Prepared for
Eskom Holdings Limited

Prepared by
Knight Piésold Ltd.
4 De la Rey Road
Rivonia
2128

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MATIMBA POWER STATION: ASH DUMP
PROJECT QCP MANUAL

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Knight Piésold CONSULTING

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1.0 GENERAL NOTE

This Construction Quality Assurance/Quality Control (CQA/QC) Manual is provided as a guide to field and laboratory personnel conducting field inspection and testing associated with construction of Matimba Power Station Ash Dump and associated works for Matimba Project. It is intended to aid field personnel in all aspects of inspection, data collection, reporting, and control onsite. CQA/QC procedures for inspecting and reporting are necessary to ensure that all work is performed to professional standards, in accordance with recognized procedures, and that specific requirements for regulatory submissions are met and that the intent of the design is met.

Standard procedures will be used for all activities and, in general, they will be those adopted by recognized organizations. These recognized organizations include the South African National Standards (SANS), American Society for Testing and Materials (ASTM and the American Association of State Highway and Transportation Officials (AASHTO),

The Design Report, Technical Specifications, and Drawings issued for construction of the Matimba Power Station Ash Dump constitute an integrated set of documents defining design intent and construction approach. This manual is intended to be read in conjunction with these documents to provide a complete understanding of the project. This manual has been prepared with the intent that site personnel will be sufficiently trained and experienced to be able to implement not only the specific criteria noted herein but to recognize conditions that differ from those described in the design documents and take a proactive role in seeing that the intent of the design documents is met. The testing described herein is the minimum required, and it is intended that site personnel will take a proactive role in performing additional testing as needed to see that construction is accomplished to meet the intent of the design.

2.0 ORGANIZATION AND RESPONSIBILITIES

For the purposes of the CQA/QC Manual, the definitions given in the Contract and the following definitions shall apply.

The **Owner** is defined as Eskom Holdings or any of its authorized representatives. “Engineer” is defined as appointed Consultant or any of its authorized representatives.

“Contractor” is defined as the party that has executed a contract agreement with Eskom Holdings. for completing the Work of the project as described in the tender and as required by Specifications and any Modifications and as detailed on the Drawings.

“Sub-Contractor” is defined as the party that has executed a contract with the Contractor for completing any other specialized work that the Contractor deems specialized. Specifications and any Modifications and as detailed on the Drawings and the installation of Geotechnical Instrumentation.

“Drawings” are defined as the construction drawings at Revision 0 or above that have been issued for the Matimba Power Station Ash Dump Construction.

“Modifications” are defined as changes made to any Specifications or the Drawings that are approved by the Engineer and Eskom Holdings. in writing, after the Specifications and Drawings have been issued for construction. These also refer to changes to design elements in the field to account for unforeseen conditions.

“Work” is defined as the entire completed construction as shown on the Drawings and as described in the Specifications and Project Contract.

“Manufacturers” is defined as the party(ies) which manufacture(s) material that will be required to complete construction of the project as detailed in Drawings and Specification. This may be more than one company.

“Site” is defined as the Matimba Power Station Ash Dump working area owned by Eskom Holdings. and where the Works are to be completed as described in the Specifications and detailed on the Drawings.

“Plant” is defined as all equipment, materials, supplies, temporary accommodations, temporary offices, or other things brought onto the Site by the Main Contractor and Sub-contractors to carry out the Work, but this shall not include any equipment, materials, supplies, or other things incorporated into the permanent portions of the Work.

“**Construction Quality Assurance**” is defined as the responsibility of technical direction of the Work to ensure conformity of the Work to the designed intent. Construction Quality Assurance (CQA) is the responsibility of the Contractor and must be carried out to meet the requirements of the CQA/QC plan or as specified by the Engineer and Eskom.

“**Engineers Representative**” is defined as a Person who is independent from the Contractor and is responsible for observing, signing off inspections, completed work and keeping record of quality assurance documents from the Contractor during the construction period. This person can be site personnel representing the Engineer or the Owner. Activities to be assured include earthwork including roadwork, pipework and concrete construction but are not limited to the mentioned list.

"**Quality Control"** is defined as the testing and inspection necessary to ensure that the Work is constructed in compliance with the Specifications of the project. Quality Control observation and/or testing for the project are the responsibility of the Contractor. This will include all components of the project that need to be tested or observed. Quality Control testing must be carried out to meet the requirements of the CQA/QC plan or as specified by Eskom and the Engineer.

"Installer" is defined as the party that has executed a contract agreement with the Contractor for the installation of works described in the Project Specifications and as detailed on the Drawings. The Installer shall at all times be responsible for CQA/QC on its portion of work. This shall not exclude the Contractor from taking overall responsibility of the quality control and assurance of the works as indicated above. The Engineer and/or Eskom shall have access to the records of the Installer to check if records are kept and updated regularly. The Engineer will still be required to sign off at different stages as work is carried out. Should the Installer cover or bury any item without the Engineer's written instruction to continue, the Installer shall open or expose the area for the Engineer to perform his duties as detailed in the project Specifications. Under no circumstances will any Installer be excused from maintaining project Specifications and the Contractor shall make sure that the Installer is notified of such requirements in writing. Failure to do so will be taken as breach of contract.

"Units." In general, the Specifications and the Drawings refer to metric units for sieve sizes, pipe diameters, geotextile thickness, weights, etc.

3.0 STANDARD PROCEDURES

Each inspection and as-built documentation item are referenced as it is in the Specifications. The Specifications and Drawings are intended to transmit the design intent to the construction professionals, inspectors, and technicians in the field. The inspection and as-built items defined herein are minimum requirements.

3.1 SAMPLING

3.1.1 SAMPLE IDENTIFICATION

The following information is to be recorded when taking samples:

- Project number
- Project name
- Material type
- Sample number
- Sample location
- Sample elevation or depth
- Sampler name
- Name of person obtaining sample
- Date

At the time the sample is taken, the sampler records all relevant information in a field book or the project records.

3.1.2 SAMPLE PROCEDURE

The following general procedure will be used, modified as appropriate for the sample type and purpose:

- Collect samples in accordance with the Earthwork, Concrete and Roads Specifications and any other Specifications that may require samples to be collected.
- Collect an adequate, representative sample.
- Handle the sample as little as possible.
- Transfer or dispatch it properly and promptly.
- Store in correct area and avoid contamination.
- Accept samples only after checking for identification and integrity.
- Retain or dispose of samples as directed by the Owner

3.2 DOCUMENTATION

3.2.1 TEST RECORDS

The Engineers Representative will maintain a record of all tests. Individual test data and results will be recorded on a standard form applicable to the test being performed. The location of all tests will be

recorded and accurately described. A plan indicating the positions of all tests and “Work Activity Inspection Forms” detailing inspection of specific areas will be maintained by the Engineers Representative. The Officer who will perform such assurance will provide Eskom Holdings with copies of all test records or maintain them on file for reference. The Contractor upon performing tests and agreeing with the Engineers Representative and cosigning any document shall make a copy of the document signed and forward it to the Engineers Representative for record keeping.

3.3 APPROVAL OF WORK BY MAIN CONTRACTOR

In certain circumstances, it is necessary that the Engineer approve in writing the quality and/or condition of a part of the Work before subsequent Work can take place.

The following general procedures will be used:

- The Contractor shall notify the Engineers Representative in writing of the area, type, and extent of inspection or testing required.
- The Engineers Representative will perform all necessary inspections and witness tests so that the least delay is caused to the Work.
- The Engineers Representative will sign off with the Contractor the test results in the Work Activity Inspection Form. The written approval will contain a clear description and plan of the Work approved. If the Work is rejected, the reasons for so doing will be clearly set out.

3.4 MATERIAL PRE-APPROVAL

All “equivalent” materials must be approved by the Engineer in writing and requests for use of equivalent materials will be submitted to the Engineer with relevant information. The Engineer will review each request in view of the requirements of the relevant Specifications and the intentions of the design.

As soon as reasonably possible, the Engineer will inform the Contractor in writing of the acceptance or rejection of the proposed equivalent material. In the case of rejections, the reasons will be clearly stated.

4.0 INSPECTION

4.1 EARTHWORK

4.1.1 FOUNDATION PREPARATION

The basin area of storm water dam, associated site access road and haul roads must be stripped, cleared, scarified, and compacted to form a Foundation. In general, the Foundation must be of material having density and strength parameters sufficient for the support of the proposed construction. In indicated Foundation areas, any unsuitable material must be removed until suitable material is reached unless approved otherwise by the Engineer, any porous zones must be noted for later treatment with impervious material, and the location of any springs, seeps, and zones of shallow groundwater must be noted for remedial design. The Engineers Representative must accept, on the Work Activity Inspection Form, prepared Foundation prior to the placement of overlying material.

Inspections required:

- Check for correct and complete stripping of topsoil, organic material, and unsuitable materials.
- Check for preparation and compaction of Foundation surface.
- Check for location of porous zones.
- Check for location of encased pipes.
- Check for location of underdrains (if needed).
- Check for compliance with the intent of the Design.

4.1.2 STABILIZATION ROCK FILL

Stabilization Rock Fill is to be used to backfill on indicated Foundation areas to strengthen the surface to be backfilled. Low areas that need to be filled to provide a reasonably level surface for the intended construction shall be filled as indicated on the Drawings or specified by the Engineer. The Engineers Representative must accept, on the Work Activity Inspection Form, prepared Foundation prior to the placement of overlying material.

Inspection required:

- Check for compliance with Specifications regarding size of Rock Fill, hardness, spreading, layer thickness, surface finish, and compaction.
- Check for compliance with the lines and grades shown on the Drawings.
- Check for compliance with the intent of the Design.
- Check for the presence of organic material.
- Check for control on maximum particle size and maximum fines content.

4.1.3 FILL MATERIAL DAM WALLS

Fill Material on Specified Zones is to be used as backfill as indicated on the Drawings or specified by the Engineer. The materials are to be placed, worked and compacted if required as per Specification. All fill shall be accepted by the Engineers Representative on the Work Activity Inspection Form.

Inspection required:

- Check for compliance with Specifications regarding moisture, spreading, layer thickness, surface finish, and compaction.
- Check for compliance with the lines and grades shown on the Drawings.
- Check for compliance with the intent of the Design.
- Check for the presence of organic material.
- Check for control on maximum particle size and maximum fines content.
- Check for regular, consistent mixing of particles to eliminate segregation of coarse particles and formation of seepage paths.

4.1.4 EROSION PROTECTION ON OUTER SLOPES OF DAM WALL

Stockpiled topsoil is to be used for the erosion protection of constructed embankments on the earthfill dam of the dam, as approved by Engineer. All Erosion Protection shall be accepted by the Engineers Representative on the Work Activity Inspection Form.

Inspections required:

- Check for compliance with Specifications regarding particle size distribution, spreading, layer thickness and surface finish.
- Check for uniform distribution of haul truck traffic over the entire fill.
- Check for control on maximum particle size.
- Check for compliance with the intent of the Design.

4.1.5 STEEL DRAINAGE PIPELINE

The Drainage Pipeline shall be checked for defects prior to being placed. The pipes shall be assembled and tested for leaks by the Contractor. The testing shall be witnessed and accepted by the Engineers Representative. If there are leaks the pipe will be made good or replaced if necessary.

Inspection required:

- Check for compliance with relevant Specifications regarding pipes, and connections
- Check for damage to pipes
- Check to be sure that all valves work before they are installed, and coating is not damaged.
- Check for compliance with the configuration shown on the Drawings.

- Check for compliance with the intent of the Design.

4.1.6 PIPES

All pipes shall be accepted by the Engineers Representative on the Work Activity Inspection Form. Inspections required:

- Prior to delivery, check material certifications for compliance with the relevant Specifications.
- On delivery, check that the material delivered is that matching the material certifications.
- Check for damage to pipe materials prior to installation.
- After installation, check for damage and conformance with Relevant Specifications and Drawings.
- Check for compliance of installation with manufacturer's recommendations.
- Check for flushing prior to acceptance testing.
- Check for compliance with the intent of the Design.

4.1.7 DENTAL CONCRETE AND GROUT

All Dental Concrete and Grout shall be accepted by the Engineers Representative on the Work Activity Inspection Form.

Dental Concrete shall be used to fill joints, cavities, depressions, and overhangs. Prior to placement, the surfaces of the joint, cavity, depression, or overhang will be thoroughly cleaned using suitable methods identified in Specifications or by the Engineer.

Inspection required:

- Check for compliance with Specifications regarding aggregate size, workability, layer thickness, surface finish, and compaction.
- Check for compliance with the lines and grades shown on the Drawings.
- Check for compliance with the intent of the Design.
- Check for control on characteristic strength of concrete.
- Check for regular, consistent mixing of concrete to eliminate segregation of coarse particles and formation of weak spots.

4.1.8 CONCRETE

All concrete shall be accepted by the Engineers Representative on the Work Activity Inspection Form.

The Engineers Representative will perform three inspections:

- One prior to placement of concrete
- One during placement of the concrete
- Final inspection following curing

Inspections required:

- Check for compliance with the relevant Specifications regarding materials and methods.
- Check for compliance with the Drawings for line, grade, and method.
- Check for reinforcing size, spacing, and alignment.
- Check for form dimensions.
- Check for casting surface cleanliness.
- Check for vibration.
- Check for surface finish.
- Check for curing.

4.2 GEOTEXTILE

4.2.1 RAW MATERIAL

Quality control testing shall be carried out by the Geotextile Manufacturer to demonstrate that the product meets the Specifications. Prior to installing any geotextile materials, the geotextile supplier, through the Main Contractor, shall provide the Engineers Representative via the Engineer with the following information:

- The origin (name and production plant), identification (brand name, number), production date, and batch (or rail car number) of the resin
- A copy of the quality control certificates issued by the geotextile manufacturer with results of the density, penetration load, tensile strength, permeability and thickness & compressibility tests
- A copy of the quality control test results issued by the geomembrane manufacturer verifying the quality of the resin used to manufacture the geomembrane

4.2.2 DELIVERY

4.2.2.1 GEOTEXTILE DELIVERY

Upon arrival of geotextile materials at the site, the Engineers Representative shall immediately receive via the Contractor a copy of the bill of lading of all geotextile materials and accessories delivered. All materials received on the site shall be immediately logged on the Log of Geosynthetics Received. Upon unloading of the geotextile, the Engineers Representative shall verify that the materials delivered:

- Meet the Geotextile Specifications
- Match those which are listed on the bill of lading

Any discrepancies shall be brought to the immediate attention of the Engineer. The materials shall be inspected for any visible damage or defects, which shall be noted in the log. Materials damaged during unloading shall be noted as such.

4.2.2.2 GEOTEXTILE STORAGE

Geotextile materials shall be stored at a site near the Workplace that is free of hazard. Materials should be stored on a smooth surface free of sharp objects and in an area that will remain in a relatively dry condition at all times. The Engineers Representative shall note any material damaged while in storage.

4.2.2.3 GEOTEXTILE ACCEPTANCE

The Engineers Representative shall neither accept nor allow the installation of any materials that do not meet the requirements of the Geosynthetics Specifications. Materials that are not acceptable shall be clearly marked as such by the Engineers Representative. The Contractor shall be notified by the Engineers Representative via the Engineer as soon as possible as to the deficiencies of materials which do not meet the Geotextile Specifications. Materials that do not meet the requirements of the Specifications shall be removed from the site.

4.2.3 SUBGRADE

4.2.3.1 SUBGRADE INSPECTION

The Engineers Representative shall inspect and accept on the Work Activity Inspection Form the subgrade prior to submittal of an area to the Contractor via the Engineer for his acceptance. The subgrade is the upper surface of the Prepared Subbase.

Inspections required:

- Check for proper compaction.
- Check for proper moisture content.
- Check for correct material type.
- Check for required surface smoothness.
- Check for fill free of debris and sharp objects.

4.2.3.2 SUBGRADE ACCEPTANCE

The Engineers Representative shall obtain from the Main and Gabion Contractor via the Engineer written acceptance for the subgrade prior to the installation of geotextile material. The acceptance of the subgrade shall be recorded on the Work Activity Inspection Form. If any damage has occurred since acceptance, the Engineers Representative shall obtain reacceptance of any area that has been damaged and repaired prior to installation of geotextile materials. The Contractor is responsible for maintaining the condition of the accepted area(s) until it is accepted by others for later stages of Work.

4.2.4 GEOTEXTILE DEPLOYMENT

4.2.4.1 GEOTEXTILE FIELD PANEL DEPLOYMENT

Deployment of geotextile shall be in a systematic and planned fashion.

Inspections required:

- Check for correct direction of deployment.
- Check for correct amount of overlap.

- Check for the amount of geotextile deployed.
- Check for prevention of water from entering between panels.
- Check for temporary anchorage.
- Check for open holes.

The Engineers Representative shall re-inspect any subgrade that may have been damaged after deployment has taken place to ensure that the subgrade still meets the Specifications. This may include removal of deployed panels. Re-inspection will be recorded on the Work Activity Inspection Form. In addition, written acceptance of the damaged and repaired area shall be provided following the guidelines set forth in 4.2.3.2, Subgrade Acceptance.

4.2.4.2 GEOTEXTILE FIELD PANEL DEPLOYMENT SCHEDULE

Deployment of geomembrane materials shall take place within an acceptable period as agreed by both the Contractor, Installer and the Engineers Representative via the Engineer. The speed of deployment shall consider the deterioration of subgrade, materials to be placed on top of the geotextile and the geotextile with time.

4.2.4.3 GEOTEXTILE FIELD PANEL DEPLOYMENT PROGRESS REPORTS

The Contractor shall record on a daily basis the location, date, and roll number of each panel deployed. Daily progress reports shall be submitted to the Engineer. The Engineer shall check these daily reports against his own records to ensure completeness.

4.2.4.4 GEOTEXTILE OVERLAP

The geotextile field panel layout shall be inspected for proper overlap prior to covering. Field joints shall be overlapped as per Drawings or Specifications.

4.2.4.5 GEOTEXTILE DEPLOYMENT WEATHER CONDITIONS

Deployment shall not take place during inclement weather. The Engineers Representative shall have the final authority to determine if weather conditions warrant halting or not starting deployment operations. These conditions include, but are not limited to, the following:

- Precipitation of any kind including condensing fogs
- Areas of ponded water
- Periods of excessive wind

4.3 HIGH DENSITY POLYETHYLENE (HDPE) GEOMEMBRANE LINER

4.3.1 SCOPE OF SUPPLY

Scope of supply shall include furnishing and installation of high-density polyethylene (HDPE) geomembrane liner, and associated quality control/quality assurance inspection and testing.

4.3.2 CODES AND STANDARDS

Work performed under these specifications shall be done in accordance with the codes and standards indicated in these specifications. Unless otherwise specified, the applicable governing edition and addenda to be used for all references to codes or standards specified herein shall be interpreted to be the jurisdictionally approved edition and addenda. If a code or standard is not jurisdictionally mandated, then the current edition and addenda in effect at the date of this document shall apply. These references shall govern the work.

Liner Installation work in accordance with **SANS 1526, SANS 10409**

4.3.3 MATERIALS

The following materials shall be used:

Component	Material
Geomembrane Liner	High density polyethylene (HDPE)

Flat Die Extruded Single or Double Textured HDPE Technical Data

Textured Geoliner is produced from HDPE resin conforming to the requirements of the GRI-GM13 specification.

Properties	Units	Test Method	Test Frequency	Min Average Values			
Thickness. Minimum Avg.(a)	mm	ASTM D 5994	Per roll	1	1.5	2.00	2.5
Asperity Height Minimum Avg.	mm	ASTM D 7466	Every 2 rolls	≥0.65	≥0.65	≥0.65	0.65
Formulated Density	g/cc	ASTM D 792 ASTM D 1505	90 000kg/ approx. every 60 rolls	≥0.94	≥0.94	≥0.94	≥0.94
Tensile Properties - Minimum Avg. (b)							
• Yield Strength	kN/m	ASTM D 6693	9 000kg/ approx. every 6 rolls	15	22	29	37
• Yield Elongation	%	Type IV		12	12	12	12
• Break Strength	kN/m	Dogbone		10	16	21	26
• Break Elongation	%			300	300	300	300
Tear Resistance. Minimum Avg.	N	ASTM D 1004	20 000kg/ approx. every 12 rolls	125	187	249	311
Puncture Resistance. Minimum Avg.	N	ASTM D 4833	20 000kg/ approx. every 12 rolls	267	400	534	667
Dimensional Stability	%	ASTM D 1204	every 40 rolls	±2	±2	±2	±2
Rapid tensile test (300mm/min)	visual	ASTM D 6693	90 000kg/ approx. every 60 rolls	No Separation Visible			
Carbon Black Content	%	ASTM D 4218	9 000kg/ approx. every 6 rolls	2 - 3	2 - 3	2 - 3	2 - 3
Carbon Black Dispersion	Category	ASTM D 5596	20 000kg/ approx. every 12 rolls	cat.1 / cat.2	cat.1 / cat.2	cat.1 / cat.2	cat.1 / cat.2
Oxidative Induction Time (OIT)							
Standard OIT	minutes	ASTM D 3895	90 000kg/ approx. every 60 rolls	>100	>100	>100	>100
— and —							
High Pressure OIT	minutes	ASTM D 5885		>400	>400	>400	>400
Stress Crack Resistance (SP - NCTL)	Hours	ASTM D 5397 Appendix	180 000kg/ approx. every 120 rolls	500	500	500	500
Oven Aging at 85°C (c)		ASTM D 5721					
Standard OIT (min. avg.) retained after 90 days	%	ASTM D 3895	Per Formulation	55	55	55	55
— or —							
High Pressure OIT (min. avg.) retained after 90 days	%	ASTM D 5885		80	80	80	80
UV Resistance - % retained after 1600 hrs.		ASTM D 7238	Per Formulation				
High Pressure OIT (min. avg.)	%	ASTM D 5885		50	50	50	50

a) Thickness: Nominal -5%. Lowest individual for 8 out of 10 values = -10%
Lowest individual for any of the 10 values = -15%
b) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.

a. Yield elongation is calculated using a gage length of 33 mm
b. Break elongation is calculated using a gage length of 50 mm

4.3.4 TEST REQUIREMENTS

The following testing shall be conducted in accordance with the specified source. This testing is to be considered part of the defined scope of work, and all associated costs are the responsibility of the Contractor unless specifically identified as Employer-conducted. Tests identified as an option are to be

priced separately. If identified as Employer-conducted, costs for the initial test will be the responsibility of the Employer. However, the Contractor is responsible for all costs associated with correcting deficiencies and retesting in the event of a test failure:

Tests	**In Accordance With**	**Conducted By**
Specific gravity	ASTM 01505/792 Method B	Contractor
Carbon black content	ASTM 01603	Contractor
Melt index	ASTM 01238	Contractor
Carbon black dispersion	ASTM 05596	Contractor
Thickness - smooth	ASTM 05199	Contractor
Thickness - textured	ASTM 05994	Contractor
Tensile strength	ASTM 0638, Type IV	Contractor
Tear resistance	ASTM 01004	Contractor
Low temperature impact	ASTM 0746	Contractor
Stress crack resistance	ASTM 05397	Contractor
Puncture resistance	ASTM 04833	Contractor
Dimensional stability	ASTM 01204	Contractor
Continuous vacuum box extrusion welded seams	ASTM 04545/4437/5641	Contractor
Bond shear strength for seams and seam peel adhesion	ASTM 06392	Contractor
Air pressurized testing on all double fusion welded seams	ASTM 05820	Contractor
Ultrasonic testing on extrusion welded seams that do not permit vacuum box testing (short slopes, corners or details)	ASTM 07006	Contractor
Spark testing on extrusion welded seams that do not permit vacuum box testing (short slopes, corners or details)	ASTM 06365	Contractor

Tests	In Accordance With	Conducted By
Oven aging at 85° C	ASTM 05721	Contractor
Test method for rubber property effect of liquids	ASTM 0471	Contractor
Oxidation Induction Time- Standard	ASTM 03895	Contractor

4.3.5 PRODUCTS

4.3.5.1 GENERAL

This section covers the material requirements for both smooth and textured HDPE geomembrane material. The geomembrane shall be installed to the limits indicated on the drawings in accordance with the manufacturer's recommendations and these specifications.

The geomembrane manufacturer and Contractor shall have sufficient experience in satisfactory production and installation of geomembrane similar to the type specified. The Contractor shall be the geomembrane manufacturer, or an installer acceptable to the manufacturer.

4.3.5.2 QUALITY CONTROL.

Quality control (QC) shall be performed by the Contractor in accordance with these specifications. Quality control testing requirements and frequency shall be in accordance with **Section 4.3.8**.

Field Quality Control. All quality control field and laboratory testing will be performed by an independent testing laboratory secured by the Contractor and acceptable to the Employer.

4.3.5.3 DRAWINGS AND DATA

The Contractor shall submit drawings, manufacturer specifications, and data for the geomembrane and all accessories to the Engineer in for approval. The installation drawings shall indicate the extent, size, and details of the proposed panel layout, panel numbers, seam locations, seam numbers, seam details, penetration details, geomembrane terminations, and all special details. The Contractor shall also submit proposals for method and sequence of installation to minimize heat expansion sheet undulations and cold contraction sheet tensions. Data shall include current test reports verifying conformance to the material specifications. The Contractor shall furnish "as-built" drawings that record all panel and seam numbers as well as the locations and dimensions of compensation strips, if any.

All changes in submitted installation drawings and procedures must be accepted by the Engineer. Requests for field changes to the approved installation drawings, procedures, and schedule shall be submitted in writing to the Engineer for review and comment. No changes shall be allowed prior to written acceptance by the Engineer. Changes shall be documented on original drawings submitted by Contractor

4.3.5.4 WARRANTIES

The following material and installation warranties shall be furnished in writing to the QC personnel, by the manufacturer and Contractor, respectively.

4.3.5.4.1 Material Warranty.

The geomembrane material shall be warranted on a prorated basis against manufacturing defects and material degradation for the period as stipulated by the manufacturer from the date of official acceptance by the Engineer. Material, which fails within 1 year of acceptance, shall be replaced and installed at no cost to Employer.

4.3.5.4.2 Installation Warranty.

The geomembrane installation shall be warranted against defects for the period as stipulated by the manufacturer from the date of official acceptance by the Engineer. Repairs required during the warranty period, caused by defects due to improper installation, shall be made at no cost to Employer.

4.3.5.5 MATERIALS

The sheet shall be extruded to produce a uniform sheet free of defects such as holes, tears, punctures, blisters, or other manufacturing defects that may affect its durability. Minimum manufactured sheet width shall be 6 m.

Physical property requirements for the HDPE geomembrane shall apply to the extrusion material used for joining sheets.

Melting behavior, melt appearance, and forming behavior shall be continuously observed during production of the geomembrane sheets. The data, labeled with the respective batch and sheet roll numbers, shall be assembled as product quality control documentation and be made available in the event of the material failing during installation or while in service. If a batch does not show favorable behavior in all three respects, it shall be excluded from production regardless of previous acceptance. Important extrusion data (processing parameters) including, but not limited to, melt temperature and production rate shall be monitored and made available. The results shall be submitted upon request.

One sample 21 by 30 centimeters or larger will be excised from the finished roll across the full sheet width. One sample from each roll will be stored with appropriate labeling, and one sample will be tested by the sheet manufacturer for each 4,645 square meters of geomembrane manufactured. This testing will include tensile strength, thickness, and density tests. Test results will meet or exceed the specified minimum requirements.

The values will be documented for each individual sample, stored with the respective sheet report and production report, and submitted upon request. The completed labeled sheet roll will not be placed in storage if any of its test values deviate from the limits. It is the manufacturer's express obligation to exclude any sheet not complying with these quality standards.

A sheet report covering the entire sheet roll shall be prepared for each roll, on which any visible faults must be accurately entered.

A stress cracking durability of range of tolerance equal to or greater than 1,000 hours shall be documented in testing. Test results shall be submitted to the Engineer upon request.

The sheet roll shall not be released for installation unless acceptable results of the production control tests are obtained. If unacceptable results are obtained, the test shall be repeated on another sample from the sheet roll in question. If these results confirm a substandard tensile cracking durability, the material shall be rejected.

4.3.6 EXECUTION

4.3.6.1 SUBGRADE PREPARATION

Geomembrane liner materials shall not be placed until the required subgrade preparation has been completed and the Contractor certifies in writing that the surface on which the geomembrane is installed is acceptable. The Engineer and Contractor, prior to placing any geomembrane, will perform a walk-through inspection.

It will be the responsibility of the Contractor to keep the previously prepared receiving surface in the accepted condition until the geomembrane installation is complete.

Subgrade prepared for geomembrane installation will be smooth and free of debris, roots, and angular or sharp rocks or other objects that might be detrimental to the performance of the geomembrane.

Maximum particle size of objects shall typically not exceed 3 mm. If the in-situ soil is unsuitable, a sand or fine gravel blinding layer of thickness at least 2.5 times the largest dimension of the largest particle in the in-situ soil, or 50 mm (whichever is the thicker), or a suitable geotextile with properties sufficient to meet the above requirements, shall be placed over the entire area to be covered. The subgrade will be protected from erosion. Any areas of the subgrade that are soft, weak; maintain inadequate moisture conditioning; contain ruts, stones, sharp breaks, or holes; or are otherwise unacceptable will be removed or repaired prior to releasing the subgrade for liner installation.

4.3.6.2 DELIVERY AND STORAGE

Upon arrival at the site, the geomembrane rolls shall be unloaded and placed on a smooth surface free of rocks, mud, debris, or any other protrusions which may damage the material. Materials shall not be stored directly on the ground. The Contractor shall provide adequate equipment and personnel at the time of each delivery in order to ensure that the geomembrane is not damaged. Personnel shall handle the geomembrane with care.

Any geomembrane rolls delivered to the site prior to the Contractor’s mobilization shall be kept covered and dry. The Contractor shall examine all rolls for defects and damage and shall report observed damage to the Engineer immediately.

The geomembrane rolls shall be stored onsite at a location that shall be selected to minimize onsite handling. Geomembrane rolls shall not be stacked in a manner that could cause damage to underlying rolls. Geomembrane shall not be stacked higher than two rolls. During storage, the rolls shall be protected from vandalism, passage of vehicle, and theft.

The CQA personnel will obtain a sample of the delivered material. The rate of sampling will be one sample per 9,290 square meters of material. The sample will be 1 meter in length across the entire roll width. The sample shall be tested for conformance at the request of the Engineer. Testing shall include thickness, specific gravity, carbon black dispersion, carbon black content, tensile properties (yield, break, and elongation), tear resistance, and puncture resistance.

4.3.6.3 GEOMEMBRANE INSTALLATION

The geomembrane will be installed in accordance with the manufacturer's recommendations, to the limits indicated on the drawings, and as specified herein.

The geomembrane shall be installed by crews experienced in the installation of HDPE sheet, the type and thickness specified. The onsite installation supervisor shall have supervised in the field or installed at least the square meters of the HDPE liner required in **Section 4.3.8**. All seamers shall have at least the required experience of HDPE geomembrane seaming.

Extreme care shall be taken during installation of the geomembrane to be certain no damage is done to any part of the material. Dragging of the geomembrane on the subgrade shall be avoided. Smoking and use of glass containers by installation personnel shall be prohibited. Installation personnel shall be equipped with boots that will not cause damage to the liner. All handling and installation procedures used by the Contractor shall not damage the liner. If damage occurs, the QC personnel shall require changes in equipment and procedures. No vehicular traffic shall be allowed on the HDPE liner without a minimum of 300 mm of soil cover between the vehicle and the membrane. Exceptions shall be as agreed by the QC personnel. All motor driven equipment using fuel shall have spark arrestors. No gasoline driven generators or cans of gas or solvent shall be placed directly on the HDPE material. Under no circumstances shall the HDPE liner be used as a work area to prepare patches or to store tools and supplies. If needed, a tarpaulin of approved material shall be spread out as a work area.

The Contractor Quality Control personnel shall perform visual inspection of geomembrane materials upon arrival at site for possible transport damage. Geomembrane materials showing damage will be isolated, clearly labeled as damaged, and returned to the manufacturer as determined by the QC personnel. The geomembrane surface will be inspected as it is unpacked or unrolled. If damage or faults not previously observed are discovered, they will be clearly marked, and the respective sheet roll will be set aside. Damaged areas will be repaired in a manner acceptable to the QC personnel, or the entire roll shall be returned to the manufacturer as determined by the CQA personnel. All scuffed surfaces resulting from abuse of any kind caused by the Contractor in performance of the work shall be repaired at no additional cost to the Employer.

Installation work shall not begin until all required drawings and data have been submitted and the Engineer and Contractor have certified the acceptability of the subgrade in writing. The geomembrane shall be installed over the prepared subgrade to the limits indicated on the drawings. Geomembrane panels shall be arranged to minimize field seaming. All geomembrane panels over 2.3 square meters in area shall be designated with a panel number. The Contractor shall be responsible for assigning the number and shall locate the number near the middle of panels less than 15.25 meters in length and at both ends of panels over 15.25 meters in length. These numbers shall be noted on "as-built" drawings and daily progress reports and shall correspond to the drawings initially submitted by the Contractor. Any panel under 2.3 square meters shall be considered a patch and shall not require a panel number; these however will be identified (location and approximate size) on the "as-built" drawings.

Only geomembrane panels scheduled for each day's field seaming shall be spread each day. Panels shall be seamed on the same day they are spread and shall be held in position by sandbags placed at the edges of the sheets until field seaming is complete. Sandbags shall be sufficiently close-knit to preclude fine material from exiting the bag. Metal or wire ties shall not be used.

All rips, tears, punctures, or other injuries to the geomembrane shall be repaired the same day they occur in accordance with procedures as specified herein. At the CQA personnel's discretion, excessive patching shall result in removal and replacement of entire geomembrane sheet at Contractor's expense.

Cleanup within the work area shall be an ongoing responsibility of the Contractor. Care shall be taken to ensure that no trash, tools, and other unwanted materials are dragged across or trapped beneath the geomembrane. Care shall be taken to ensure that all scraps of geomembrane material and other installation related debris are removed from the work area.

Installation. The geomembrane shall be installed on the prepared subgrade to the limits indicated on the drawings. The geomembrane panels shall be arranged in a manner to minimize the number and length of field seaming. The geomembrane panels shall be installed such that field seams run longitudinally down the embankment slope. The installation shall allow for thermal expansion and contraction of the geomembrane. Adequate compensation for liner thermal effects and sheet stability shall be allowed for by the Contractor. Compensations strips shall be installed as required and shall be clearly noted on the "as-built" drawing.

Prior to liner installation, the Contractor shall provide the QC personnel with a table listing the required additional compensation material necessary versus sheet temperature. The minimum design operating liner temperature for this table shall be -34.4' C. This table shall include the necessary compensation for sheet stability. No liner shall be installed until the table has been submitted to the QC personnel. The Contractor shall install at each pipe penetration, roadway edge, or concrete cover enough compensation to eliminate stress at the liner anchorage due to temperature and sheet stability contraction.

The Contractor shall provide temporary wind anchorage during geomembrane installation. All faulty areas shall be repaired. The geomembrane panels shall be installed by experienced workmen and handled carefully. All rips, tears, punctures, or other injuries to the geomembrane shall be repaired the same day to the satisfaction of the QC personnel and in accordance with procedures specified herein.

Liner attachments to structures and penetrations shall be performed by the Contractor in accordance with the drawings.

4.3.6.4 SEAMING.

Field seams shall be made by fusion or extrusion welding methods. Extrusion welding shall only be used in areas where fusion welding equipment cannot operate.

The Contractor shall use only welding apparatus on which proper control of extrudate or wedge temperature, apparatus pressure, welding speed, width of weld, and sheet preheating temperature can be maintained. Certification that the welding apparatus meets these requirements shall be presented before any field seams are made. Welding apparatus or employees shall not damage the geomembrane.

No horizontal seams shall be placed in areas of potential stress concentrations, such as the toe of slopes. The location of horizontal seams shall be discussed with the QC personnel.

A seam numbering system compatible with a panel numbering system shall be established prior to commencing geomembrane installation and submitted to the QC personnel. This information shall be included on the "as-built" drawings and the daily progress reports.

A test weld of length in accordance with **Section 4.3.3**, a determination of sheet surface temperature, and visual inspection of the seam surface and cross section shall be performed satisfactorily before any seam welding is begun each day and before startup of any welding equipment after it has been shut down for any time period exceeding 30 minutes. Trial seams shall be made under the same conditions as actual seams. The CQA personnel may require a trial seam be made at any time during seaming production to verify equipment, operator performance, and seam integrity.

Three 25 mm wide specimens shall be cut from the trial seam, each having the seam centrally located. Using a field tensiometer, the specimens shall be tested in peel and shear, respectively. If either of the'

samples fail in the seam, the operation shall be repeated until the deficiencies are corrected and two successful trial welds are achieved. After positive evaluation of the test weld, the seaming shall begin.

Before welding, the seam areas will be cleaned of wall dust, dirt, and other foreign materials. Welding shall not be performed unless the sheet is dry, and the sheet temperature is within the temperatures specified in **Section 4.3.8**. Welding may be required in cold temperatures. Cold temperature welding procedures shall be provided to the CQA personnel for review prior to start of welding. In no case shall seaming continue if the peel and shear tests fail to meet the specified requirements. Panel layout and other preparatory work may be completed with the aid of artificial light (light plants). A visual inspection of the seaming surface and cross section will be performed before any seam welding or equipment startup has begun.

The Contractor may propose seaming procedures for adverse weather conditions, which will be evaluated by the QC personnel prior to use. Work at night shall take place only with acceptable lighting and the Engineer's approval. All personnel onsite shall be required to carry suitable flashlights during no-day light.

Extrusion field seams shall be made only in areas where fusion seaming is not practical. The sheet surface for extrusion welding shall be roughened by an acceptable means before extrudate is placed. Excessive grinding resulting in grooving of the liner or reducing liner thickness greater than 10 percent shall not be permitted. Grinding shall be performed perpendicular to the seam.

Extrusion seams shall be made by overlapping adjacent sheets a minimum of 80 mm and extruding a ribbon of hot fusion-joining resin no less than 20 mm in width between the overlapped sheets or over the seams between the overlapped sheets.

Fusion field seams shall be made by overlapping adjacent sheets a minimum of 80 mm and forming a double welded seam separated by an air space approximately 10 mm in width. Welded seams shall be produced by a double hot shoe welder capable of maintaining a recordable temperature determined by onsite conditions.

Penetrations through the geomembrane for pipe, patches, concrete structures, other structures, etc. will be field welded, using an extrusion weld joint gun. The seaming procedure shall consist of cleaning and roughening the surface and softening the geomembrane material by application of heated air. Directly following the application of heat, a hot strip of the same HDPE from which the sheet is made will be extruded over the seam to produce the fusion-welded seam.

Repairs of small holes less than 50 mm in the geomembrane surface shall be made with an extrusion joint gun. Geomembrane materials shall be cleaned of all dirt, dust, and other foreign material; all smooth HDPE surfaces roughened, heated to the prescribed temperature, and a hot strip of HDPE resin shall be extruded over the hole to produce a fusion-welded repair.

Larger holes shall be repaired with a HDPE patch and extrusion joint gun. A HDPE patch, meeting the requirements of the HDPE membrane, shall be placed over the hole. The patch shall completely cover the hole, with a minimum clearance between the hole and edge of patch of 80 mm. Membrane and patch material shall be cleaned of all dirt, dust, and other foreign material. All smooth HDPE surfaces shall be roughened, heated to the prescribed temperature, and the patch extrusion welded to the membrane to complete the repair. All patches shall have rounded corners.

4.3.6.5 INSPECTION AND TESTING.

Along with observance of the welding parameters, continuous vacuum box testing shall be performed on all extrusion welded seams and air pressure testing on all double fusion welded seams according to **Section 4.3.4**, as product control. All double fusion seams will be tested at the pressure required in **Section 4.3.3** over the maximum uninterrupted panel seam length for the time required in **Section 4.3.3**. If the pressure drop in the seam is greater than that required, the leak will be located, repaired and the seam retested.

Extrusion welded seams that do not permit vacuum box testing (on short slopes, corners, or details) shall undergo ultrasonic testing similar to the Ultrasonic Shadow Method or Spark testing in accordance with ASTM 06365. The Contractor shall be responsible for submitting the testing method to be used in these instances to the QC personnel.

Weak or unbonded seams shall be repaired with a minimum 155 mm overlay patch and retested. All liner repairs shall be made using patches with rounded corners.

A sample coupon of production seams approximately 915 mm long by 305 mm wide shall be taken in accordance with the specification requirements. The sample coupon shall allow for a total of ten 25.4 mm wide production field seams to be tested. All testing will be performed at the Contractor's onsite quality control laboratory. A portion of each sample coupon 305 by 305 mm shall be labeled and submitted to the CQA personnel for archiving purposes.

Five samples shall be tested for bonded shear strength and five samples shall be tested for seam peel adhesion in accordance with **ASTM 04437**.

The samples obtained from double fusion and extrusion welded seams shall exhibit at least the minimum percent of sheet tensile yield strength in shear required in **Section 4.3.3**. The samples obtained from double fusion and extrusion weld seams shall exhibit at least the minimum percent of sheet yield strength in peel required in **Section 4.3.3**.

All five of the specimens tested in shear and four out of five of the specimens tested in peel shall fail in film tear bond (FTB), that is, the break should occur in the parent geomembrane. The failure mechanism of the seam shall be ductile in nature, with no indication of crystallization.

Test results shall be submitted as soon as possible to the QC personnel and signed by the Contractor's

4.3.6.6 QUALITY CONTROL MANAGER.

If the sample proves defective, by either destructive or nondestructive testing, additional testing shall be performed to determine the extent of the defect. A test section a minimum of 3 meter on both sides of the failed seam shall be retested. If these tests pass, the weld between these areas shall be cap stripped. If failure occurs, the testing shall be continued until the extent of the defect is established. All defects shall be repaired to the satisfaction of the QC personnel.

Destructive weld test sample reports shall be delivered to the QC personnel within 48 hours of obtaining the sample from the production seam. The geomembrane shall not be covered until acceptable destructive and nondestructive testing has been completed.

It is the Contractor's obligation to forward to the Engineer all weld seam reports, labeled with the weld seam number in accordance with the installation drawings.

Faulty spots shall be repaired by one of the two methods previously specified, patching or filling, and the repaired sections subjected to thorough visual inspection and vacuum box testing.

4.3.6.7 LINER DEGRADATION MONITORING (APPLIES TO DAM LINERS).

To monitor durability and compliance with warranty requirements, test samples shall be installed at several locations within the dam. Each test sample shall include factory seams, field seams, patches, and other representative operations performed during liner installation. Each test sample shall be 1.5 meters wide by 3.0 meters long with Hach seam running the long dimension. Each test sample shall be placed over the permanent liner on 50 mrn of fill material.

The number of test samples installed within the dam shall be in accordance with the specifications or as directed by the Engineer. The location of test samples shall be acceptable to the Engineer.

4.3.7 DOCUMENTATION

4.3.7.1 SHEET INSTALLATION.

The Contractor shall perform a visual inspection on each liner sheet for puncture, tears, rips, or other injuries. Daily installation progress reports shall be prepared including the following information:

- Names and job description of personnel. Date.
- Weather conditions, including range of wind speed and temperature, cloud cover, and precipitation.
- Project location
- . Panels installed.
- Panels seamed, including panel and seam number.
- Liner repair (puncture, tears, rips, or other injuries and method of repair). Field observations.
- Roll number.

Copies shall be provided to the QC personnel on a daily basis.

4.3.7.2 LINER SEAMING.

Quality control records shall be prepared by the Contractor detailing the initial weld qualification of equipment and welding crews. Daily seam quality control reports shall be maintained on all field seaming including, but not limited to, the following information:

- Date.
- Project location.
- Weld location, seam number, and panel number (including liner repair situations). Sheet temperature.
- Weld crew identification. Weld machine identification.
- Weld samples, if taken (including test weld documentation). General observations.

4.3.8 FIELD QUALITY CONTROL

This article describes the activities necessary to monitor the construction of the geomembrane. Specific tests mentioned in this section shall be performed by the Contractor's QC personnel as part of the construction quality control for the project. Additional confirmation tests may be performed by the CQA personnel.

4.3.8.1 PRECONSTRUCTION.

Preconstruction activities for the liners include observation of the raw materials, manufacturing operations, fabrication operations, and final product quality; observations related to transportation, handling, and storage of the synthetic liner; monitoring of the subgrade (base) preparation; and evaluation of the personnel and equipment to be used to install the liners. These activities are discussed in the following articles.

4.3.8.2 QUALITY CONTROL OF MANUFACTURER.

The Contractor must provide documentation confirming that the raw materials comply with the manufacturer's product properties and performance requirements. The manufacturer must have a manufacturing quality control program that the CQA personnel will review. If there are areas where the QC personnel feel that the manufacturer's quality control program is weak, they may request that the manufacturer conduct additional tests.

The liner will be tested by the manufacturer after it is manufactured into rolls and these documented test results reviewed by CQA personnel for compliance with the test methods and properties included in the specifications.

The synthetic liner manufacturer shall retain a sample of the finished liner from each raw material batch (identified by lot number) for future reference. Appropriate documentation (e.g., product specifications, lot number) will be included with each sample. Documentation will be available to the QC personnel.

No factory seam of the synthetic liners will be allowed. The QC personnel shall observe the synthetic liner material for the presence of factory seams.

4.3.8.3 TRANSPORTATION AND STORAGE.

CQA personnel will confirm that the synthetic liner has been protected with appropriate covering material. The roll of finished liner material must be marked to show the following minimum information:

- Name of manufacturer. Product type.
- Product thickness. Manufacturing batch code. Date of manufacture.
- Physical dimensions (length and width).

The liner material will be observed to confirm that it is not damaged by the following: Punctures from handling, nails, splinters, etc.

Tears from operation of equipment or inadequate packaging. Exposure to temperature extremes resulting in unusable material.

Blocking resulting from the bonding together of adjacent membrane layers due to excessive heat and pressure.

Crumpling or tearing from inadequate packaging support.

When damage to a roll cover has occurred, examination of the underlying material will be conducted. If damage is found, CQA personnel will examine the entire shipment tor damage.

The CQA personnel will review delivery tickets and quality control documentation to confirm that the liner rolls received onsite meet the project specifications. Samples of the product may be "fingerprinted" and compared with the fingerprint of the product originally contracted for. If these fingerprints are different, the material will be rejected.

The CQA personnel will confirm that the synthetic liner material is stored in a secure area with provisions for protection from adverse weather to avoid damage caused by heavy winds, precipitation, temperature extremes, vandals, and any other causes.

4.3.8.4 CONSTRUCTION.

The observations and tests necessary to detect defects during construction are discussed in the following articles.

4.3.8.4.1 Synthetic liner placement.

Identifying labels from each roll will be taken and saved for future reference. Further, the position of each roll of material will be noted on a final installation drawing. This document can be used for future reference. Monitoring activities that are necessary and that will be documented during liner placement include the following:

Written acceptance by the Contractor that subgrade is in a condition suitable for liner deployment.

Observations regarding the liner placement plan.

Observations of the weather conditions (i.e., temperature, humidity, precipitation, and wind) and that they are appropriate for liner placement and seaming.

Observations and measurements of the anchor trench so that it is as specified in the construction drawings; that trench corners are rounded to limit stressing the membrane; and that backfilling of the trench is performed as soon as possible and compacted with care so as not to damage the liner.

Observations and tests to confirm that all designed liner connections are appropriately installed.

Measurements to confirm that the required overlaps of adjacent synthetic liner sheets were achieved, that proper temporary anchorage was used, that specified temporary and final seaming materials techniques were used, and that the synthetic liner was placed in a relaxed (non-stressed) state. As each synthetic membrane panel is placed, it shall be inspected for tears, punctures, and thin spots.

To accomplish this, the panels will be traversed by CQA personnel in such a way that the entire surface is observed.

If the weather becomes unacceptable for installation of the liner, the QC personnel will stop the synthetic liner installation until conditions again become favorable, thus minimizing the potential for unacceptable installation.

4.3.8.4.2 Liner seaming.

The following will be documented by the Contractor during field seaming operations:

- Observations that the membrane seaming areas are free from dirt, dust, and moisture. Observations that the seaming materials and equipment are as specified.

- Observations that the seaming placement plan was followed.
- Observation that a firm foundation, free from sharp rocks, debris or other deleterious material supports the liner.
- Observation of weather conditions.
- Measurement of temperatures, pressures, and speed of seaming, when applicable, and that they are as specified (e.g., gauges and dials will be read, and readings recorded).
- Measurement of the curing time between seaming and seam testing.
- Observation of the liner to detect damage caused by equipment or personnel during the seaming process.
- Observation of the startup testing of welding equipment including peel and shear testing of sample welds.
- Observation of field seam installation so that a homogeneous bond was formed. Observation of nondestructive tests on 100 percent of the field seams. Failed seams will be recorded as to location and seaming crew and equipment. The data will be reviewed for possible patterns. Repairs will be made in accordance with approved techniques and retested to confirm their integrity.
- Observation of destructive seam testing at frequency required in the specifications of as directed by the Engineer. If different seaming techniques are used, additional tests in accordance with seaming type will be added. Additional test locations and shorter testing frequency may be necessary at the QC personnel's discretion. Test locations and testing frequency will be based on suspicion of contamination by dirt or moisture, change in seaming materials, increase in ambient temperature, increase in failed nondestructive tests, and other causes that could result in unacceptable seams.
- Confirmation that destructive seam samples are large enough for the Contractor to test in the laboratory, for an independent laboratory evaluation and for Employer archiving. Seam samples will be a minimum of 305 mm wide by 915 mm long.
- Confirmation that testing is performed in accordance with design specifications with predetermined pass/fail values. Both peel and shear testing should be performed as specified.
- Confirmation that for field seams that fail, the installer did go on either side of the failed seam location (3 meters minimum), take another sample, test it and if it passes, cap strip the seam between the two locations. Acceptable seams must be bounded by two passed-test locations, unless the capped seam extends to the edge of the lining.
- Confirmation that repairs are performed as soon as possible and in accordance with the specifications. Each repair will be nondestructively tested for continuity. Documentation of all repairs including location, type, and method used will be made.

4.4 GEOSYNTHETIC CLAY LINER (GCL)

4.4.1 EQUIPMENT REQUIREMENTS

GCLs are delivered in rolls typically 2,600-2,950 lbs (1180-1340 kg). Roll dimensions and weights will vary with the dimensions of the product ordered. It is necessary to support this weight using an appropriate core pipe. For any installation, the core pipe must not deflect more than 3 inches (75 mm) as measured from end to midpoint when a full GCL roll is lifted.

4.4.2 SHIPPING, UNLOADING & STORAGE

All lot and roll numbers should be recorded and compared to the packing list. Each roll of GCL should also be visually inspected during unloading to determine if any packaging has been damaged. Damage, whether obvious or suspected, should be recorded and the affected rolls marked.

4.4.2.1 UNLOADING

Major damage suspected to have occurred during transit should be reported immediately to the Engineer. The nature of the damage should also be indicated on the bill of lading with the specific lot and roll numbers. Accumulation of some moisture within roll packaging is normal and does not damage the product.

The party directly responsible for unloading the GCL should refer to the manufacturers manual prior to shipment to ascertain the appropriateness of their unloading equipment and procedures. Unloading and on-site handling of the GCL should be supervised.

4.4.2.2 STORAGE

Rolls should be stored at the job site away from high-traffic areas but sufficiently close to the active work area to minimize handling. The designated storage area should be flat, dry and stable. Moisture protection of the GCL is provided by its packaging; however, an additional tarpaulin or plastic sheet is recommended.

Rolls should be stacked in a manner that prevents them from sliding or rolling. This can be accomplished by chocking the bottom layer of rolls. Rolls should be stacked no higher than the height at which they can be safely handled by laborers (typically no higher than four layers of rolls). Rolls should never be stacked on end.

4.4.3 SUBGRADE PREPARATION

Subgrade surfaces consisting of granular soils or gravel may not be acceptable due to their large void fraction and puncture potential. In high-head (greater than one foot or 30 cm) applications, subgrade soils should possess a particle size distribution such that at least 80 percent of the soil is finer than a #60 sieve (0.250 mm) unless a membrane-laminated GCL (Bentomat CL or Bentomat CLT) is used.

When the GCL is placed over an earthen subgrade, the subgrade surface must be prepared in accordance with the project specifications. The Engineer's approval of the subgrade must be obtained prior to installation. The finished surface should be firm and unyielding, without abrupt elevation changes, voids, cracks, ice, or standing water.

The subgrade surface must be smooth and free of vegetation, sharp-edged rocks, stones, sticks, construction debris, and other foreign matter that could contact the GCL. The subgrade should be rolled with a smooth-drum compactor to remove any wheel ruts greater than 1 inch in depth, footprints, or other abrupt grade changes. Furthermore, all protrusions extending more than12 mm from the subgrade

surface shall be removed, crushed, or pushed into the surface with a smooth-drum compactor. The GCL may be installed on a frozen subgrade, but the subgrade soil in the unfrozen state should meet the above requirements.

4.4.4 INSTALLATION

GCL rolls should be taken to the work area of the site in their original packaging. The orientation of the GCL (i.e., which side faces up) may be important if the GCL has two different types of geosynthetics. Check with the Engineer in order to determine if there is a preferred installation orientation for the GCL. If no specific orientation is required, allow the roll to unwind from the bottom rather than pulling from the top. The arrow sticker on the plastic sleeve indicates the direction the GCL will naturally unroll when placed on the ground Prior to deployment, the packaging should be carefully removed without damaging the GCL.

Equipment which could damage the GCL should not be allowed to travel directly on it. Acceptable installation, therefore, may be accomplished such that the GCL is unrolled in front of backwards-moving equipment. If the installation equipment causes rutting of the subgrade, the subgrade must be restored to its originally accepted condition before placement continues.

If sufficient access is available, GCL may be deployed by suspending the roll at the top of the slope with a group of laborers pulling the material off of the roll and down the slope. GCL rolls should not be released on the slope and allowed to unroll freely by gravity.

Care must be taken to minimize the extent to which the GCL is dragged across the subgrade in order to avoid damage to the bottom surface of the GCL. Care must also be taken when adjusting Bentomat CLT panels to avoid damage to the geotextile surface of one panel of GCL by the textured sheet of another panel of GCL. A temporary geosynthetic subgrade covering, commonly known as a slip sheet or rub sheet, may be used to reduce friction damage during placement.

The GCL should be placed so that seams are parallel to the direction of the slope. End-of-panel seams should also be located at least 1m from the toe and crest of slopes steeper than 4H:1V. End-of-roll seams on slopes should be used only if the liner is not expected to be in tension.

All GCL panels should lie flat, with no wrinkles or folds, especially at the exposed edges of the panels. When Bentomat with SuperGroove is repositioned, it should be gripped inside the SuperGroove by folding the edge.

The GCL should not be installed in standing water or during rainy weather. Only as much GCL shall be deployed as can be covered at the end of the working day with soil, geomembrane, or a temporary waterproof tarpaulin. The GCL shall not be left uncovered overnight. If the GCL is hydrated when no confining stress is present, it may be necessary to remove and replace the hydrated material.
The Engineer and the Manufacturer should be consulted for specific guidance if premature hydration occurs. The type of GCL, duration of exposure, degree of hydration, location in the liner system, and expected bearing loads should be considered.
In many instances, a needle punch reinforced GCL may not require removal/replacement if the following are true:

a) The geotextiles have not been separated, torn or otherwise damaged;
b) There is no evidence that the needle punching between the two geotextiles has been compromised;
c) The Bentomat does not leave deep indentations when stepped upon; and
d) Any overlapped seams with bentonite enhancement are intact.

For the convenience of the installer, hash marks are placed on Bentomat every 1.5 m of length.

4.4.5 ANCHORAGE

If required by the project drawings, the end of the GCL roll should be placed in an anchor trench at the top of a slope. The front edge of the trench should be rounded to eliminate any sharp corners that could cause excessive stress on the GCL. Loose soil should be removed or compacted into the floor of the trench.

If a trench is used for anchoring the end of the GCL, soil backfill should be placed in the trench to provide resistance against pullout. The size and shape of the trench, as well as the appropriate backfill procedures, should be in accordance with the project drawings and specifications.

The GCL should be placed in the anchor trench such that it covers the entire trench floor but does not extend up the rear trench wall.

Sufficient anchorage may alternately be obtained by extending the end of the GCL roll back from the crest of the slope and placing cover soil. The length of this “runout” anchor should be prepared in accordance with project drawings and specifications.

4.4.6 SEAMING

GCL seams are constructed by overlapping adjacent panel edges and ends. Care should be taken to ensure that the overlap zone is not contaminated with loose soil or other debris. Supplemental bentonite is not required for Claymax 200R. Bentomat ST, DN, and SDN with Supergroove have self-seaming capabilities in their longitudinal overlaps and do not require supplemental bentonite. For pond applications, supplemental bentonite must be used in longitudinal seams regardless of the GCL used.

- Longitudinal seams should be overlapped a minimum of 6 inches (150mm) for Bentomat and 12 inches (300mm) for Claymax.
- End-of-panel overlapped seams should be overlapped 24 inches (600mm) for Bentomat and 48 inches (1,200mm) for Claymax.
- End-of-panel overlapped seams are constructed such that they are shingled in the direction of the grade to prevent runoff from entering the overlap zone.
- Bentomat end-of-panel, bentonite-enhanced, overlapped seams are constructed first by overlapping the adjacent panels, exposing the underlying panel, and then applying a continuous bead or fillet of granular sodium bentonite from the edge of the underlying panel. (The minimum application rate at which the bentonite is applied is one-quarter pound per linear foot (0.4 kg/m).

4.4.7 SEALING AROUND PENETRATIONS AND STRUCTURES

Cutting the GCL should be performed using a sharp utility knife. Frequent blade changes are recommended to avoid irregular tearing of the geotextile components of the GCL during the cutting process.

The GCL should be sealed around penetrations and structures embedded in the subgrade in accordance with the drawings or as directed by the Engineer. Granular bentonite or a bentonite mastic shall be used liberally (approx. 2 lbs. /ln ft. or 3 kg/m) to seal the GCL to these structures.

When the GCL is placed over a horizontal pipe penetration, a “notch” should be excavated into the subgrade around the penetration. The notch should then be backfilled with granular bentonite. A secondary collar of GCL should be placed around the penetration. It is helpful to first trace an outline of the penetration on the GCL and then cut a “star” pattern in the collar to enhance the collar’s fit to the penetration. Granular bentonite should be applied between the primary GCL layer and the secondary GCL collar.

Vertical penetrations are prepared by notching into the subgrade. The penetration can be completed with two separate pieces of GCL. Alternatively, a secondary collar can be placed.

When the GCL is terminated at a structure or wall that is embedded into the subgrade on the floor of the containment area, the subgrade should be notched as indicated on the drawings or directed by the Engineer.
The notch is filled with granular bentonite, and the GCL should be placed over the notch and up against the structure. Connection to the structure can be accomplished by placement of soil or stone backfill in this area.

5.0 TESTING

Standard testing forms developed by the Engineers Representative or the Contractor shall be used for the tests described in this section. When reference is made to an external test procedure, e.g., ASTM, the relevant test procedure documentation is considered to be an integral part of this manual. If these external test procedures reference or require other additional external procedures, they also are considered to be an integral part of this document.

The tests required are divided into two categories:

- Control tests
- Record tests

Control tests are used to determine that materials comply with the Earthwork, Concrete, Roads, Gabions & Pitching and Riprap Specifications prior to placement and to determine other parameters such as optimum moisture content and maximum dry density so that the requirements of the Specifications are achieved. The frequency of control tests can be reduced when material characteristics are relatively constant and consistent. Record tests are performed, usually after placement of the materials, to determine that the in-place materials meet the requirements as set forth in the Specifications and/or are in accordance

with the Design intent. Tests are performed by the methods indicated and at the frequencies shown in the Specifications. The tests will be performed at least the minimum number of times indicated. The Engineer may increase the number of tests required.

5.1 EARTHWORK

Testing of all fill materials shall be completed in accordance with the procedures and at the frequencies detailed in Specifications.

If the layer thickness for fill exceeds the test equipment working depth, compaction through the layer must be verified at the commencement of fill placement. This is done by excavating a pit. Thereafter, the compaction profile is established by testing the top of the layer. Periodic testing using pits may then be used to confirm continued acceptable compaction throughout the layer. Acceptance of riprap shall be based on the visual observation of the placed riprap by the Engineers Representative. If the Engineers Representative deems it necessary, field measurements to determine the particle size distribution of the riprap shall be undertaken and other test work undertaken to determine its suitability and compliance with the requirements of the Specifications.

5.2 PIPEWORK

The following tests are required prior to burial:

- Visual inspection of all non-welded joints connected by bolts.
- Visual inspection of all welds.

The following tests are required after backfill placement and compaction around the culverts.

- Visual inspection and testing, as required, of all culvert backfill. Periodically, the backfilled culvert shall be exposed when specified by the Engineers Representative to allow inspection of the completed backfill.
- Sections of the pipe shall be tested for leaks as indicated in the Specifications.

All inspections and test results are to be recorded on the Work Activity Inspection Form.

5.3 CONCRETE

Inspections required are shown in the Specifications. Any testing deemed necessary will be performed at the discretion of the Engineer. All concrete shall be accepted by the Engineers Representative on the Work Activity Inspection Form.

5.4 FIELD DENSITY TESTS

5.4.2 SAND REPLACEMENT TEST

In general, the in-place density and unit weight of soil and rock are determined using the appropriate ASTM test method:

- ASTM D 5030:
  - Minimum test pit volume
  - Maximum particle size
- ASTM D 1556 or D 2167
  - Minimum test pit volume
  - Minimum particle size

The material being tested must be sufficiently cohesive to maintain stable sides during testing. It must not deform or slough while digging the hole or pouring the sand. In general, these test methods are limited to materials in an unsaturated condition and are not recommended for soft, friable, or seeping materials.

5.5 FAILED TESTS

The Engineers Representative will individually consider each record test which fails to meet the requirements of the Specifications and recommend an appropriate course of action. This may involve resampling, reworking, and retesting or some combination of these. In every case, all documentation associated with the original test and the recommended remedial work will be clearly cross referenced so that the entire sequence of activities can be completely reconstructed.

5.6 EQUIPMENT CALIBRATION, MAINTENANCE, AND OPERATION

Manufacturers' specifications for instrument calibration and maintenance will be followed. A record of calibration and maintenance activities will be maintained in field notebooks. The calibration, maintenance, and operating procedures for all instruments, equipment, and

sampling tools are based on or are the actual manufacturer's instructions, specifications, and criteria for calibration, maintenance, and operation. Each piece of equipment used in activities affecting data quality shall be calibrated at a frequency specified by the manufacturer.

Each piece of equipment used in activities affecting data quality shall be maintained. Following maintenance, instruments will be calibrated according to the manufacturer's specifications to ensure proper completion of the maintenance procedure.

6.0 REPORTS

6.1 DAILY REPORTS

The Engineers Representative will prepare a daily report summarizing work inspected, tests performed, and other relevant items. The daily report will indicate any failed inspections or tests, the actions taken to rectify these, and reports received or given about unacceptable or substandard procedures or materials.

6.2 MONTHLY PROGRESS REPORT

The Engineers Representative will prepare a monthly progress report. This report will:

- Summarize construction activities
- Summarize construction methods
- Summarize all CQA/QC activities
- Summarize all inspection and testing results
- Indicate problems encountered and resolutions
- Indicate potential difficulties
- Provide photographs

The Engineers Representative may include such other items as Drawings, figures, and tables as are necessary to clearly present the work performed and planned.

6.1 AS-BUILT REQUIREMENTS

A record of all changes to Drawings due to unforeseen design omissions shall be recorded on a standard As-built Record Sheet and updated timeously. This sheet will include item/s changed, date, brief description, a sketch that is clear and descriptive with dates and originator referenced to the item and information on correspondence between the Main Contractor and the Engineer or Owner. Changes that take place and need to be updated on Drawings for As-built Drawings shall be forwarded to the Engineer as soon as practicable. They should also be reported in the daily and monthly progress reports.

6.4 CONSTRUCTION REPORT

Upon completion of the work, the Engineer will prepare a comprehensive Construction Report.

This report will include:

- A summary of construction methods and materials
- A summary of any problems encountered and the solutions to them

- Results of inspections
- Results of all tests
- A record of Construction Drawings
- Photographs

The Construction Report will be submitted to the Owner.

6.5 TEST METHODS AND TESTING FREQUENCIES

Test Methods – Earthwork

Type of Test Method

(ASTM)

Atterberg Limits D 4318

Particle Size Distribution D 422 a

Laboratory Compaction D 1557

Nuclear Method Field Density D 2922 b

Sand Cone Field Density D 1556

Notes:

C = Control Tests

R = Record Tests

All test frequencies are listed in the relevant Specifications.

Approval that this document adheres to Knight Piésold Quality Systems: