURES
Base Preparation	Layer Thickness (Rip & Compact)	Survey or Excavation and Measure	Min of 150 mm	1 Test per 1000m2						
	Moisture Content (OMC)	SANS 3001-GR30:2015	OMC 2+2%							
	Compaction Density	(a). Troxler (Nuclear Density Gauge Test)	95% STD Proctor MDD	1 Test per 1000m2						
		(b). ASTM (Sand Replacement)								
	Max Particle Sizes	(a) ASTM D6913 / D6913M - 17 Sieve Analysis	Maximum Size of 25 mm	1 Test per 1000m2						
		(b). ASTM D7928 - 17 Hydrometer Test								
CLAY LINERS										
a) CCL	Layer Thickness	Survey or Excavation and Measure	150 mm Layers	1 Test per 1000m2						
	Permeability (cm/s)	ASTM D3385 (In-situ-Double Ring Infiltrometers)	1 x 10-6 cm/s	1 Test per 1 000m2						
	Grading (Particle Size Distribution)	ASTM D6913 / D6913M - 17 Sieve Analysis	Maximum size of 0.002 mm	1 Test per 1000m2						
	Density	Proctor Test (ASTM D1557-91)	95% STD Proctor MDD							
	Moisture Content (OMC)	SANS 3001-GR30:2015	OMC 2+2%	1 Test per 1000m2						
	Plasticity Index (PI)	ASTM D4318-Atterburg Limits	Min of 10 to Max that will not result in excessive desiccation cracking	1 Test per 1000m2						
	Surface Smoothness	SANS 10409								
b) GCL	Mass of GCL (g/m2)(	ASTM D5993	4000	4000m2						
	Moisture content (%) min	ASTM D5993	35	4000m2						
	Swelling index (ml/2g) min	ASTM D5890	24	50 Tons						
	Tensile str., MD (kN/m)	ASTM D6768	4	20 000m2						
	Peel strength (N/m) (min)	ASTM D6496	360 (for reinforced GCL only)	4000m2						
	GCL permeability (on pure bentonite not polymer modified)									
	Permeability (m/s) max @35 Kpa	ASTM D6766	1x10^-8	yearly						
	Permeability (m/s) max @500 Kpa	ASTM D6766 mod.	5x10^-10	yearly						
	Component Durability									
	Geotextile & reinforcing yarns (% strength retained)	ASTM D5721/ASTM D6768,	65	yearly						
	Overlap	GRI GCL3	Min of 150 mm	all edges						
HDPE GM	Thickness	ASTM D5994 / SANS 1526 :2015		Per roll						
	Density	ASTM D1505/D792	0.940g/cc	90 00kg						
	Tensile Properties	ASTM D6693		9 000kg						
	Yield strength		11,15,18,22,29,37,44 kN/m							
	Break strength		20,27,33,40,53,67,80kN/m							
	Yield elongation		12%							
	Break elogation	ASTM D6693 (Type 5)	700%	9 000kg						
	Tear resistance	ASTM D1004	93 N, 125 N, 156 N, 187 N, 249 N, 311	20 000kg \1 per site						
	Puncture resistance	ASTM D4833	240 N,320 N ,400 N,480 N,640 N,800 N	20 000kg						
	Stress crack Resistance	ASTM D5397	500hr	Per GRI GM10						
	OIT (oxidative Induction Time (min.ave)									
	(a) STD OIT or	ASTM D 3895	100min	1 per site or 1 every 90 000kg						
	(b) High Pressure OIT	ASTM D 5885	400min	1 per site or 1 every 90 000kg						
	Oven Aging at 85°C**	ASTM D 5721								
	(a) STd OIT (min.ave)-%retained after 90 days or...	ASTM D 3895	55%	1 per site or every 2 every 90 00kg						
	(b) High Pressure OIT (min.ave)-% retained after 90 days	ASTM D 5885	80%	1 per site or every 2 every 90 00kg						
	**(It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response)									
	UV Resistance	ASTM D 7238								
	(a) STd OIT (min.ave)	ASTM D 3895	Not recommended(unrealistic results due to high temp)	–						
	(b) High Pressure OIT (min.ave)-% retained after 1600 hrs	ASTM D 5885	50% (for all thickness)	20hr uv cycles @ 75 C followed by 4hr condensation at 60C						
	Seaming	GRI GM 14 &19(Vacuum box/Spark Testing/Seam Pressure Test)	Test	Test Every Seam						
	Peel Tensile Test : Seaming	GRI GM 19/ASTM D7747	90 % of parent material strength							
GM Protection Layer										
a) Sand Layer										
	Thickness	Excavation & Mesuare or Survey	min 100 mm	1 Test per 1000m2						
	Particle Size Distribution	ASTM D6913 / D6913M - 17 Sieve Analysis	max 4.75 mm	1 Test per 1000m2						
	Grading distribution			1 Test per 1000m2						
	Compaction	Sand Replacement Test	95% STD Proctor MDD	1 Test per 1000m2						
b) Geotextile	**(Protection or Cushioning Materials)**									
	Mass /unit area (g/m2)	ISO 09864	350,400,600,800,1000,2000	9 000kg						
	Tensile Properties									
	Strength	ISO 10319	16,21,27,32,36,45	9 000kg						
	Strain at Max. Load	ISO 10319	50%							
	Trapezoidal Tear Strength	ISO 13434	0.42,0.51,0.66,0.89,0.96,1.32							
	CBR Puncture (kN/mm)			9 000kg						
	Max. Force	ISO 12236	3.1,3.6,4.1,4.9,7.6,11.0							
	Elongation at Max Force	ISO 12236	38							
	UV Str. Ret. after 500 lt. HRS EXPOSURE	ASTM D7238	70%							
	Joint Strength		90 % Strength of Parent Material							
	Strip Tensile	Strip Tensile Test	90 % of Parent Material							
	Overlap	Measure	Min of 120 mm							
Leachate Collection System										
a) Aggregate	Layer Thickness	Survey or Excavation and Measure	150 mm -200 mm per Design Drawing	1 Test per 1000m2						
	Grading	SANS 3001-AG:2014-Sive analysis	38-53 mm with 2% less than fines							
	Aggregate crushing value (ACV)	SANS 3001-AG10 Aggregate Crushing Value		1 Test per 10 000m2						
	Flakiness index	SANS 5847 : Flekiness Index	Max 35%	1 Test per 10 000m2						
b) HDPE Pipe	Crushing Strength	ASTM D2412		Test Every Pipe Lenghts						
	Orifice Size	Measure/Inspection	10 mm	Min of 1 hole per meter						
	Slope	Survey	Min 2%	As per Detailed Design Drawings						
Filter Geotextile	Mass per Unit Area									
	Maximum Opening Size (o95)	ASTM D4751	max 0.423mm	40 000m2						
	Permittivity	ASTM D4491								
	Trapezoid Tear Strength	ASTM D 4533	0.8x1.2 kn	7500 m2						
	CBR Puncture Strength	ASTM D 6241	1.2 kn	7500 m2						
	Apparent Opening Size	ASTM D 4751	max 0.423mm	40 000m2						
	Ultraviolet Stability	ASTM D 7238	65%	1 per site/ every 40 000kg						
	Overlap	Inspection	Min of 150 mm	All Overlaps						
Pioneer Waste layer										