Zitholele Consulting
Reg. No. 2000/000392/07

PO Box 6002 Halfway House 1685, South Africa
Building 1, Maxwell Office Park, Magwa Crescent West
c/o Allandale Road & Maxwell Drive, Waterfall City, Midrand
Tel + (27) 11 207 2060
Fax + (27) 86 674 6121
E-mail : mail@zitholele.co.za

REPORT ON

Construction Quality Assurance Plan for Kendal Power Station 30 Year Ash Disposal Facility Project Liner Installation

Report No : 12935-45-Rep-013

Submitted to:

Eskom
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2000

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ACROYNYMS

CQA	Construction Quality Assurance
CQC	Construction Quality Control
HDPE	High Density Polyethylene
MQC	Manufacturing Quality Control
UV	Ultraviolet
ASTM	American Society for Testing and Materials
OIT	Oxidative Induction Time
MD	Machine Direction
XMD	Cross Machine Direction

1 INTRODUCTION

1.1 Purpose and Scope of the Construction Quality Assurance (CQA) Plan

The purpose of the CQA Plan is to address the CQA procedures and monitoring requirements for construction of the project. The CQA Plan is intended to:

(i) define the responsibilities of parties involved with the construction;
(ii) provide guidance in the proper construction of the major components of the project;
(iii) establish testing protocols;
(iv) establish guidelines for construction documentation; and
(v) provide the means for assuring that the project is constructed in conformance to the Technical Specifications, permit conditions, applicable regulatory requirements, and Construction Drawings.

2 DEFINITIONS RELATING TO CQA

In the context of this document, Construction Quality Assurance and Construction Quality Control are defined as follows:

Construction Quality Assurance (CQA) - A planned and systematic pattern of means and actions designed to assure adequate confidence that material and/or services meet contractual and regulatory requirements and will perform satisfactorily in service. CQA refers to means and actions employed by the Client and the Engineer to assure conformity of the project “Work” with this CQA Plan, the Drawings, and the Technical Specifications.

Construction Quality Control (CQC) - Actions which provide a means to measure and regulate the characteristics of an item or service in relation to contractual and regulatory requirements. CQC refers to those actions taken by the Contractor, Manufacturer, or Geosynthetic Installer to verify that the materials and the workmanship meet the requirements of this CQA Plan, the Drawings, and the Technical Specifications. In the case of the geosynthetic components and piping of the Work, CQC is provided by the Manufacturer, Geosynthetic Installer, and Contractor.

2.1 Client

The Client on this project is Eskom SOC Ltd.

2.2 Construction Manager

The Construction Manager is responsible for managing the construction and implementation of the Drawings, and Technical Specifications for the project work. The Construction Manager is selected/appointed by the Owner.

2.3 Engineer

The Engineer is responsible for the design, Drawings, and Technical Specifications for the project work. The Engineer of Record shall be a qualified engineer, registered as a professional engineer with the Engineering Council of South Africa. The Engineer should have expertise, which demonstrates significant familiarity with piping, geosynthetics and soils, as appropriate, including design and construction experience related to liner systems.

2.4 Contractor

In this CQA Plan, Contractor refers to an independent party or parties, contracted by the Owner, performing the work in general accordance with this CQA Plan, the Drawings, and the Technical Specifications. The Contractor will be responsible for the installation of the soils, pipe, drainage aggregate, and geosynthetic components of the liner systems

The Contractor will be responsible for constructing the liner system and appurtenant components in general accordance with the Drawings and complying with the quality control requirements specified in the Technical Specifications.

Qualifications of the Contractor are specific to the construction contract. The Contractor should have a demonstrated history of successful earthworks, piping, and liner system construction.

2.5 Manufacturers

The Manufacturers are responsible for the production of finished material (geomembrane, geotextile, and pipe) from appropriate raw materials. The Manufacturer(s) will be able to provide sufficient production capacity and qualified personnel to meet the demands of the project. The Manufacturer(s) must be well established firms that meet the requirements identified in the Technical Specifications.

2.6 Geosynthetic Installer

The Geosynthetic Installer is responsible for field handling, storage, placement, seaming, ballasting or anchoring against wind uplift, and other aspects of the geosynthetic material installation.

The Geosynthetic Installer will be trained and qualified to install the geosynthetic materials of the type specified for this project. The Geosynthetic Installer shall meet the qualification requirements identified in the Technical Specifications.

2.7 Resident Engineer

Responsibilities

The Resident Engineer is a party, independent from the Owner, Contractor, Manufacturer, and Geosynthetic Installer, who is responsible for observing, testing, and documenting activities related to the CQC and CQA of the earthwork, piping, and geosynthetic components used in the construction of the Project as required by this CQA Plan and the Technical Specifications. The Resident Engineer will also be responsible for issuing a CQA report at the completion of the Project construction, which documents construction and associated CQA activities.

Qualifications

The Resident Engineer will be experienced with earthwork and installation of geosynthetic materials similar to those materials used in construction of the Project. The Resident Engineer will be experienced in the preparation of CQA documentation including CQA Plans, field documentation, field testing procedures, laboratory testing procedures, construction specifications, construction Drawings, and CQA reports.

2.8 Surveyor

The Surveyor is a party, independent from the Contractor, Manufacturer, and Geosynthetic Installer, that is responsible for surveying, documenting, and verifying the location of all significant components of the Work. The Surveyor's work is coordinated and employed by the Contractor. The Surveyor is responsible for issuing Record Drawings of the construction.

3 DEFECTS IDENTIFICATION AND RECTIFICATION

If a defect is discovered in the work, the Engineer will evaluate the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the Engineer will determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the Engineer deems appropriate.

After evaluating the extent and nature of a defect, the Engineer will notify the Construction Manager and schedule appropriate re-tests when the work deficiency is corrected by the Contractor.

The Contractor will correct the deficiency to the satisfaction of the Engineer. Defect corrections will be monitored and documented.

4 SITE AND PROJECT PROTOCOL

4.1 Project Coordination Meetings

Meetings of key project personnel are necessary to assure a high degree of quality during installation and to promote clear, open channels of communication. Therefore, Project Coordination Meetings are an essential element in the success of the project. Several types of Project Coordination Meetings are described below, including: (i) pre-construction meetings; (ii) progress meetings; and (iii) problem or work deficiency meetings.

4.1.1 Pre-Construction Meeting

A Pre-Construction Meeting will be held at the site prior to construction of the Project. At a minimum, the Pre-Construction Meeting will be attended by the Contractor, the Geosynthetic Installer's Superintendent, the Engineer, and the Construction Manager.

Specific items for discussion at the Pre-Construction Meeting include:

- Appropriate modifications or clarifications to the CQA Plan;
- The Drawings and Technical Specifications;
- The responsibilities of each party;
- The lines of authority and communication;
- The methods for documenting and reporting, and for distributing documents and reports;
- The acceptance and rejection criteria;

- The protocols for testing;
- The protocols for handling deficiencies, repairs, and re-testing;
- The time schedule for all operations;
- The procedures for packaging and storing archive samples;
- The panel layout and numbering systems for panels and seams;
- The seaming procedures;
- The repair procedures; and
- The soil stockpiling locations.

The Construction Manager will conduct a site tour to observe the current site conditions and to review construction material and equipment storage locations. A person in attendance at the meeting will be appointed by the Construction Manager to record the discussions and decisions of the meeting in the form of meeting minutes. Copies of the meeting minutes will be distributed to all attendees.

4.1.2 Progress Meetings

Progress meetings will be held between the Engineer, the Contractor, Construction Manager, and other concerned parties participating in the construction of the project. This meeting will include discussions on the current progress of the project, planned activities for the next week, and revisions to the work plan and/or schedule. The meeting will be documented in meeting minutes prepared by a person designated for the purpose. Within 2 working days of the meeting, draft minutes will be transmitted to representatives of parties in attendance for review and comment. Corrections and/or comments to the draft minutes shall be made within 2 working days of receipt of the draft minutes to be incorporated in the final meeting minutes.

4.1.3 Problem or Work Deficiency Meeting

A special meeting will be held when and if a problem or deficiency is present or likely to occur. The meeting will be attended by the Contractor, the Construction Manager, the Engineer, and other parties as appropriate. The purpose of the work deficiency meeting is to define and resolve the problem or work deficiency as follows:

- Define and discuss the problem or deficiency;
- Review alternative solutions;
- Select a suitable solution agreeable to all parties; and

- Implement an action plan to resolve the problem or deficiency.

The Construction Manager will appoint one attendee to record the discussions and decisions of the meeting. The meeting record will be documented in the form of meeting minutes and copies will be distributed to all affected parties. A copy of the minutes will be retained in facility records.

5 DOCUMENTATION

5.1 Daily Recordkeeping

Preparation of daily CQA documentation will consist of daily field reports prepared by the Resident Engineer which may include CQA monitoring logs and testing data sheets. This information may be regularly submitted to and reviewed by the Construction Manager. Daily field reports will include documentation of the observed activities during each day of activity. The daily field reports may include monitoring logs and testing data sheets. At a minimum, these logs and data sheets will include the following information:

- The date, project name, location, and other identification;
- A summary of the weather conditions;
- A summary of locations where construction is occurring;
- Equipment and personnel on the project;
- A summary of meetings held and attendees;
- A description of materials used and references of results of testing and documentation;
- Identification of deficient work and materials;
- Results of re-testing corrected “deficient work;”
- An identifying sheet number for cross referencing and document control;
- Descriptions and locations of construction monitored;
- Type of construction and monitoring performed;
- Description of construction procedures and procedures used to evaluate construction;
- A summary of test data and results;
- Calibrations or re-calibrations of test equipment and actions taken as a result of re-calibration;

- Decisions made regarding acceptance of units of work and/or corrective actions to be taken in instances of substandard testing results;
- A discussion of agreements made between the interested parties which may affect the work; and
- Signature of the Engineer and Construction Manager.

5.2 Construction Problems and Resolution Data Sheets

Construction Problems and Resolution Data Sheets, to be submitted with the daily field reports prepared by the Resident Engineer, describing special construction situations, will be cross-referenced with daily field reports, specific observation logs, and testing data sheets and will include the following information, where available:

- An identifying sheet number for cross-referencing and document control;
- A detailed description of the situation or deficiency;
- The location and probable cause of the situation or deficiency;
- How and when the situation or deficiency was found or located;
- Documentation of the response to the situation or deficiency;
- Final results of responses;
- Measures taken to prevent a similar situation from occurring in the future; and
- Signature of the Engineer and a signature indicating concurrence by the Construction Manager.

The Construction Manager will be made aware of significant recurring non-conformance with the Drawings, Technical Specifications, or CQA Plan. The cause of the non-conformance will be determined and appropriate changes in procedures or specifications will be recommended. These changes will be submitted to the Construction Manager for approval. When this type of evaluation is made, the results will be documented and any revision to procedures or specifications will be approved by the Contractor and Engineer.

5.3 Photographic Documentation

Photographs will be taken and documented in order to serve as a pictorial record of work progress, problems, and mitigation activities. These records will be presented to the Construction Manager upon completion of the project. Photographic reporting data sheets, where used, will be cross-referenced with observation and testing data sheet(s), and/or construction problem and solution data sheet(s).

5.4 Design and/or Specification Changes

Design and/or specifications changes may be required during construction. In such cases, the Engineer will be notified. Design and/or specification changes will be made with the written agreement of the Engineer and will take the form of an addendum to the Drawings and Technical Specifications.

5.5 CQA Report

At the completion of the Project, the Engineer will submit to the Client a CQA report. The CQA report will acknowledge: (i) that the work has been performed in compliance with the Drawings and Technical Specifications; (ii) physical sampling and testing has been conducted at the appropriate frequencies; and (iii) that the summary document provides the necessary supporting information. At a minimum, this report will include:

- A summary report describing the CQA activities and indicating compliance with the Drawings and Technical Specifications;
- A summary of CQA/CQC testing, including failures, corrective measures, and retest results;
- Contractor and Installer personnel CV's and qualifications as necessary;
- Documentation that the geomembrane trial seams were performed in general accordance with the CQA Plan and Technical Specifications;
- Documentation that field seams were non-destructively tested using a method in general accordance with the applicable test standards;
- Documentation that non-destructive testing was monitored by the Resident Engineer;
- Records of sample locations, the name of the individual conducting the tests, and the results of tests;
- Record Drawings as provided by the Surveyor;
- Daily field reports.

The Record Drawings will include scale drawings depicting the location of the construction and details pertaining to the extent of construction (e.g., plan dimensions and appropriate elevations).

6 EARTHWORKS

6.1 Introduction

This section prescribes the CQA activities to be performed to monitor that prepared subgrade is constructed in general accordance with Drawings and Technical Specifications. The prepared subgrade construction procedures to be monitored by the Resident Engineer, if required, shall include:

- Vegetation removal;
- Subgrade preparation;
- Fine-grading; and
- Anchor trench excavation and backfill.

6.2 CQA Monitoring Activities

6.2.1 Vegetation Removal

The Resident Engineer will monitor and document that vegetation is sufficiently cleared and grubbed in areas where geosynthetics are to be placed. Vegetation removal shall be performed as described in the Technical Specification and the Drawings.

6.2.2 Grading

Construction of the liner system will require minor re-grading in certain areas. The Resident Engineer shall monitor and document that site re-grading performed meets the requirements of the Technical Specifications and the Drawings. At a minimum, the Resident Engineer shall monitor that:

- The subgrade surface is free of sharp rocks, debris, and other undesirable materials;
- The subgrade surface is smooth and uniform by visually monitoring proof rolling activities; and
- The subgrade surface meets the lines and grades shown on the Drawings.

6.2.3 Anchor Trench Construction

During construction, the Resident Engineer will monitor the anchor trench excavation and backfill methods are consistent with the requirements specified in the Technical Specifications and the Drawings. The Resident Engineer will monitor, at a minimum, that:

- The anchor trench is free of sharp rocks, debris and other undesirable materials and that particles are no larger than 150 mm in longest dimension;
- The anchor trench is constructed to the lines and grades shown on the Drawings; and
- Compaction requirements are met, through visual observations, as specified in the Technical Specifications.

6.3 Deficiencies

If a defect is discovered in the earthwork product, the Resident Engineer will immediately determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the Resident Engineer will determine the extent of the defective area by additional tests, observations, a review of records, or other means that the Resident Engineer deems appropriate. If the defect is related to adverse site conditions, such as overly wet soils or non-conforming particle sizes, the Resident Engineer will define the limits and nature of the defect.

6.3.1 Notification

After evaluating the extent and nature of a defect, the Resident Engineer will notify the Construction Manager and Contractor and schedule appropriate re-evaluation when the work deficiency is to be corrected.

6.3.2 Repairs and Re-Testing

The Contractor will correct deficiencies to the satisfaction of the Resident Engineer. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the Resident Engineer will develop and present to the Construction Manager suggested solutions for his approval.

Re-evaluations by the Resident Engineer shall continue until it is verified that defects have been corrected before any additional work is performed by the Contractor in the area of the deficiency.

7 DRAINAGE AGGREGATE

7.1 Introduction

This section prescribes the CQA activities to be performed to monitor that drainage aggregates are constructed in general accordance with Drawings and Technical Specifications. The drainage aggregates construction procedures to be monitored by the Resident Engineer include drainage aggregate placement.

7.2 Testing Activities

Aggregate testing will be performed for material qualification and material conformance. These two stages of testing are defined as follows:

- Material qualification tests are used to evaluate the conformance of a proposed aggregate source with the Technical Specifications for qualification of the source prior to construction;
- Aggregate conformance testing is used to evaluate the conformance of a particular batch of aggregate from a qualified source to the Technical Specifications prior to installation of the aggregate.

The Contractor will be responsible for submitting material qualification test results to the Construction Manager and to the Resident Engineer for review. The Laboratory will perform the conformance testing and CQC testing. Aggregate testing will be conducted in general accordance with the current versions of the South African National Standards (SANS).

7.2.1 Sample Frequency

The frequency of aggregate testing for material qualification and material conformance will conform to the minimum frequencies presented in **Table 7-1 and Table 7-2**. The actual frequency of testing required will be increased by the Resident Engineer, as necessary, if variability of materials is noted at the site, during adverse conditions, or to isolate failing areas of the construction.

Table 7-1: Test procedures for evaluating of aggregate

Test Method	Description	Test Standard
Sieve Analysis	Particle Size Distribution of Fine and Coarse Aggregates	ASTM C 136
Hydraulic Conductivity (Rigid Wall Permeater)	Permeability of Aggregates	ASTM D 2434

Table 7-2: Minimum aggregate testing frequencies for conformance testing

Test	Test Method	Test Standard
Sieve Analysis	ASTM C 136	1 per 3800 m^3
Hydraulic Conductivity	ASTM D 2434	1 per 7600 m^3

7.2.2 Sample Selection

With the exception of qualification samples, sampling locations will be selected by the Resident Engineer. Conformance samples will be obtained from borrow pits and/or stockpiles of material. The Contractor must plan the work and make aggregate available for sampling in a timely and organized manner so that the test results can be obtained before the material is installed. The Resident Engineer must document sample locations so that failing areas can be immediately isolated. The Resident Engineer will follow standard sampling procedures to obtain representative samples of the proposed aggregate materials.

7.3 CQA Monitoring Activities

7.3.1 Drainage Aggregate

The Resident Engineer will monitor and document the installation of the drainage aggregates. In general, monitoring of the installation of drainage aggregate includes the following activities:

- Reviewing documentation of the material qualification test results provided by the Contractor;
- Sampling and testing for conformance of the materials to the Technical Specifications;
- Documenting that the drainage aggregates are installed using the specified equipment and procedures;
- Documenting that the drainage aggregates are constructed to the lines and grades shown on the Drawings; and

- Monitoring that the construction activities do not cause damage to underlying geosynthetic materials.

7.4 Deficiencies

If a defect is discovered in the drainage aggregates, the Resident Engineer will evaluate the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the Resident Engineer will determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the Resident Engineer deems appropriate.

7.4.1 Notification

After evaluating the extent and nature of a defect, the Resident Engineer will notify the Construction Manager and Contractor and schedule appropriate re-tests when the work deficiency is to be corrected.

7.4.2 Repairs & Re-testing

The Contractor will correct the deficiency to the satisfaction of the Resident Engineer. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the Resident Engineer will develop and present to the Construction Manager suggested solutions for approval.

Re-tests recommended by the Resident Engineer shall continue until it is verified that the defect has been corrected before any additional work is performed by the Contractor in the area of the deficiency. The Resident Engineer will also verify that installation requirements are met and that submittals are provided.

8 GEOMEMBRANE

8.1 General

This section discusses and outlines the CQA activities to be performed for high density polyethylene (HDPE) geomembrane installation. The Resident Engineer will review the Drawings, Technical Specifications, and any approved Addenda regarding this material.

8.2 Geomembrane Material Conformance

8.2.1 Introduction

The Resident Engineer will document that the geomembrane delivered to the site meets the requirements of the Technical Specifications prior to installation. The Resident Engineer will:

- Review the manufacturer's submittals for compliance with the Technical Specifications;
- Document the delivery and proper storage of geomembrane rolls; and
- Conduct conformance testing of the rolls before the geomembrane is installed.

The following sections describe the CQA activities required to verify the conformance of geomembrane.

8.2.2 Review of Quality Control

8.2.2.1 Material Properties Certification

The Manufacturer will provide the Construction Manager and the Resident Engineer with the following:

- Property data sheets, including, at a minimum, all specified properties, measured using test methods indicated in the Technical Specifications, or equivalent;
- Sampling procedures and results of testing.

The Resident Engineer will document that:

- The property values certified by the Manufacturer meet all of the requirements of the Technical Specifications; and
- The measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.

8.2.2.2 Geomembrane Roll MQC Certification

Prior to shipment, the Manufacturer will provide the Construction Manager and the Resident Engineer with Manufacturing Quality Control (MQC) certificates for every roll of geomembrane provided. The MQC certificates will be signed by a responsible party

employed by the Geomembrane Manufacturer, such as the production manager. The MQC certificates shall include:

- Roll numbers and identification; and
- Results of MQC tests - as a minimum, results will be given for thickness, specific gravity, carbon black content, carbon black dispersion, tensile properties, and puncture resistance evaluated in general accordance with the methods indicated in the Technical Specifications or equivalent methods approved by the Construction Manager.

The Resident Engineer will document that:

- That MQC certificates have been provided at the specified frequency, and that the certificates identify the rolls related to the roll represented by the test results; and
- Review the MQC certificates and monitor that the certified roll properties meet the specifications.

8.2.3 Conformance Testing

The Resident Engineer shall obtain conformance samples (at the manufacturing facility or site) at the specified frequency and forward them to the Geosynthetics Laboratory for testing to monitor conformance to both the Technical Specifications and the list of properties certified by the Manufacturer. The test procedures will be as indicated in **Table 8-1**. Where optional procedures are noted in the test method, the requirements of the Technical Specifications will prevail.

Table 8-1: Geomembrane conformance testing requirements

Test Name	Test Method	Frequency
Specific Gravity	ASTM D 792 Method A or ASTM D 1505	18600 m^2
Thickness	ASTM D 5199	18600 m^2
Tensile Strength at Yield	ASTM D 638	18600 m^2
Tensile Strength at Break	ASTM D 638	18600 m^2
Elongation at Yield	ASTM D 638	18600 m^2
Elongation at Break	ASTM D 638	18600 m^2
Carbon Back Content	ASTM D 1603	18600 m^2
Carbon Back Dispersion	ASTM D 5596	18600 m^2
Interface Shear Strength	ASTM D 5321	1 per project

Samples will be taken across the width of the roll and will not include the first linear 75 mm of material. Unless otherwise specified, samples will be 75 mm long by the roll width. The Resident Engineer will mark the machine direction on the samples with an arrow along with the date and roll number. The required minimum sampling frequencies are provided in **Table 8-1**.

The Resident Engineer will examine results from laboratory conformance testing and will report any non-conformance to the Construction Manager and the Geosynthetic Installer. The procedures prescribed in the Technical Specifications will be followed in the event of a failing conformance test.

The number of tests shall be in accordance with the appropriate test methods listed in **Table 8-2 and 8-3** from the GRI Test Method GM13.

Table 8-2: High Density Polyethylene (HDPE) Geomembrane - Smooth

Properties	Test Method	Test							Testing Frequency
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness - mils (min. ave.) • lowest individual of 10 values	D5199	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	per roll
Density (min.)	D 1505/D 792	0.940 g/cc	0.940	0.940	0.940	0.940	0.940	0.940 g/cc	90,000 kg
Tensile Properties *(1)* (min. ave.) • yield strength • break strength • yield elongation	D 6693 Type IV	 11 kN/m 20 kN/m 12% 700%	 15 kN/m 27 kN/m 12% 700%	 18 kN/m 33 kN/m 12% 700%	 22 kN/m 40 kN/m 12% 700%	 29 kN/m 53 kN/m 12% 700%	 37 kN/m 67 kN/m 12% 700%	 44 kN/m 80 kN/m 12% 700%	9,000 kg
Tear Resistance (min. ave.)	D 1004	93 N	125 N	156 N	187 N	249 N	311 N	374 N	20,000 kg
Puncture Resistance (min. ave.)	D 4833	240 N	320 N	400 N	480 N	640 N	800 N	960 N	20,000 kg
Stress Crack Resistance *(2)*	D 5397 (App.)	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	per GRI GM-10
Carbon Black Content - %	D 4218 *(3)*	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	9,000 kg
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(5)* (a) Standard OIT — or — (b) High Pressure OIT	 D 3895 D 5885	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	90,000 kg
Oven Aging at 85°C *(5), (6)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90	D 5721 D 3895 D 5885	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	per each formulation
UV Resistance *(7)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 7238 D 3895 D 5885	 N. R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	per each formulation

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm
(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.
(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(7) The condition of the test should be 20 hr. UV cycle at 75□C followed by 4 hr. condensation at 60□C.
(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Table 8-3: High Density Polyethylene (HDPE) Geomembrane - Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness mils (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) - 10% - 15%	nom. (-5%) - 10% - 15%	nom. (-5%) - 10% - 15%	nom. (-5%) - 10% - 15%	nom. (-5%) - 10% - 15%	nom. (-5%) - 10% - 15%	nom. (-5%) - 10% - 15%	per roll
Asperity Height mils (min. ave.) *(1)*	D 7466	0.25 mm	0.25 mm	0.25 mm	0.25 mm	0.25 mm	0.25 mm	0.25 mm	every 2nd roll *(2)*
Density (min. ave.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	90,000 kg
Tensile Properties (min. ave.) *(3)* • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	11 kN/m 8 kN/m 12% 100 %	15 kN/m 10 kN/m 12% 100 %	18 kN/m 13 kN/m 12 % 100 %	22 kN/m 16 kN/m 12% 100 %	29 kN/m 21 kN/m 12% 100 %	37 kN/m 26 kN/m 12% 100 %	44 kN/m 32 kN/m 12% 100 %	9,000 kg
Tear Resistance (min. ave.)	D 1004	93 N	125 N	156 N	187 N	249 N	311 N	374 N	20,000 kg
Puncture Resistance (min. ave.)	D 4833	200N	267 N	333 N	400 N	534 N	667 N	800 N	20,000 kg
Stress Crack Resistance *(4)*	D 5397 (App.)	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	per GRI GM10
Carbon Black Content (range)	D 4218 *(5)*	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	9,000 kg
Carbon Black Dispersion	D 5596	note *(6)*	note *(6)*	note *(6)*	note *(6)*	note *(6)*	note *(6)*	note *(6)*	20,000 kg

Oxidative Induction Time (OIT) (min. ave.) *(7)* (a) Standard OIT — or — (b) High Pressure OIT	 D 3895 D 5885	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	90,000 kg
Oven Aging at 85°C *(7), (8)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 55% 80%	 55% 80%	55 % 80 %	 55% 80%	 55% 80%	 55% 80%	 55% 80%	per each formulation
UV Resistance *(9)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(11)*	D 7238 D 3895 D 5885	N.R. *(10)* 50%	N.R. *(10)* 50%	N.R. *(10)* 50 %	N.R. *(10)* 50%	N.R. *(10)* 50%	N.R. *(10)* 50%	N.R. *(10)* 50%	per each formulation

(1) Of 10 readings; 8 out of 10 must be □ 0.18 mm, and lowest individual reading must be □ 0.13 mm; also see Note 6.
(2) Alternate the measurement side for double sided textured sheet
(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm
(4) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
(5) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.
(6) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3
(7) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(8) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(9) The condition of the test should be 20 hr. UV cycle at 75□C followed by 4 hr. condensation at 60□C.
(10) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(11) UV resistance is based on percent retained value regardless of the original HP-OIT value.

8.2.4 Cuspated Drainage Sheet Specifications

The following table, **Table 8-4**, indicated the specifications for the Cuspated Drainage Sheet, Leakdrain Super S6U:

Table 8-4: Cuspated Drainage Sheet, Leakdrain Super S6U Specifications

Physical Properties:		
Colour	Black	
Type	Single Cuspated (Dimpled)	
Material	HDPE (High Density Polyethylene)	
Mass per unit area	800 g/m	EN ISO 9864
Equivalent sheet thickness	0.85 mm	
Dimple Height	6.65 mm	EN ISO 9863-1
Dimple Centres	8.0 mm	
Height of Flow path	5.5 mm	
Surface contact - top	10%	
Surface contact - bottom	60%	
Performance:		
Carbon Black Content	0.8 – 2.5%	ASTM D1603:94
Tensile Strength (MD/CD)	8 / 5.5 kN/m	EN ISO 10319
Elongation (MD/CD)	50 / 35%	EN ISO 10319
CBR puncture resistance	1000 N	EN ISO 12236
Compressive strength	500 kPa	ASTM D1621 (mod)
Life expectancy	120 Years (manufacturers declaration)	
Working Temperature	-20 to 80 °C	
Chemical resistance	Excellent resistance to all common chemicals	
Resistance to microbes	No significant effect	
Compatibility with geomembranes	Fully compatible. All components compatible with potable water	

Performance:		
Slope Stability	Data Available on request	
Health, safety, environment	INERT. No known health hazard. No precautions necessary.	
Roll Dimensions		
Roll Width & Length	2.2 x 100 mm	
Roll weight and diameter	180 kg, 0.83 m with 100mm ID tube	
Overlap & Wastage allowance	2%, 1-5% depending on the shape of the area to be covered	

Notes:
1. The values given are indicative and correspond to nominal results obtained in the manufacturer's laboratories and testing institutes.
2. Flow values in excess of 200kPa are outside the scope of EN ISO 12958.
3. The product will continue to perform well under short term loading in excess of 500 kPa. Please request details.
4. Unless otherwise stated allowable tolerances are ±10% of the typical value. The tolerance on roll length is 1.5% and on roll width is 1.0%.

8.3 Delivery

8.3.1 Transportation & Handling

The Resident Engineer will document that the transportation and handling does not pose a risk of damage to the geomembrane.

Upon delivery of the rolls of geomembrane, the Resident Engineer will document that the rolls are unloaded and stored on site as required by the Technical Specifications. Damage caused by unloading will be documented by the Resident Engineer and the damaged material shall not be installed.

8.3.2 Storage

The Geosynthetic Installer will be responsible for the storage of the geomembrane on site. The Contractor will provide storage space in a location (or several locations) such that on-site transportation and handling are optimized, if possible, to limit potential damage.

The Resident Engineer will document that storage of the geomembrane provides adequate protection against sources of damage.

8.4 Geomembrane Installation

8.4.1 Introduction

The Resident Engineer will document that the geomembrane installation is carried out in general accordance with the Drawings, Technical Specifications, and Manufacturer's recommendations.

8.4.2 Earthworks

8.4.2.1 Surface Preparation

The Resident Engineer will document that:

- The prepared subgrade meets the requirements of the Technical Specifications and has been approved; and
- Placement of the overlying materials does not damage, create large wrinkles, or induce excessive tensile stress in any underlying geosynthetic materials.

The Geosynthetic Installer will certify in writing that the surface on which the geomembrane will be installed is acceptable. The Certificate of Acceptance, as presented in the Technical Specifications, will be signed by the Geosynthetic Installer and given to the Resident Engineer prior to commencement of geomembrane installation in the area under consideration.

After the subgrade has been accepted by the Geosynthetic Installer, it will be the Geosynthetic Installer's responsibility to indicate to the Construction Manager any change in the subgrade soil condition that may require repair work. If the Resident Engineer concurs with the Geosynthetic Installer, then the Resident Engineer shall monitor and document that the subgrade soil is repaired before geosynthetic installation begins.

At any time before and during the geomembrane installation, the Resident Engineer will indicate to the Construction Manager locations that may not provide adequate support to the geomembrane.

8.4.2.2 Geosynthetic Termination

The Resident Engineer will document that the geosynthetic terminations (Anchor Trench) have been constructed in general accordance with the Drawings. Backfilling above the terminations will be conducted in general accordance with the Technical Specifications.

8.4.3 Geomembrane Placement

8.4.3.1 Panel Identification

A field panel is the unit area of geomembrane which is to be seamed in the field, i.e., a field panel is a roll or a portion of roll cut in the field. It will be the responsibility of the Resident Engineer to document that each field panel is given an "identification code" (number or letter-number) consistent with the Panel Layout Drawing. This identification code will be agreed upon by the Construction Manager, Geosynthetic Installer and Resident Engineer. This field panel identification code will be as simple and logical as possible. Roll numbers established in the manufacturing plant must be traceable to the field panel identification code.

The Resident Engineer will establish documentation showing correspondence between roll numbers, and field panel identification codes. The field panel identification code will be used for all CQA records.

8.4.3.2 Field Panel Placement

Location

The Resident Engineer will document that field panels are installed at the location indicated in the Geosynthetic Installer's Panel Layout Drawing, as approved or modified by the Construction Manager.

Installation Schedule

Field panels may be installed using one of the following schedules:

- All field panels are placed prior to field seaming in order to protect the subgrade from erosion by rain;
- Field panels are placed one at a time and each field panel is seamed after its placement (in order to minimize the number of unseamed field panels exposed to wind); and
- Any combination of the above.

If a decision is reached to place all field panels prior to field seaming, it is usually beneficial to begin at the high point area and proceed toward the low point with "shingle" overlaps to facilitate drainage in the event of precipitation. It is also usually beneficial to proceed in the direction of prevailing winds. Accordingly, an early decision regarding installation scheduling should be made if and only if weather conditions can be predicted with reasonable certainty. Otherwise, scheduling decisions must be made during installation, in general accordance with varying conditions. In any event, the Geosynthetic Installer is fully responsible for the decision made regarding placement procedures.

The Resident Engineer will evaluate every change in the schedule proposed by the Geosynthetic Installer and advise the Construction Manager on the acceptability of that change. The Resident Engineer will document that the condition of the subgrade soil has not changed detrimentally during installation.

The Resident Engineer will record the identification code, location, and date of installation of each field panel.

Weather Conditions

Geomembrane placement will not proceed unless otherwise authorized when the ambient temperature is below 5°C or above 50°C. In addition, wind speeds and direction will be monitored for potential impact to geosynthetic installation. Geomembrane placement will not be performed during any precipitation, in the presence of excessive moisture (e.g., fog, dew), and/or in an area of ponded water.

The Resident Engineer will document that the above conditions are fulfilled. Additionally, the Resident Engineer will document that the subgrade soil has not been damaged by weather conditions. The Geosynthetics Installer will inform the Construction Manager if the above conditions are not fulfilled.

Method of Placement

The Resident Engineer will document the following:

- Equipment used does not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons or other means;
- The surface underlying the geomembrane has not deteriorated since previous acceptance, and is still acceptable immediately prior to geomembrane placement;
- Geosynthetic elements immediately underlying the geomembrane are clean and free of debris;
- Personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane;
- The method used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting soil;
- The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels); and
- Adequate temporary loading and/or anchoring (e.g., sand bags, tires), not likely to damage the geomembrane, has been placed to prevent uplift by wind (in case of high winds, continuous loading, e.g., by adjacent sand bags, is recommended along edges of panels to minimize risk of wind flow under the panels).

The Resident Engineer will inform the Construction Manager if the above conditions are not fulfilled.

Damaged panels or portions of damaged panels that have been rejected will be marked and their removal from the work area recorded by the Resident Engineer. Repairs will be made in general accordance with procedures described in Section 8.4.5.

8.4.4 Field Seaming

This section details CQA procedures to document that seams are properly constructed and tested in general accordance with the Manufacturer's specifications and industry standards.

8.4.4.1 Requirements of Personnel

All personnel performing seaming operations will be qualified by experience or by successfully passing seaming tests, as outlined in the Technical Specifications. The most experienced seamer, the "master seamer", will provide direct supervision over less experienced seamers.

The Geosynthetic Installer will provide the Construction Manager and the Resident Engineer with a list of proposed seaming personnel and their experience records. These documents will be reviewed by the Construction Manager and the Resident Engineer.

8.4.4.2 Seaming Equipment & Products

Approved processes for field seaming are fillet extrusion welding and double-track fusion welding.

Fillet Extrusion Process

The fillet extrusion-welding apparatus will be equipped with gauges giving the temperature in the apparatus.

The Geosynthetic Installer will provide documentation regarding the extrusion welding rod to the Resident Engineer, and will certify that the extrusion welding rod is compatible with the Technical Specification, and in any event, is comprised of the same resin as the geomembrane.

The Resident Engineer will log apparatus temperatures, ambient temperatures, and geomembrane surface temperatures at appropriate intervals.

The Resident Engineer will document that:

- The Geosynthetic Installer maintains, on site, the number of spare operable seaming apparatus decided at the Pre-construction Meeting;
- Equipment used for seaming is not likely to damage the geomembrane;
- The extruder is purged prior to beginning a seam until all heat- degraded extrudate has been removed from the barrel;
- The electric generator is placed on a smooth base such that no damage occurs to the geomembrane;
- A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage; and
- The geomembrane is protected from damage in heavily trafficked areas.

Fusion Process

The fusion-welding apparatus must be automated vehicular-mounted devices. The fusion-welding apparatus will be equipped with gauges giving the applicable temperatures and pressures.

The Resident Engineer will log ambient, seaming apparatus and geomembrane surface temperatures as well as seaming apparatus speeds.

The Resident Engineer will also document that:

- The Geosynthetic Installer maintains on-site the number of spare operable seaming apparatus decided at the Pre-construction Meeting;
- Equipment used for seaming is not likely to damage the geomembrane;
- For cross seams, the edge of the cross seam is ground to a smooth incline (top and bottom) prior to welding;
- The electric generator is placed on a smooth cushioning base such that no damage occurs to the geomembrane from ground pressure or fuel leaks;
- A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage; and
- The geomembrane is protected from damage in heavily trafficked areas.

8.4.4.3 Seam Preparation

The Resident Engineer will document that:

- Prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris, and foreign material; and
- Seams are aligned with the fewest possible number of wrinkles and “fishmouths.”

8.4.4.4 Weather Conditions for Seaming

The normally required weather conditions for seaming are as follows unless authorized in writing by the Engineer:

- Seaming will only be approved between ambient temperatures of 5°C or above 50°C.

If the Geosynthetic Installer wishes to use methods that may allow seaming at ambient temperatures below 5°C or above 50°C, the Geosynthetic Installer will demonstrate and certify that such methods produce seams which are entirely equivalent to seams produced within acceptable temperature, and that the overall quality of the geomembrane is not adversely affected.

The Resident Engineer will document that these seaming conditions are fulfilled and will advise the Geosynthetics Installer if they are not.

8.4.4.5 Overlapping & Temporary Bonding

The Resident Engineer will document that:

- The panels of geomembrane have a finished overlap of a minimum of 75 mm for both extrusion and fusion welding;
- No solvent or adhesive bonding materials are used; and
- The procedures utilized to temporarily bond adjacent panels together do not damage the geomembrane.

The Resident Engineer will log appropriate temperatures and conditions, and will log and report non-compliances to the Construction Manager.

8.4.4.6 Trial seams

Trial seams shall be prepared with the procedures and dimensions as indicated in the Technical Specifications. The Resident Engineer will observe trial seam procedures and will document the results of trial seams on trial seam logs. Each trial seam samples will be assigned a number. The Resident Engineer will log the date, time, machine temperature(s), seaming unit identification, name of the seamer, and pass or fail description for each trial seam sample tested.

Separate trial seaming logs shall be maintained for fusion welded and extrusion welded trial seams.

8.4.4.7 General Seaming Procedures

Unless otherwise specified, the general production seaming procedure used by the Geosynthetic Installer will be as follows:

- Fusion-welded seams are continuous, commencing at one end to the seam and ending at the opposite end.
- Cleaning, overlap, and shingling requirements shall be maintained.
- If seaming operations are carried out at night, adequate illumination will be provided at the Geosynthetic Installer's expense.
- Seaming will extend to the outside edge of panels to be placed in the anchor trench.

The Resident Engineer shall document geomembrane seaming operations on seaming logs. Seaming logs shall include, at a minimum:

Seam identifications (typically associated with panels being joined);

- Seam starting time and date;
- Seam ending time and date;
- Seam length;
- Identification of person performing seam; and
- Identification of seaming equipment.

Separate logs shall be maintained for fusion and extrusion welded seams. In addition, Resident Engineer shall monitor during seaming that:

- Fusion-welded seams are continuous, commencing at one end of the seam and ending at the opposite end.
- Cleaning, overlap, and shingling requirements are maintained.

8.4.4.8 Non-destructive Seam Continuity Testing

Concept

The Geosynthetic Installer will non-destructively test field seams over their length using a vacuum test unit, air pressure test (for double fusion seams only), or other method approved by the Construction Manager. The purpose of non-destructive tests is to check the continuity of seams. It does not provide information on seam strength. Continuity testing will be carried out as the seaming work progresses, not at the completion of field seaming.

The Resident Engineer will:

- Observe continuity testing;
- Record location, date, name of person conducting the test, and the results of tests; and
- Inform the Geosynthetic Installer of required repairs.

The Geosynthetic Installer will complete any required repairs in general accordance with Section 8.4.5.

The Resident Engineer will:

- Observe the repair and re-testing of the repair;
- Mark on the geomembrane that the repair has been made; and
- Document the results.

The following procedures will apply to locations where seams cannot be non-destructively tested:

All such seams will be cap-stripped with the same geomembrane.

- If the seam is accessible to testing equipment prior to final installation, the seam will be non-destructively tested prior to final installation.

- If the seam cannot be tested prior to final installation, the seaming and cap-stripping operations will be observed by the Resident Engineer and Geosynthetic Installer for uniformity and completeness.

The seam number, date of observation, name of tester, and outcome of the test or observation will be recorded by the Resident Engineer.

Vacuum Testing

Vacuum testing shall be performed utilizing the equipment and procedures specified in the Technical Specifications. The Resident Engineer shall observe the vacuum testing procedures and document that they are performed in accordance with the Technical Specifications. The result of vacuum testing shall be recorded on the CQA seaming logs. Results shall include, at a minimum, the personnel performing the vacuum test and the result of the test (pass or fail), and the test date. Seams failing the vacuum test shall be repaired in accordance with the procedures listed in the Technical Specifications. The Resident Engineer shall document seam repairs in the seaming logs.

Air Pressure Testing

Air channel pressure testing shall be performed on double-track seams created with a fusion welding device, utilizing the equipment and procedures specified in the Technical Specifications. The Resident Engineer shall observe the vacuum testing procedures and document that they are performed in accordance with the Technical Specifications. The result of air channel pressure testing shall be recorded on the CQA seaming logs. Results shall include, at a minimum, personnel performing the air pressure test, the starting air pressure and time, the final air pressure and time, the drop in psi during the test, and the result of the test (pass or fail). Seams failing the air pressure test shall be repaired in accordance with the procedures listed in the Technical Specifications. The Resident Engineer shall document seam repairs in the seaming logs.

8.4.4.9 Destructive Testing

Concept

Destructive seam testing will be performed on site and at an independent laboratory in general accordance with the Drawings and the Technical Specifications. Destructive seam tests will be performed at selected locations. The purpose of these tests is to evaluate seam

strength. Seam strength testing will be done as the seaming work progresses, not at the completion of all field seaming.

Location and Frequency

The Resident Engineer will select locations where seam samples will be cut out for laboratory testing. Those locations will be established as follows.

- The frequency of geomembrane seam testing is a minimum of one destructive sample per 150 m of weld. The minimum frequency is to be evaluated as an average taken throughout the entire facility.
- A minimum of one test per seaming machine over the duration of the project.
- Additional test locations may be selected during seaming at the Resident Engineer's discretion. Selection of such locations may be prompted by suspicion of excess crystallinity, contamination, offset welds, or any other potential cause of imperfect welding.

The Geosynthetic Installer will not be informed in advance of the locations where the seam samples will be taken.

Sampling Procedure

Samples will be marked by the Resident Engineer following the procedures listed in the Technical Specifications. Preliminary samples will be taken from either side of the marked sample and tested before obtaining the full sample per the requirements of the Technical Specifications. Samples shall be obtained by the Geosynthetic Installer. Samples shall be obtained as the seaming progresses in order to have laboratory test results before the geomembrane is covered by another material. The Resident Engineer will:

- Observe sample cutting and monitor that corners are rounded;
- Assign a number to each sample, and mark it accordingly;
- Record sample location on the Panel Layout Drawing; and
- Record reason for taking the sample at this location (e.g., statistical routine, suspicious feature of the geomembrane).

Holes in the geomembrane resulting from destructive seam sampling will be immediately repaired in general accordance with repair procedures described in Section 8.4.5. The

continuity of the new seams in the repaired area will be tested in general accordance with Section 8.4.4.8.

Size and Distribution of Samples

The destructive sample will be 0.3 m wide by 1.1 m long with the seam centred lengthwise. The sample will be cut into three parts and distributed as follows:

- One portion, measuring 30 cm × 30 cm, to the Geosynthetic Installer for field testing;
- One portion, measuring 30 cm × 45 cm, for Laboratory testing; and
- One portion, measuring 30 cm × 30 cm, to the Construction Manager for archive storage.

Final evaluation of the destructive sample sizes and distribution will be made at the Pre-Construction Meeting.

Field Testing

Field testing will be performed by the Geosynthetic Installer using a gauged tension-meter. Prior to field testing the Geosynthetic Installer shall submit a calibration certificate for gauge tension-meter to the Engineer for review. Calibration must have been performed within one year of use on the current project. The destructive sample shall be tested according to the requirements of the Technical Specifications. The specimens shall not fail in the seam and shall meet the strength requirements outlined in the Technical Specifications. If any field test specimen fails, then the procedures outlined in Procedures for Destructive Test Failures of this section will be followed.

The Resident Engineer will witness field tests and mark samples and portions with their number. The Resident Engineer will also document the date and time, ambient temperature, number of seaming unit, name of seamer, welding apparatus temperatures and pressures, and pass or fail description.

CQA Laboratory Testing

Destructive test samples will be packaged under the responsibility of the Resident Engineer in a manner that will not damage the test sample. The Construction Manager will be responsible for storing the archive samples. This procedure will be outlined at the Pre-

construction Meeting. Samples will be tested by a Laboratory. The Laboratory will be selected by the Resident Engineer with the concurrence of the Engineer.

Testing will include “Bonded Seam Strength” and “Peel Adhesion.” The minimum acceptable values to be obtained in these tests are given in the Technical Specifications. At least five specimens will be tested for each test method. Specimens will be selected alternately, by test, from the samples (i.e., peel, shear, peel, shear...). A passing test will meet the minimum required values in at least four out of five specimens.

The Laboratory will provide test results no more than 24 hours after they receive the samples. The Resident Engineer will review laboratory test results as soon as they become available, and make appropriate recommendations to the Construction Manager.

Geosynthetic Installer’s Laboratory Testing

The Geosynthetic Installer’s laboratory test results will be presented to the Construction Manager and the Resident Engineer for comments.

Procedures for Destructive Test Failure

The following procedures will apply whenever a sample fails a destructive test, whether that test conducted by the Laboratory, the Geosynthetic Installer’s laboratory, or by gauged tension-meter in the field. The Geosynthetic Installer has two options:

- The Geosynthetic Installer can reconstruct the seam between two passed test locations.
- The Geosynthetic Installer can trace the welding path to an intermediate location at 3 m minimum from the point of the failed test in each direction and take a small sample for an additional field test at each location. If these additional samples pass the test, then full laboratory samples are taken. If these laboratory samples pass the tests, then the seam is reconstructed between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed.

Acceptable seams must be bounded by two locations from which samples passing laboratory destructive tests have been taken. Repairs will be made in general accordance with Section 8.4.5.

The Resident Engineer will document actions taken in conjunction with destructive test failures.

8.4.5 Defects & Repairs

This section prescribes CQA activities to document that defects, tears, rips, punctures, damage, or failing seams shall be repaired.

8.4.5.1 Identification

Seams and non-seam areas of the geomembrane shall be examined by the Resident Engineer for identification of defects, holes, blisters, undispersed raw materials and signs of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane shall be clean at the time of examination.

8.4.5.2 Evaluation

Potentially flawed locations, both in seam and non-seam areas, shall be non-destructively tested using the methods described in Section 8.4.4.8 as appropriate. Each location that fails the non-destructive testing will be marked by the Resident Engineer and repaired by the Geosynthetic Installer. Work will not proceed with any materials that will cover locations which have been repaired until laboratory test results with passing values are available.

8.4.5.3 Repair Procedures

Portions of the geomembrane exhibiting a flaw, or failing a destructive or non-destructive test, will be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure will be at the discretion of the Engineer with input from the Construction Manager and Geosynthetic Installer. The procedures available include:

- Patching, used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter;
- Grinding and re-welding, used to repair small sections of extruded seams;
- Spot welding or seaming, used to repair small tears, pinholes, or other minor, localized flaws;
- Capping, used to repair large lengths of failed seams;

- Removing bad seam and replacing with a strip of new material welded into place (used with large lengths of fusion seams).

In addition, the following provisions will be satisfied:

- Surfaces of the geomembrane which are to be repaired will be abraded no more than 20 minutes prior to the repair;
- Surfaces must be clean and dry at the time of the repair;
- All seaming equipment used in repairing procedures must be approved;
- The repair procedures, materials, and techniques will be approved in advance by the Resident Engineer with input from the Engineer and Geosynthetic Installer;
- Patches or caps will extend at least 150 mm beyond the edge of the defect, and all corners of patches will be rounded with a radius of at least 75 mm;
- Cuts and holes to be patched shall have rounded corners; and
- The geomembrane below large caps should be appropriately cut to avoid water or gas collection between the two sheets.

8.4.5.4 Verification Repairs

The Resident Engineer shall monitor and document repairs. Records of repairs shall be maintained on repair logs. Repair logs shall include, at a minimum:

- Panel containing repair and approximate location on panel;
- Approximate dimensions of repair;
- Repair type, i.e. fusion weld or extrusion weld;
- Date of repair;
- Seamer making the repair; and
- Results of repair non-destructive testing (pass or fail).

Each repair will be non-destructively tested using the methods described herein, as appropriate. Repairs that pass the non-destructive test will be taken as an indication of an adequate repair. Large caps may be of sufficient extent to require destructive test sampling, per the requirements of the Technical Specifications. Failed tests shall be redone and re-tested until passing test results are observed.

8.4.5.5 Large Wrinkles

When seaming of the geomembrane is completed (or when seaming of a large area of the geomembrane liner is completed) and prior to placing overlying materials, the Resident Engineer will observe the geomembrane wrinkles. The Resident Engineer will indicate to the Geosynthetic Installer which wrinkles should be cut and re-seamed. The seam thus produced will be tested like any other seam.

8.4.6 Lining System Acceptance

The Geosynthetic Installer and the Manufacturer(s) will retain all responsibility for the geosynthetic materials in the liner system until acceptance by the Construction Manager.

The geosynthetic liner system will be accepted by the Construction Manager when:

- The installation is finished;
- Verification of the adequacy of all seams and repairs, including associated testing, is complete;
- All documentation of installation is completed including the Resident Engineer acceptance report and appropriate warranties; and
- CQA report, including “as built” drawing(s), sealed by a registered professional engineer has been received by the Construction Manager.

The Resident Engineer will document that installation preceded in general accordance with the Technical Specifications for the project.

9 GEOTEXTILE

9.1 Introduction

This section of the CQA Plan outlines the CQA activities to be performed for the geotextile installation.

9.2 Manufacturing

The Manufacturer will provide the Construction Manager with a list of guaranteed “minimum average roll value” properties (defined as the mean less two standard deviations), for each type of geotextile to be delivered. The Manufacturer will also provide the Construction Manager with a written quality control certification signed by a responsible party

employed by the Manufacturer that the materials actually delivered have property "minimum average roll values" which meet or exceed all property values guaranteed for that type of geotextile.

The quality control certificates will include:

- Roll identification numbers; and
- Results of MQC testing.

The Manufacturer will provide, as a minimum, test results for the following:

- Mass per unit area;
- Grab strength;
- Tear strength;
- Puncture strength;
- Permittivity; and
- Apparent opening size.

MQC tests shall be performed at the frequency listed in the Technical Specifications. CQA tests on geotextile produced for the project shall be performed according to the test methods specified and frequencies presented in Table 9-1.

Table 9-1: Geotextile conformance testing requirements

Test Name	Test Method	Min. Frequency
Mass per Unit Area	ASTM D 5261	2.5 ha
Grab Strength	ASTM D 4632	2.5 ha
Puncture Resistance	ASTM D 4833	2.5 ha
Permittivity	ASTM D 4491	2.5 ha
Apparent Opening Size	ASTM D 4751	2.5 ha

The Resident Engineer will examine Manufacturer certifications to evaluate that the property values listed on the certifications meet or exceed those specified for the particular type of geotextile and the measurements of properties by the Manufacturer are properly documented, test methods acceptable and the certificates have been provided at the specified frequency properly identifying the rolls related to testing. Deviations will be reported to the Construction Manager.

9.3 Labelling

The Manufacturer will identify all rolls of geotextile with the following:

- Manufacturer's name;
- Product identification;
- Lot number;
- Roll number; and
- Roll dimensions.

The Resident Engineer will examine rolls upon delivery and deviation from the above requirements will be reported to the Construction Manager.

9.4 Shipment & Storage

During shipment and storage, the geotextile will be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions. To that effect, geotextile rolls will be shipped and stored in relatively opaque and watertight wrappings.

Protective wrappings will be removed less than one hour prior to unrolling the geotextile. After the wrapping has been removed, a geotextile will not be exposed to sunlight for more than 15 days, except for UV protection geotextile, unless otherwise specified and guaranteed by the Manufacturer.

The Resident Engineer will observe rolls upon delivery at the site and deviation from the above requirements will be reported to the Geosynthetic Installer.

9.5 Conformance Testing

9.5.1 Tests

Upon delivery of the rolls of geotextiles, the Resident Engineer will obtain conformance samples and forward to the Geosynthetics Laboratory for testing to evaluate conformance to Technical Specifications. Required test and testing frequency for the geotextiles are presented in Table 9-1. These conformance tests will be performed in general accordance with the test methods specified in the Technical Specifications and will be documented by the Resident Engineer.

9.5.2 Sampling Procedures

Samples will be taken across the width of the roll and will not include the first three feet. Unless otherwise specified, samples will be 1 m long by the roll width. The Resident engineer will mark the machine direction on the samples with an arrow.

Unless otherwise specified, samples will be taken at a rate as indicated in Table 9-1 for geotextiles.

9.5.3 Test Results

The Resident Engineer will examine results from laboratory conformance testing and will report non-conformance with the Technical Specifications and this CQA Plan to the Construction Manager.

9.5.4 Conformance Sampling Failure

The following procedure will apply whenever a sample fails a conformance test that is conducted by the Laboratory:

- The Manufacturer will replace every roll of geotextile that is in non-conformance with the Technical Specifications with a roll(s) that meets Technical Specifications; or
- The Geosynthetic Installer will remove conformance samples for testing by the Laboratory from the closest numerical rolls on both sides of the failed roll. These two samples must conform to the Technical Specifications. If either of these samples fails, the numerically closest rolls on the side of the failed sample will be tested by the Laboratory. These samples must conform to the Technical Specifications. If any of these samples fail, every roll of geotextile on site from this lot and every subsequently delivered roll that is from the same lot must be tested by the Laboratory for conformance to the Technical Specifications. This additional conformance testing will be at the expense of the Manufacturer.

The Resident Engineer will document actions taken in conjunction with conformance test failures.

9.6 Handling & Placement

The Geosynthetic Installer will handle all geotextiles in such a manner as to document they are not damaged in any way, and the following will be complied with:

- In the presence of wind, all geotextiles will be weighted with sandbags or the equivalent. Such sandbags will be installed during placement and will remain until replaced with earth cover material.
- Geotextiles will be cut using an approved geotextile cutter only. If in place, special care must be taken to protect other materials from damage, which could be caused by the cutting of the geotextiles.
- The Geosynthetic Installer will take all necessary precautions to prevent damage to underlying layers during placement of the geotextile.
- During placement of geotextiles, care will be taken not to entrap in the geotextile stones, excessive dust, or moisture that could damage the geotextile, generate clogging of drains or filters, or hamper subsequent seaming.
- A visual examination of the geotextile will be carried out over the entire surface, after installation, to document that no potentially harmful foreign objects, such as needles, are present.

The Resident Engineer will note non-compliance and report it to the Construction Manager.

9.7 Seams & Overlaps

All geotextiles will be continuously sewn in accordance with Technical Specifications. Geotextiles will be overlapped 300 mm prior to seaming. No horizontal seams will be allowed on side slopes (i.e. seams will be along, not across, the slope), except as part of a patch.

Sewing will be done using polymeric thread with chemical and ultraviolet resistance properties equal to or exceeding those of the geotextile.

9.8 Repair

Holes or tears in the geotextile will be repaired as follows:

- On slopes: A patch made from the same geotextile will be double seamed into place. Should a tear exceed 10 percent of the width of the roll, that roll will be removed from the slope and replaced.
- Non-slopes: A patch made from the same geotextile will be spot- seamed in place with a minimum of 0.60 m overlap in all directions.

Care will be taken to remove any soil or other material that may have penetrated the torn geotextile.

The Resident Engineer will observe any repair, note any non-compliance with the above requirements and report them to the Construction Manager.

9.9 Placement of Soil or Aggregate Materials

The Contractor will place all soil or aggregate materials located on top of a geotextile, in such a manner as to document:

- No damage of the geotextile;
- Minimal slippage of the geotextile on underlying layers; and
- No excess tensile stresses in the geotextile.

Non-compliance will be noted by the Resident Engineer and reported to the Construction Manager.

ZITHOLELE CONSULTING (PTY) LTD

J Heera
Civil Engineering Technologist

N Rajasakran PrEng
Lead Engineer