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SECTION 02771
TPO GEOMEMBRANE

PART 1 - GENERAL

1.1 SUMMARY

- A. Section includes the scrim reinforced Thermoplastic Polyolefin (TPO) geomembrane components used in the exposed geomembrane temporary cover. The scrim reinforced TPO is 60 mil UltraPly™ TPO as manufactured by Firestone Building Products or equivalent.
- B. Related Sections:
 - 1. Section 02200 –Earthwork - Landfill.
Section 02778 - Geotextile.

1.2 QUALITY ASSURANCE

- A. Referenced Standards:
 - 1. ASTM International (ASTM):
 - a. ASTM D751– Standard Test Methods for Coated Fabrics
 - b. ASTM D6878– Standard Specification for Thermoplastic Polyolefin Based Sheet Roofing
 - c. ASTM D5261– Test Method for Measuring Mass per Unit Area of Geotextiles
 - d. ASTM D4885– Standard Test Method for Determining Performance Strength of Geomembranes by the Wide Strip Tensile Method
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 - g. ASTM D1204– Standard Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature
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 - i. FTM 101 C– Test Method for Puncture Resistance and Elongation Test
 - j. ASTM D471– Standard Test Method for Rubber Properties—Effect of Liquids (Water Absorption)
 - k. ASTM G 151 – Practice for Exposing Non-Metallic Materials in Accelerated Test Devices that use Laboratory Light Sources
 - l. ASTM G 155 – Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials
 - 2. The Geosynthetic Research Institute (GRI).
 - a. GRI/G 16 – Observation of Surface Cracking of Geomembranes
- B. Qualifications:
 - 1. Each manufacturing and fabricating firm shall demonstrate 5 years continuous experience with a minimum of 10,000,000 SF of TPO geomembranes.
 - 2. Installer:
 - a. Demonstrate 5 years continuous experience with a minimum 10,000,000 SF of geomembranes.
 - b. Trained and certified by at least one of the named manufacturers in this Specification (not necessarily the manufacturer supplying materials for this Project).
 - c. Geomembrane Installer Personnel Qualifications:
 - 1) Installation Superintendent shall have worked in a similar capacity on at least five geomembrane liner jobs similar in size and complexity to the project described in the Contract Documents.

- 2) The Master Welder shall have completed a minimum of 5,000,000 sf geomembrane seaming work using the type of seaming apparatus proposed for use on this Project.
 - 3) Other welders shall have seamed a minimum of 1,000,000 sf geomembrane.
3. CQC Testing Laboratory shall demonstrate 3 years of continuous experience in similar geosynthetic materials testing.
- C. Quality Assurance / Control:
1. The Owner or Engineer's representative will conduct independent testing to support construction quality assurance (CQA) program and to provide documentation of such to appropriate regulatory agencies.
 2. Unless specifically superseded by these contract documents or approved plans submitted by the Contractor, the geosynthetic materials shall be manufactured, stored, placed, seamed, tested and protected as described in EPA/600/R-93/182 and EPA/530/SW-91/051.
 - a. This specifically includes:
 - 1) Material Composition.
 - 2) Manufacturing.
 - 3) Handling and Packaging.
 - 4) Shipment.
 - 5) Storage (Manufacturer and Site).
 - 6) Placement:
 - a) Seaming and Joining.
 - b) Destructive and Non Destructive Testing.
 - c) Protection, Backfilling and Covering.
 - 7) Conformance Testing.
 - 8) Anchoring and Anchor Trenches.
 - 9) Access Roads/Ramps.
- D. CQA Plan Implementation: Construction Quality Control will be performed in accordance with the CQA Plan prepared for this project. The Contractor and Geomembrane Installer should familiarize themselves with the CQA Plan.
- E. Installer's construction quality control programs to include, but not be limited to, product acceptance testing, installation testing, including both nondestructive and destructive quality control field testing of the sheets and seams during installation of the geomembrane, proposed methods of testing geosynthetic joints and connections at appurtenances for continuity, documentation and changes, alterations, repairs, retests, and acceptance.
- F. Geomembrane Installer's installation manual to include:
1. Ambient temperature at which the seams are made
 2. Control of panel lift up by wind
 3. Acceptable condition of the subsurface beneath the geomembrane
 4. Quality and consistency of the welding material
 5. Proper preparation of the liner surfaces to be joined
 6. Cleanliness of the seam interface (e.g., the amount of airborne dust and debris present)
 7. Proposed details for connecting the TPO liner to appurtenances, i.e. penetrations of the containment facilities.
 8. A complete description of seaming by hot-air welding and hot-wedge welding.
 9. Requirements of the Manufacturer's Installation Manual unless exceptions are noted and approved by the Engineer.

1.3 DEFINITIONS AND RESPONSIBILITIES

- A. Geomembrane Manufacturer: Manufacturer of geomembranes producing geomembrane sheets from resin and additives. The manufacturer is responsible for producing geomembrane sheet which complies with these Specifications. These responsibilities include but are not limited to:
1. Acceptance of the resin and additives from chemical formulators. Testing of the raw resin and additives to ensure compliance with the manufacturer's specifications and with this Specification.

2. Formulation of the resin and additives into geomembrane sheeting using mixing and extrusion equipment.
 3. Testing of the geomembrane sheet to ensure compliance with manufacturer's specification and this Specification.
 4. Shipping of the geomembrane sheet to installer designated facilities.
 5. Certification of the raw materials and finished geomembrane sheet to comply with this Specification.
 6. Certification of installer's training, experience, and methods for welding and inspection of geomembrane installations in compliance with manufacturer's standards.
- B. Geomembrane Installer. Installer of geomembranes are responsible for handling, fitting, welding, and testing of geomembrane sheets or blankets in the field. These responsibilities include but are not limited to:
1. Acceptance (in writing) of the geomembrane from the manufacturer.
 2. Acceptance (in writing) of the surface which will serve as a base for the geomembrane. This acceptance shall precede installation of the geomembrane, and shall state that the installer has inspected the surface, and reviewed the Specifications for material and placement, and finds all conditions acceptable for placement of geomembrane liners. The written acceptance shall explicitly state any and all exceptions to acceptance.
 3. Handling, welding, testing, and repair geomembrane liners in compliance with this Specification and the Geomembrane Installer's Installation Procedures Manual.
 4. Performance of QC testing and record keeping as required by the approved Geomembrane Installer's Field Installation Procedures Manual.
 5. Repair or replacement of defects in the geomembrane as required by the Installer's CQC Consultant or the CQA Inspector.
- C. CQA Inspector:
1. Inspectors of TPO geomembrane are the individuals responsible for observing field installation of the geosynthetic materials and providing the Manufacturer, Installer, CQA Engineer, and Owner with verbal and written documentation of the compliance of the installation with this specification and with written procedures manuals prepared by the Manufacturer or Installer.
- D. CQA Testing Laboratory shall:
1. Perform destructive testing of the TPO geomembrane.
 2. Perform conformance testing of TPO geomembrane.
- E. Installer's CQC Consultant: Responsible for observing field installation of the geomembrane and performance of material conformance and CQC testing to provide the Contractor with verbal and written documentation of the compliance of the installation with these Specifications.
- F. CQA Engineer: Responsible for implementing CQA Plan including overview of material conformance testing, field installation of the geomembrane, and CQC activities, and to perform limited CQA conformance testing to provide Owner with verbal and written documentation of the compliance of the installation with these Specifications. The CQA Engineer will use the written results of the CQC program and the CQA program in the preparation of the facility Certification Document. The CQA Engineer reports to the Owner and is not part of this contract.
- G. Refer to the accompanying CQA Plan for additional definitions.

1.4 SUBMITTALS

- A. Shop Drawings:
1. Submit for Engineer's approval Shop Drawings, including:
 - a. Manufacturer's certification that raw materials and sheet materials comply with required materials, mil thickness, and material properties.
 - 1) Original certificates are required.
 - b. Manufacturer/Fabricator/Installer quality control requirements.
 - c. Qualifications and experience of key personnel per 1.2 B of this section.

- d. Manufacturer's written acceptance of Geomembrane Installer's qualifications for installation of the TPO geomembrane.
 - e. TPO Geomembrane layout plan with proposed size, number, position and sequencing of liner panels and showing the location and direction of all field or factory joints.
 - 1) Proposed details for connecting the geosynthetic materials to appurtenances.
 - 2) Proposed methods of welding, seaming or jointing geosynthetic materials.
 - 3) Proposed method of testing TPO geomembrane and other geosynthetic materials, joints and connections at appurtenances for continuity.
 - 4) Location and configuration of haul roads and access points.
 - 5) Proposed details for anchor trench if different than included in Contract Documents.
- B. Miscellaneous:
- 1. Test results:
 - a. Resin test, tests of sheet material and factory seam tests at frequency specified in respective quality control manuals.
 - 1) Results shall include or bracket the rolls delivered for use in the Work.
 - b. Daily test seam results.
 - c. Daily results of production seam testing.
 - 2. Warranties as described below.
 - 3. Submit written certifications that:
 - a. Utilize certification forms approved for use on this project by the Owner and Engineer. Make appropriate number of copies, as required.
 - b. The TPO geomembrane material delivered to site meets the requirements of this Specification.
 - c. The TPO geomembrane was received and accepted in undamaged condition from shipper.
 - d. The TPO geomembrane liner was installed in accordance with this Specification and with approved Shop Drawings.
 - e. The TPO geomembrane joints were inspected, tested for strength and continuity, and passed all inspections and tests.
 - 1) All test and inspection data shall be incorporated into this certification.
 - 4. Manufacturer/Installer's Field Installation Procedures Manual shall clearly identify any exceptions taken to the specified execution of the Work.
 - 5. Record Drawings: Submit reproducible drawings of record showing changes from the approved installation drawings. The record drawings shall include the identity and location of each repair, cap strip, penetration, boot, and sample taken from the installed geosynthetic for testing. The record drawings shall show locations of each type of material, anchor trenches and the construction baseline.
- C. Provide all submittals in a single coordinated transmittal. Partial submittals will not be accepted. All submittals must be submitted prior to the Geomembrane Preconstruction Meeting and a minimum of four weeks prior to installation.
- D. The acceptable color of the material will be a shade of green. The proposed color and a sample of material and color shall be submitted for acceptance and approval by the Owner and Engineer.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. The TPO geomembrane should be protected from punctures, abrasions, vandalism, excessive heat or cold or other damaging conditions
- B. The TPO geomembrane shall be delivered to the project site intact and free from any tears, abrasion, or damage. Store TPO geomembrane rolls in a dry area off the ground on 4 rails with each rail being a minimum of 3.5 inches wide, and protected from the direct heat of the sun, where possible, and accessories in original containers in a dry area protected from the elements.
- C. Each roll shall be labeled with the manufacturers name, type, lot number, roll number, and roll dimensions (length, width, gross weight).

1. TPO geomembrane or plastic wrapping damaged as a result of storage or handling shall be repaired or replaced, as directed.
 2. TPO geomembrane shall not be exposed to temperatures in excess of 60 Deg C (140 Deg F) or less if recommended by the Manufacturer.
- D. No hooks, tongs or other sharp instruments shall be used for handling the TPO geomembrane.
1. Rolls shall not be lifted by use of cables or chains in contact with the TPO geomembrane.
 2. TPO geomembrane shall not be dragged along the ground.

1.6 PROJECT CONDITIONS

- A. When the weather is of such a nature as to endanger the integrity and quality of the installation, whether this is due to rain, high winds, cold temperatures, or other weather elements, the installation of the geomembrane shall be halted at the direction of, or with the concurrence of, the Owner until the weather conditions are satisfactory.
- B. The contractor shall ensure that adequate dust control methods are in effect to prevent the unnecessary accumulation of dust and dirt on geosynthetic surfaces which hamper the efficient field seaming of geosynthetic panels or performance.
- C. Maintain natural surface water drainage diversions around the work area and provide for the disposal of water which may collect in the work area directly from precipitation falling within the area or from inadequate diversion structures or practices.
- D. All materials shall be placed and spread with low ground pressure equipment (10 psi ground pressure or less) as approved by the CQA Engineer to reduce potential damage to the geosynthetics. The geosynthetics surface shall be off limits to construction traffic. Hard turning of tracked equipment on the protective cover and stone must be avoided.
1. At least 12 inches of separation between the geosynthetics and all low ground pressure equipment shall be maintained.
 2. Stockpiling of materials within the limits of the cell shall be subject to advanced approval by the CQA Inspector. Any hauling equipment (dump trucks, etc.) operating within the cell limits (and including access ramps), shall have a minimum of 4 feet of separation between the vehicle wheels and the geosynthetics.
 3. No vehicle shall access the completed Work unless it can be demonstrated that its weight, movement or activities will not damage the Work.
 4. When damage is suspected, uncover area, repair damage if required, and recover area at no cost to Owner.
 5. Suspect areas may be identified by Owner or Engineer.

1.7 WARRANTIES

- A. Written warranties addressing TPO geomembrane material and installation workmanship shall be furnished by the Contractor and shall be made to the Owner.
- B. Submit material samples and warranties prior to shipment.
- C. Suitability of geosynthetic liner system shall be subject to Owner's approval of warranty.
1. The Manufacturer's warranty shall be against manufacturing defects and workmanship and against deterioration due to ozone, ultra- violet exposure from direct sunlight, and other exposure to the elements, for a period of 20 years on a pro rata basis. The warranty shall be limited to replacement of material, and shall not cover installation of replacement geomembrane.
 2. The Installer's warranty shall state that the materials were properly installed, properly (field and factory) welded, seamed and jointed and will not fail within two years of the date of final acceptance of the Work by the Owner.
 - a. Warranty shall not be prorated.
- D. Warranties shall provide for complete repair/replacement excluding installation costs at no additional cost to the Owner for the warranty period.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS AND/OR GEOMEMBRANE INSTALLERS

- A. Subject to compliance with the Contract Documents, the following manufacturers and installers are acceptable:
 - 1. TPO Geomembrane liners manufacturers:
 - a. Firestone Building Products
 - b. Carlisle SynTec
 - 2. TPO Geomembrane Liner Installers:
 - a. Authorized installers of approved manufacturers.
 - b. Other installers may qualify by providing references for a minimum of 10,000,000 SF of TPO liner installations.

2.2 MATERIALS

- A. The membrane will be Firestone UltraPly TPO 60 mil geomembrane or equivalent.
- B. Accessories will be as supplied or approved by geomembrane manufacturer.
- C. Geomembrane meets or exceeds the property values listed in Table 1.
- D. Interface testing of liner and geotextile will be submitted as specified in Table 2.

Table 1: Physical Properties

Description	Test Method	Property
UNAGED PROPERTIES:		
Thickness (min average)	ASTM D751 and D6878	0.060" (1.52 mm, 60 mil) Lowest individual -10%
Thickness Over Scrim	ASTM D 4637 (Optical Method) 0.060" Membrane	0.024" (0.609 mm) ± 10%
Mass per unit area (min)	ASTM D5261	0.3 lb/sf (1.42 Kg/m ²)
Breaking Strength (TD and MD) (min)	ASTM D 4885	150 ppi (26.3 kN/m)
Elongation at Reinforcement break (TD and MD) (min)	ASTM D 4885	30%
Tearing Strength (TD and MD) (min)	ASTM D 751 (8"x8" specimen)	86 lbf (382 N) 55lbf (245 N)
Brittleness Point (max)	ASTM D 2137	-50°F (-46°C) -40°F (-40°C)
Linear Dimension Change (max)	ASTM D 120 (6 hrs @70° C)	4 %
Ozone Resistance	ASTM D 1149	PASS (no cracks)
Factory Seam Strength (min)	ASTM D 4885	150 ppi (26.3 kN/m)
Puncture Resistance (min)	FTM 101C Method 2031	265 lbf (1174 N)
Water Absorption (max, mass)	ASTM D471 166 hrs at 158 ⁰ F	+/- 3%
HEAT AGED PROPERTIES:		
Breaking Strength (TD and MD) (min)	ASTM D 4885	150 ppi (26.3 kN/m)*
Elongation at Reinforcement Break (TD and MD) (min)	ASTM D 4885	30%*
Tearing Strength (TD and MD) (min)	ASTM D 5884 (8"x8" specimen)	86 lbf (382N)*
Weight Change (max) (Membrane)	ASTM D 471	1% (change in mass)
AGED PROPERTIES:		
Ozone Resistance	ASTM D 1149	PASS (No cracks)
Weather resistance (Retained Values)	ASTM G 151/ G 154	
Visual Inspection		PASS
Breaking Strength, (min)		90% retained
Elongation at Reinforcement Break (min)	ASTM D 4885	90% retained
Resistance to Xenon-Arc Weathering	ASTM G 151/ G155	Pass

*ASTM D 6878 requires retained values of 90% for original breaking strength and elongation and 60% for tearing strength

Table 2: Interface Friction Angles

PROPERTIES	QUALIFIERS	UNITS	VALUES	TEST METHOD
Engineering Properties				
Interface friction between geomembrane liner and geotextile material in the anchor trench	minimum	degrees	22 ⁽¹⁾	ASTM D 5321 ⁽²⁾

- (1) Perform testing using normal stress range of 144 lb/sf, 288 lb/sf and 432 lb/sf.
 (2) Wet the geotextile/TPO geomembrane interface prior to testing: perform test using: (i) normal stress indicator above; and (ii) a strain rate calculated in accordance with ASTM D 3080, Sections 9.12 and 9.13, not to exceed 1 mm/min. (0.04 in./min.).

2.3 MANUFACTURING QUALITY CONTROL

A. Rolls:

1. The Manufacturer will continuously monitor the TPO geomembrane sheets during the manufacturing process for inclusions, bubbles, or other defects.
2. No TPO geomembrane will be accepted that exhibits any defects.
3. The Manufacturer will continuously monitor the TPO geomembrane thickness during the manufacturing process.
4. No TPO geomembrane will be accepted that fails to meet the specified minimum thickness.
5. The Manufacturer will sample and test the geomembrane, at a minimum, at the test frequencies specified in Table 3.
 - a. Samples taken from stored rolls will be taken across the entire width of the roll and will not include the first wrapping or outer layer of the roll (about 3.3 feet).
 - b. Samples taken at the time of manufacturing can be obtained from the start/end of the roll.
 - c. Unless otherwise specified, samples will be 2 feet long by the roll width. The Manufacturer will mark the machine direction on the samples with an arrow.
 - d. Manufacturer quality control data shall accompany the geomembrane shipment.

Table 3: Manufacturer Quality Control Requirements

Material Property	Method	Test Frequency
Thickness	ASTM D751	Per roll
Tensile Properties	ASTM D4885	Once per day or 20,000 lb
Tear Resistance	ASTM D751	Once per day or 45,000 lb
Scrim Orientation	Visual	Every Lot or Every Scrim Roll
Mass per Unit Area	ASTM D5261	Once per day or 200,000 lb
Tear Resistance	ASTM D5884	Once per day or 45,000 lb
Thickness over Scrim	ASTM D6878	45,000 lb or Every other lot

6. Any TPO geomembrane sample that does not comply with the Specifications will result in rejection of the roll from which the sample was obtained. Contractor will replace any rejected rolls at no additional cost to Owner.
7. If a TPO geomembrane sample fails to meet the quality control requirements of this Section, the Manufacturer will sample and test each roll manufactured, in the same resin batch, or at the same time, as the failing roll. Sampling and testing of rolls will continue until a pattern of acceptable test results is established.
8. Additional testing may be performed at the Manufacturer’s discretion and expense, to more closely identify the non-complying rolls and/or to qualify individual rolls.

2.4 CONFORMANCE TESTING

- A. At the Geomembrane Manufacturer’s plant or upon delivery of the rolls of geomembrane at the site, the CQA Officer will verify that samples are removed at the specified frequency and forwarded to the Geosynthetics CQA Laboratory for testing to verify conformance to both the design specifications and the list of guaranteed properties. The minimum number of tests to be performed and test procedures will be as indicated in Table 4.
- B. Samples will be taken across the entire width of the roll and will not include the first linear 3 ft. Unless otherwise specified, samples will be 3-ft long by the roll width. The CQA Officer will mark the machine direction on the samples with an arrow. The required minimum sampling frequencies are provided in Table 4.
- C. The CQA Officer will examine the results from laboratory conformance testing and will report non-conformance to the Project Manager.
- D. The following procedure will apply whenever a sample fails a conformance test that is conducted by the Geosynthetics CQA Laboratory:
 - 1. Installer will replace the roll of geomembrane that is in nonconformance with the specifications with a roll that meets specifications;
 - 2. Installer will remove conformance samples for testing by the Geosynthetics CQA Laboratory from the closest numerical roll on both sides of the failed roll.
 - 3. These two samples must both conform to specifications. If either of these samples fail, then every roll of geomembrane on site and every roll delivered subsequently must be tested by the Geosynthetics CQA Laboratory for conformance to the specifications. This additional conformance testing will be at the expense of the Installer.
- E. The CQA Officer will document actions taken in conjunction with conformance test failures.

Table 4: Geomembrane Conformance Testing Requirements

TEST NAME	TEST METHOD	MINIMUM FREQUENCY OF TESTING
Thickness	ASTM D 4637751	1 test per 100,000 ft ²
Tensile Strength at Break	ASTM D 4885	1 test per 100,000 ft ²
Elongation at Break	ASTM D 4885	1 test per 100,000 ft ²
Tear Strength	ASTM D 5884	1 test per 100,000 ft ²
Puncture Resistance	ASTM D 4833 FTM 101C Method 2031	1 test per 100,000 ft ²
Resistance to Xenon-Arc Weathering	ASTM G 155	Manufacturer’s Certification Only
Ozone Resistance	ASTM D 1149	1 test per 100,000 ft ²

2.5 EQUIPMENT AND ACCESSORIES

- A. Welding and Seaming Equipment:
 - 1. Equipped with gages showing temperatures at the nozzle or at the wedge (wedge welder).
 - 2. Maintained in adequate numbers to avoid delaying work.

3. Supplied by a power source capable of providing constant voltage under a combined-line load.
 4. Electric generator shall not be placed on the TPO geomembrane.
- B. Field Tensiometer:
1. Provide a tensiometer for on-site shear and peel testing of TPO geomembrane seams.
 - a. Tensiometer shall be in good working order.
 - b. Built to ASTM specifications.
 - c. Accompanied by evidence of calibration of equipment and gages within the past six months.
 2. Tension meter:
 - a. Motor driven.
 - b. Jaws capable of traveling a measure rate of 2 IN per minute.
 - c. Equipped with a gauge that measures the force in unit pounds exerted between the jaws.
 - d. Digital readout.
- C. Punch Press:
1. Provide a punch press for the onsite preparation of specimens for testing.
 2. Capable of cutting specimens in accordance with ASTM D4437.
- D. Air Lance Test:
1. Provide equipment for air lance test per ASTM D4337.
- E. Equipment necessary to perform "Pressurized Air Channel Evaluation of Dual Seamed Geomembranes" in accordance with ASTM D5820.
- F. Gages:
1. Calibrated within past six months.
 2. Specified test values reading near mid-range of the gage scale.
- G. Equipment necessary to perform "Non-Destructive Testing of Geomembrane Seams Using The Spark Test" in accordance with ASTM D6365.

PART 3 - EXECUTION

3.1 GEOSYNTHETIC LINER SYSTEM

- A. Geomembrane Subgrade:
1. Protect subgrade at all times from damage until such time as the placement of TPO geomembrane liner and other components of the geosynthetic liner system are complete.
 2. The subgrade shall be prepared in a manner consistent with proper subgrade preparation techniques for the installation of TPO Geomembrane.
 - a. The subgrade shall be properly compacted so as not to settle and cause excessive strains in the TPO Geomembrane or other synthetic liner materials.
 - b. Prior to installation, ensure a surface free of debris, roots, or angular stones larger than 1/2 inch.
 - c. In addition, ensure that the subgrade has been rolled to provide a uniform surface.
 - d. During installation, ensure that rutting or ravelling is not caused by installation equipment or weathering.
- B. Anchor Trenches:
1. Geosynthetic materials placed on side slopes shall be anchored into trenches as detailed on the Contract Drawings.
 2. Excavation, backfill and compaction shall be in accordance with Section 02200.
- C. TPO Geomembrane:
1. General:
 - a. Installer of TPO geomembranes is responsible for handling, fitting, welding, seaming, jointing and testing of geosynthetic materials sheets or blankets in the field in accordance with the Construction Quality Assurance (CQA) Plan.

- b. These responsibilities include but are not limited to:
 - 1) Acceptance (in writing) of the geosynthetic materials sheets or blankets from the transporter.
 - 2) Acceptance (in writing) of the surface which will serve as a base for the TPO geomembrane.
 - a) This acceptance shall precede installation of the TPO geomembrane.
 - b) Shall state that the Installer has inspected the surface, and reviewed the Specifications for material and placement, and finds all conditions acceptable for placement of TPO geomembrane liners.
 - c) Shall explicitly state any and all exceptions to acceptance.
 - 3) Handling, welding, seaming, jointing, testing and repair of TPO geomembrane liners and other geosynthetic materials in compliance with this Specification and with written procedures manuals prepared by the Manufacturer or Fabricator.
 - a) Manual shall be submitted to the Engineer together with Shop Drawings showing the layout of TPO geomembrane within the facility.
 - (1) Do not deviate from the procedures included in the manual.
 - b) TPO Geomembrane shall not be placed upon frozen foundation, standing water or other conditions which will result in deterioration of the foundation.
 - c) TPO Geomembrane liner materials shall be laid out according to plans previously approved by the Engineer.
 - d) Adjacent rolls of TPO geomembrane shall overlap a minimum of 3 IN.
 - 4) Repair or replacement of defects in the geosynthetic materials as required by the Inspector or the Owner.
 - 5) Installer and Manufacturer may be the same firm.
- 2. Panel deployment:
 - a. Subgrade Preparation:
 - 1) Prepare subgrade in a manner consistent with proper subgrade preparation techniques for the installation of TPO geomembrane liner.
 - 2) Properly compact the subgrade so as not to settle and cause excessive strains in the TPO geomembrane liner.
 - 3) Prior to installation, ensure a surface free of debris, roots, or angular stones larger than 1/2 IN.
 - 4) Subgrade soils proof-rolled with a ten (10) ton drum roller, two (2) passes parallel to slope or as directed by CQA Inspector. The subbase shall be compacted and proof-rolled under observation of the CQA Inspector to assure the maximum practical compaction under the existing field conditions has been achieved. See specification Section 02200 for project specific compaction requirement.
 - 5) Ensure rutting or raveling is not caused by installation equipment or weather.
 - 6) Ensure that lines and grades have been verified by the Contractor and a subgrade acceptance form has been submitted.
 - b. Construct and backfill anchor trenches
 - c. Deploy TPO geomembrane liner in a manner to ensure it is not damaged
 - d. On slopes, anchor the TPO geomembrane liner securely and deploy it down the slope in a controlled manner.
 - e. Weight the TPO geomembrane liner with sandbags or equivalent in the presence of wind.
 - f. Minimize cutting the TPO geomembrane liner. Whenever possible, overlap instead of cutting material. If cutting is required, cut TPO geomembrane liner with a cutter or other approved device. Seal all cut edges, as recommended by Manufacturer.
 - g. Only those panel/sheets that can be seamed in 1 day shall be deployed.
 - h. Place panels with minimal handling.
 - 1) Protect panels from tear, puncture or abrasion.
 - i. Equipment used to deploy the geomembrane shall not damage the TPO geomembrane.
 - j. Minimize foot traffic.
 - 1) Do not allow personnel access to wet or slippery liners without adequate safety precautions.

- 2) Do not allow footwear that may damage the geomembrane.
- k. Ballast with sandbags to prevent wind uplift as recommended by Manufacturer based on local climatic conditions.
 - 1) Remove and replace all wind damaged panels at no additional cost to Owner.
 - 2) If wind causes panels to be displaced, displaced panel may not be reused.
- l. Install TPO geomembrane in stress free, tension free and relaxed condition.
 - 1) Account for temperature and weather-related impacts when deploying and covering.
 - 2) Stretching to fit and folding are not permitted.
- m. Do not allow TPO geomembrane to bubble, fold, or create ripples as a result of deployment of drainage layer or protective soil cover placement.
 - 1) Except as noted on Contract Drawings no folds in TPO geomembrane will be allowed.
- n. Any panel exhibiting stretching caused by placement, covering techniques, or wind shall be removed and may not be incorporated in the final construction.
- o. Field seaming:
 - 1) Field seaming shall be done in accordance with seaming recommendations furnished by the geomembrane Manufacturer, referenced EPA documents, and this specification.
 - 2) Each piece of seaming equipment and each operator shall perform trial seams at the start of a shift, whenever equipment has broken down or seaming is interrupted for more than 30 minutes, and at other times at the discretion of the Installer and Inspector.
 - 3) Trial seams shall use the same seaming materials and methods to be used in the actual construction.
 - 4) Surfaces to be seamed shall be clean and dry at the time of seaming.
 - a) Precipitation and ponding of water on the TPO geomembrane shall cause termination of seaming operations.
 - b) TPO geomembrane shall not be seamed when ambient temperatures are below 41 DegF or above 104 DegF, without written consent of TPO geomembrane Manufacturer and Engineer.
 - 5) TPO geomembrane sheets shall be seamed continuously without fishmouths or breaks in the seam.
 - a) Where fishmouths are unavoidable, the sheet shall be slit to a point such that the sheet lies flat and with no remaining wrinkle.
 - b) The two edges of the slit shall be seamed together provided that the overlap for this seam shall be a minimum of 6 IN.
 - c) Areas of the slit which do not achieve an overlap of 6 IN, including the terminus of the slit, shall be provided with a patch as discussed below.
 - 6) All TPO geomembranes shall be seamed by thermal fusion methods as recommended by the TPO geomembrane Manufacturer.
 - a) TPO geomembrane seaming shall be either hot-air or double wedge welded as approved by the Engineer.
 - 7) Manufacturer's seaming instructions shall specifically address seaming materials, temporary and permanent jointing, seaming temperatures including temperatures for seaming materials, seam finishing and curing.
 - 8) A copy of Manufacturer's seaming instructions shall be available on site at all times and shall not be deviated from without written approval of the Manufacturer and Engineer.
 - 9) All panels/sheets should be overlapped a minimum of 3 IN.
 - 10) Seaming shall not be conducted in the presence of standing water.
 - a) The seamed area shall be cleaned of dust, dirt and foreign material prior to and during the seaming operation.
 - 11) Seaming shall extend to the outside edge of panels/sheets to be placed in anchor and/or drainage trenches.

- 12) Tack welds shall conform to manufacturer's seaming techniques and shall not damage underlying membrane.
- p. Patching:
 - 1) Defects in and damage to TPO geomembrane sheets shall be repaired by seaming a patch over the defect.
 - a) The patch material shall consist of an undamaged piece of TPO geomembrane cut to provide a minimum of 6 IN of overlap in all directions from the defect.
 - b) Round corners shall be utilized on all patches. No bead or spot patching will be accepted.
 - c) Torn or permanently twisted TPO geomembrane shall be replaced at no expense to the Owner.
 - 2) Test all patch seams non-destructively using the air lance tests .
 - a) Test patch seams destructively if the seam is greater than 100 feet in contiguous length (i.e. a single seam greater than 100 feet).
 - b) Perform a destructive test for every 100 feet of contiguous seam over 200 total feet of contiguous seam. For example if a patch seam is 340 feet, 2 destructive tests would be required for the seam. Smoking is not permitted while on the geomembrane.
- q. Field Panel Identification: The Installer's CQC Consultant will document that the Geomembrane Installer labels each field panel with an "identification code" consistent with the approved panel layout plan. The location of the label and the color of marker used must be as agreed to in the QA/QC Preconstruction Meeting.
- r. Exposed reinforcement from cut TPO edges must be sealed with a hot-air weld.

3.2 FIELD QUALITY CONTROL

- A. The CQA inspector shall not be a part of the installation program and shall not serve as a substitute for performing the duties or certification required of the Manufacturer and Installer.
 1. The CQA inspector's responsibilities include, but are not limited to:
 - a. Inspection of the material and the handling and field installation of the geomembranes. Inspection of all welds, repairs and quality control test results.
 - b. All exceptions to material or installation shall be documented and furnished to the CQA firm in writing within 48 HRS of discovery.
 - c. Inspection and Certification of TPO geomembrane integrity until completion of placement of protective soil cover.
- B. Non-Destructive Testing:
 1. The Geosynthetics Installer will nondestructively test all field seams over their full length using a air lance test (TPO hot air weld), vaccum box (HDPE and LLDPE extrusion weld), or air pressure test (TPO, HDPE and LLDPE double fusion seams). Continuity testing will be carried out as the seaming work progresses, not at the completion of all field seaming. The Installer will complete any required repairs in accordance with specifications. The following procedures will apply to locations where seams cannot be nondestructively tested:
 - a. If the seam is accessible to testing equipment prior to final installation, the seam will be nondestructively tested prior to final installation.
 - b. If the seam cannot be tested prior to final installation, the seaming operations must be observed in their entirety by the CQA Officer for uniformity and completeness.
 2. Air Pressure Testing (For Double Fusion Seams Only):
 - a. The following procedures are applicable to those processes that produce a double seam with an enclosed space.
 - b. The equipment will comprise the following.
 - 1) An air pump (manual or motor driven), equipped with a pressure gauge, capable of generating and sustaining a pressure between 25 and 30 psi, mounted on a cushion to protect the geomembrane.
 - 2) A rubber hose with fittings and connections.
 - 3) A sharp hollow needle, or other approved pressure feed device.
 - c. The following procedures will be followed.

- 1) Seal both ends of the seam to be tested.
 - 2) Insert needle, or other approved pressure feed device, into the channel created by the fusion weld.
 - 3) Insert a protective cushion between the air pump and the geomembrane.
 - 4) Energize the air pump to a pressure between 25 and 30 psi, close valve, allow two minutes for pressure to stabilize, and sustain the pressure for not less than 5 minutes.
 - 5) If loss of pressure exceeds 4 psi, or if the pressure does not stabilize, locate faulty area and repair in accordance with Section 3.3.
 - 6) Cut opposite end to verify continuity of seam, remove needle, or other approved pressure feed device, and repair in accordance with Section 3.3.
3. Air Lance Testing
- a. Mechanical point stressing method (see ASTM D4437, article 4.5) or the air lance test method will be used to verify seam integrity for hot air seams and wedge seams without air channel. Since the mechanical point stressing method cannot evaluate the bond over its entire width, and since there is a potential for damaging the membrane with the sharp point of the probe, the air lance test method is recommended to verify seam integrity.
- C. Trial Seams
1. Trial seams shall be made prior to production seaming by all seamers and by all equipment to be used during production seaming. The trial seams shall be made on fragment pieces of geomembrane to verify that seaming conditions are adequate. Such trial seams shall be made at the beginning of each seaming period, seaming operation has been suspended for more than 1/2 hour, breakdown of the seaming equipment occurs or at least once each five hours, for each seaming apparatus used that day. Also, each seamer shall make at least one trial seam each day. Trial seams shall be made under the same conditions as actual seams. The trial seam sample shall be at least 5 ft long by 1 ft wide (after seaming) with the seam centered lengthwise. Seam overlap shall be as specified.
 2. Two adjoining specimens, each 1-inch wide for peel and 2-inch wide for shear, shall be cut from the trial seam sample by the Geosynthetics Installer. Fully support the test specimen within the grips across the width of the specimen. The specimens shall be tested in shear and peel, using a field tensiometer, and the specimen shall fail by film tear bond rather than in the seam. The minimum requirements for the seams strengths shall be as specified in Table 5. If a specimen fails, the entire operation shall be repeated. If the additional specimen fails, the seaming apparatus or seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved.
- D. After completion of the above-described tests, the remaining portion of the trial seam sample can be discarded. If a trial seam sample fails a test, then a destructive test seam sample shall be taken from the seams completed by the seamer during the shift related to the considered trial seam. These samples shall be forwarded to the CQA Consultant and, if they fail the tests, the procedure indicated in Paragraph 3.3 of this section shall apply. The conditions of this paragraph shall be considered as met for a given seam if a destructive seam test sample has already been taken from the considered seam
- E. Destructive Testing:
- F. Destructive Seam Testing:
1. A minimum of one destructive test per 500 LF of seam, and as many other samples as CQA firm determines appropriate, shall be obtained at locations specified by the CQA firm.
 - a. Sample locations shall not be identified prior to seaming.
 - b. The samples shall be a minimum of 12 IN wide by 48 IN long with the seam centered lengthwise.
 - c. Each sample shall be cut into three equal pieces with one piece retained by the Installer, one piece given to a CQA Testing Laboratory, and the remaining piece given to the CQA Engineer for quality assurance testing and/or permanent record.
 - d. Each sample shall be numbered and recorded on the final panel layout record drawing, and cross-referenced to a field log which identifies:

- 1) Panel/sheet number.
 - 2) Seam number.
 - 3) Top sheet.
 - 4) Date and time cut.
 - 5) Ambient temperature.
 - 6) Seaming unit designation.
 - 7) Name of seamer.
 - 8) Seaming apparatus temperature and pressures (where applicable).
2. A minimum of four 1 IN wide replicate specimens shall be cut from the Installer's sample.
 - a. A minimum of 2 specimens shall be tested for shear strength and 2 for peel adhesion using an approved field quantitative tensiometer. Jaw separation speed shall be 2 IN per minute.
 - b. To be acceptable, all field test specimens must meet the specified seam strength requirements and all must fail as Film Tear Bond.
 - c. If all field tests pass, 5 specimens shall be tested at the CQA Testing Laboratory for shear strength and 5 for peel adhesion in accordance with ASTM D4437.
 - d. To be acceptable, 4 out of 5 replicate test specimens must meet the specified seam strength requirements and fifth sample must meet 80% required strength and fail at Film Tear Bond.
 - e. Shear elongation and Peel separation shall not exceed values given in GRI GM19

Table 5: Seam Strength and Related Properties of Thermally Bonded TPO Geomembrane per ASTM D 4437/GM 19

Geomembrane Nominal Thickness	60 mils
Hot Wedge Seams ⁽¹⁾	
Shear strength ⁽²⁾ , lb/in	150
Peel strength ⁽²⁾ , lb/in	20
Hot-air Seams	
Shear strength ⁽²⁾ , lb/in	150 125
Peel strength ⁽²⁾ , lb/in	20

Notes:

1. Also for hot air seaming methods
2. Value listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values.
3. For destructive samples which have failed the passing criterion, the Contractor will reconstruct all the field seams between any two previous passed seam locations which include the failed seam or will go on both sides of the failed seam location (10 feet minimum), take another sample each side and test both. If both pass, the Contractor may patch or cap strip the seam between the passed samples. If either fails, the Contractor will remove and replace the entire seam. In all cases, acceptable field seams must be bounded by two passed test locations. The decision of the CQA Engineer will be final.
 - a. In addition, all destructive seam sample holes shall be repaired the same day as cut.
 - b. Certified test results on all field seams shall be submitted to and approved by the CQA Engineer prior to acceptance of the seam.
4. All repaired areas shall be non-destructively tested and destructively tested as described in Part 3.1B.2.p (2) of this specification.
5. Destructive testing shall be performed by a CQA Testing Laboratory not employed by the Installer.
6. A map showing the locations, number and type of all patches shall be prepared and provided to the Owner.

7. Documentation: The following documentation must be maintained at the project site for review by the CQA Engineer or Inspector.
 - a. Geomembrane Installer's Documentation:
 - 1) Daily Log: daily record that summarizes panels deployed, seams completed, seam testing, seam repair, personnel on site, weather conditions, and equipment on site.
 - 2) Material Conformance: maintain original conformance certificate(s) from geomembrane manufacturer.
 - 3) Subgrade Acceptance Log: maintained originals of subgrade acceptance forms for each panel and signed by the Geomembrane Installer.
 - 4) Panel Log: provides geomembrane roll number used and subgrade acceptance for each panel deployed.
 - 5) Seam Testing Log: provides a complete record of all nondestructive and destructive seam tests performed as part of the Geomembrane Installer's QC program.
 - 6) Seam/Panel Repair Log: provides a complete record of all repairs and vacuum box testing of repairs made to defective seams or panels.
 - 7) As-Built Drawing: maintain an as-built drawing updated on a weekly basis.

3.3 DEFECTS AND REPAIRS

- A. All seams and non-seam areas of the geomembrane will be examined by the CQA Officer for evidence of defects, holes, blisters, undispersed raw materials and any sign of contamination by foreign matter. The surface of the geomembrane shall be clean at the time of examination. The geomembrane surface shall be swept or washed by the Geosynthetics Installer if surface contamination inhibits examination. The Geosynthetics Installer shall ensure that this examination of the geomembrane precedes any seaming of that section.
- B. Each suspect location, both in seam and non-seam areas, shall be nondestructively tested using the methods described, as appropriate. Each location that fails nondestructive testing shall be marked by the CQA Consultant and repaired by the Geosynthetics Installer. Work shall not proceed with any materials that will cover repaired locations until laboratory test results with passing values are available.
- C. When seaming of a geomembrane is completed (or when seaming of a large area of a geomembrane is completed) and prior to placing overlying materials, the CQA Consultant shall identify excessive geomembrane wrinkles. The Geosynthetics Installer shall cut and reseam all wrinkles so identified. The seams thus produced shall be tested like any other seams.
- D. Repair Procedures:
 1. Any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, shall be repaired by the Geosynthetics Installer. Several repair procedures are specified below. The final decision as to the appropriate repair procedure shall be agreed upon between the CQA Consultant and the Geosynthetics Installer. The procedures available include:
 - a. patching - used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter;
 - b. abrading and reseaming - used to repair small sections of extruded seams;
 - c. spot seaming - used to repair small tears, pinholes, or other minor, localized flaws;
 - d. capping - used to repair long lengths of failed seams; and
 - e. removing bad seam and replacing with a strip of new material seamed into place (used with long lengths of fusion seams).
 2. In addition, the following shall be satisfied:
 - a. surfaces of the geomembrane that are to be repaired shall be abraded no more than one hour prior to the repair;
 - b. all surfaces must be clean and dry at the time of repair;
 - c. all seaming equipment used in repair procedures must be approved by Engineer;
 - d. the repair procedures, materials, and techniques shall be approved in advance, for the specific repair, by the CQA Consultant and Geosynthetics Installer;

- e. patches or caps shall extend at least 6 inches beyond the edge of the defect, and all corners of patches shall be rounded with a radius of at least 3 inches.; and
 - f. the geomembrane below large caps shall be appropriately cut to avoid water or gas collection between the two sheets.
- E. Each repair shall be numbered and logged and shall be nondestructively tested using the methods described in this section, as appropriate. Repairs that pass the nondestructive test shall be taken as an indication of an adequate repair. Failed tests will require the repair to be redone and retested until a passing test result is achieved. At the discretion of the CQA Consultant, destructive testing may be required on large caps at no additional cost to OWNER.

3.4 DOCUMENTATION

- A. The following documentation must be maintained at the project site for review by the CQA Engineer or Inspector as the Geomembrane Installer's Documentation:
- 1. Daily Log: daily record that summarizes panels deployed, seams completed, seam testing, seam repair, personnel on site, weather conditions, and equipment on site.
 - 2. Material Conformance: maintain original conformance certificate(s) from geomembrane manufacturer.
 - 3. Subgrade Acceptance Log: maintained originals of subgrade acceptance forms for each panel and signed by the Geomembrane Installer.
 - 4. Panel Log: provides geomembrane roll number used and subgrade acceptance for each panel deployed.
 - 5. Seam Testing Log: provides a complete record of all nondestructive and destructive seam tests performed as part of the Geomembrane Installer's QC program.
 - 6. Seam/Panel Repair Log: provides a complete record of all repairs and air lance testing of repairs made to defective seams or panels.
 - 7. As-Built Drawing: maintain an as-built drawing updated on a weekly basis.

3.5 GEOSYNTHETIC LINER SYSTEM ACCEPTANCE

- A. Contractor shall retain all ownership and responsibility for the geosynthetic liner system until final acceptance by the Owner.
- 1. Owner will accept the geosynthetic liner system installation when the installation is finished and all required warranties, test results, and documentation from the Contractor, Manufacturer, Inspector and Installer have been received and approved, and verification of the adequacy of all field seams and repairs, including associated testing, is complete.

END OF SECTION

SECTION 02775
LLDPE GEOMEMBRANE LINER SYSTEM

PART 1 - GENERAL

1.01 SUMMARY

- A. Section Includes:
 - 1. Furnishing, installation, quality control, and testing of a LLDPE geomembrane liner with texture on both sides. LLDPE geomembrane liner will be used as part of the final cover system.
- B. Related Sections include but are not necessarily limited to:
 - 1. Section 02200 – Earthwork: Landfill.
 - 2. Construction Quality Assurance Plan.

1.2 QUALITY STANDARDS

- A. Referenced Standards:
 - 1. ASTM International (ASTM).
 - a. ASTM D1004, Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting.
 - b. ASTM D1238 Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.
 - c. ASTM D1505 Standard Test Method for the Density of Plastics by the Density-Gradient Technique. ASTM D1603 Standard Test Method for Carbon Black in Olefin Plastics.
 - d. ASTM D1603 Standard Test Method for Carbon Black in Olefin Plastics.
 - e. ASTM D3895 Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis.
 - f. ASTM D4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique.
 - g. ASTM D4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
 - h. ASTM D5199 Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.
 - i. ASTM D5321, Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method.
 - j. ASTM D5596 Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics.
 - k. ASTM 5641 Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber.
 - l. ASTM D5820, Standard Practice for Pressured Air Channel Evaluation of Dual Seamed Geomembrane.
 - m. ASTM D5994 Test Method for Measuring the Core Thickness of Textured Geomembranes.
 - n. ASTM D6365 Non-Destructive Testing of Geomembrane Seams Using the Spark Test
 - o. ASTM D6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.
 - p. ASTM D6693 Standard Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexibly Polypropylene Geomembranes.
 - 2. The Geosynthetic Research Institute (GRI).
 - a. GRI GM12, Asperity Measurement of Textured Geomembranes Using a Depth Gage.
 - b. GRI GM17 Test Methods, Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes.

- c. GRI GM19, Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes
- B. Qualifications:
- 1. Each manufacturing and fabricating firm shall demonstrate 5 years continuous experience with a minimum of 10,000,000 SF of LLDPE geomembranes.
 - 2. Installer:
 - a. Demonstrate 5 years continuous experience with a minimum 10,000,000 SF of LLDPE geomembranes.
 - b. Trained and certified by at least one of the named manufacturers in this Specification (not necessarily the manufacturer supplying materials for this Project).
 - c. Geomembrane Installer Personnel Qualifications:
 - 1) Installation Superintendent shall have worked in a similar capacity on at least five geomembrane liner jobs similar in size and complexity to the project described in the Contract Documents.
 - 2) The Master Welder shall have completed a minimum of 5,000,000 SF of LLDPE geomembrane seaming work using the type of seaming apparatus proposed for use on this Project.
 - 3) Other welders shall have seamed a minimum of 1,000,000 SF of LLDPE geomembrane.
 - 3. CQC Testing Laboratory shall demonstrate 3 years of continuous experience in similar geosynthetic materials testing.
- C. Quality Assurance / Control:
- 1. The Owner or Engineer's representative will conduct independent testing to support construction quality assurance program and to provide documentation of such to appropriate regulatory agencies.
 - 2. Unless specifically superseded by these contract documents or approved plans submitted by the Contractor, the geosynthetic materials shall be manufactured, stored, placed, seamed, tested and protected as described in EPA/600/R-93/182 and EPA/530/SW-91/051.
 - a. This specifically includes:
 - 1) Material Composition.
 - 2) Manufacturing.
 - 3) Handling and Packaging.
 - 4) Shipment.
 - 5) Storage (Manufacturer and Site).
 - 6) Placement:
 - a) Seaming and Joining.
 - b) Destructive and Non Destructive Testing.
 - c) Protection, Backfilling and Covering.
 - 7) Conformance Testing.
 - 8) Anchoring and Anchor Trenches.
 - 9) Access Roads/Ramps.
- D. CQA Plan Implementation: Construction Quality Control will be performed in accordance with the CQA Plan prepared for this project. The Contractor and Geomembrane Installer should familiarize themselves with the CQA Plan.
- E. Certifications:
- 1. Certifications are required for various aspects of the project related to the LLDPE geomembrane liner system construction.
 - a. Utilize certification forms approved for use on this project by the Owner and Engineer.
- F. Installer's construction quality control programs to include, but not be limited to, product acceptance testing, installation testing, including both nondestructive and destructive quality control field testing of the sheets and seams during installation of the geomembrane, proposed methods of testing geosynthetic joints and connections at appurtenances for continuity, documentation and changes, alterations, repairs, retests, and acceptance.

- G. Geomembrane Installer's installation manual to include:
- 1) Ambient temperature at which the seams are made
 - 2) Control of panel lift up by wind
 - 3) Acceptable condition of the subsurface beneath the geomembrane
 - 4) Quality and consistency of the welding material
 - 5) Proper preparation of the liner surfaces to be joined
 - 6) Cleanliness of the seam interface (e.g., the amount of airborne dust and debris present)
 - 7) Proposed details for connecting the LLDPE liner to appurtenances, i.e. penetrations of the containment facilities.
 - 8) A complete description of seaming by extrusion welding and hot-wedge welding.
 - 9) Requirements of the Manufacturer's Installation Manual unless exceptions are noted and approved by the Engineer.

1.3 DEFINITIONS AND RESPONSIBILITIES

- A. Geomembrane Manufacturer: Manufacturer of geomembranes producing geomembrane sheets from resin and additives. The manufacturer is responsible for producing geomembrane sheet which complies with these Specifications. These responsibilities include but are not limited to:
1. Acceptance of the resin and additives from chemical formulators. Testing of the raw resin and additives to ensure compliance with the manufacturer's specifications and with this Specification.
 2. Formulation of the resin and additives into geomembrane sheeting using mixing and extrusion equipment.
 3. Testing of the geomembrane sheet to ensure compliance with manufacturer's specification and this Specification.
 4. Shipping of the geomembrane sheet to installer designated facilities.
 5. Certification of the raw materials and finished geomembrane sheet to comply with this Specification.
 6. Certification of installer's training, experience, and methods for welding and inspection of geomembrane installations in compliance with manufacturer's standards.
- B. Geomembrane Installer. Installer of geomembranes are responsible for handling, fitting, welding, and testing of geomembrane sheets or blankets in the field. These responsibilities include but are not limited to:
1. Acceptance (in writing) of the geomembrane from the manufacturer.
 2. Acceptance (in writing) of the surface which will serve as a base for the geomembrane. This acceptance shall precede installation of the geomembrane, and shall state that the installer has inspected the surface, and reviewed the Specifications for material and placement, and finds all conditions acceptable for placement of geomembrane liners. The written acceptance shall explicitly state any and all exceptions to acceptance.
 3. Handling, welding, testing, and repair geomembrane liners in compliance with this Specification and the Geomembrane Installer's Installation Procedures Manual.
 4. Performance of QC testing and record keeping as required by the approved Geomembrane Installer's Field Installation Procedures Manual.
 5. Repair or replacement of defects in the geomembrane as required by the Installer's CQC Consultant or the CQA Inspector.
- C. CQA Inspector:
1. Inspectors of LLDPE geomembrane are the individuals responsible for observing field installation of the geosynthetic materials and providing the Manufacturer, Installer, CQA Engineer, and Owner with verbal and written documentation of the compliance of the installation with this specification and with written procedures manuals prepared by the Manufacturer or Installer.
- D. CQA Testing Laboratory shall:
1. Perform destructive testing of the LLDPE geomembrane.
 2. Perform conformance testing of LLDPE geomembrane.

- E. Installer's CQC Consultant: Responsible for observing field installation of the geomembrane and performance of material conformance and CQC testing to provide the Contractor with verbal and written documentation of the compliance of the installation with these Specifications.
- F. CQA Engineer: Responsible for implementing CQA Plan including overviewing material conformance testing, field installation of the geomembrane, and CQC activities, and to perform limited CQA conformance testing to provide Owner with verbal and written documentation of the compliance of the installation with these Specifications. The CQA Engineer will use the written results of the CQC program and the CQA program in the preparation of the facility Certification Document. The CQA Engineer reports to the Owner and is not part of this contract.
- G. Refer to the accompanying CQA Plan for additional definitions.

1.4 SUBMITTALS

- A. Shop Drawings:
 - 1. Submit for Engineer's approval Shop Drawings, including:
 - a. Manufacturer's certification that raw materials and sheet materials comply with required materials, mil thickness, and material properties.
 - 1) Original certificates are required.
 - b. Manufacturer/Fabricator/Installer quality control requirements.
 - c. Qualifications and experience of key personnel per 1.2 B of this section.
 - d. Manufacturer's written acceptance of Geomembrane Installer's qualifications for installation of the LLDPE geomembrane.
 - e. LLDPE Geomembrane layout plan with proposed size, number, position and sequencing of liner panels and showing the location and direction of all field or factory joints.
 - 1) Proposed details for connecting the geosynthetic materials to appurtenances.
 - 2) Proposed methods of welding, seaming or jointing geosynthetic materials.
 - 3) Proposed method and sequencing for placement of drainage layer on top of the LLDPE geomembrane liner.
 - 4) Proposed method of testing LLDPE geomembrane and other geosynthetic materials, joints and connections at appurtenances for continuity.
 - 5) Location and configuration of haul roads and access points.
 - 6) Proposed details for anchor trench if different than included in Contract Documents.
- B. Miscellaneous:
 - 1. Test results:
 - a. Resin test, tests of sheet material and factory seam tests at frequency specified in respective quality control manuals.
 - 1) Results shall include or bracket the rolls delivered for use in the Work.
 - b. Daily test seam results.
 - c. Daily results of production seam testing.
 - 2. Warranties as described below.
 - 3. Submit written certifications that:
 - a. Utilize certification forms approved for use on this project by the Owner and Engineer. Make appropriate number of copies, as required.
 - b. The LLDPE geomembrane material delivered to site meets the requirements of this Specification.
 - c. The LLDPE geomembrane was received and accepted in undamaged condition from shipper.
 - d. The LLDPE geomembrane liner was installed in accordance with this Specification and with approved Shop Drawings.
 - e. The LLDPE geomembrane joints were inspected, tested for strength and continuity, and passed all inspections and tests.
 - 1) All test and inspection data shall be incorporated into this certification.

- f. The drainage composite and protective cover soil on top of the LLDPE geomembrane liner was placed properly and carefully.
 - 4. Manufacturer/Installer's Field Installation Procedures Manual shall clearly identify any exceptions taken to the specified execution of the Work.
 - 5. Record Drawings: Submit reproducible drawings of record showing changes from the approved installation drawings. The record drawings shall include the identity and location of each repair, cap strip, penetration, boot, and sample taken from the installed geosynthetic for testing. The record drawings shall show locations of each type of material, anchor trenches and the construction baseline.
- C. Provide all submittals in a single coordinated transmittal. Partial submittals will not be accepted. All submittals must be submitted prior to the Geomembrane Preconstruction Meeting and a minimum of four weeks prior to installation.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Unused or stockpiled LLDPE geomembrane shall be stored in accordance with the manufacturer's recommendations.
- B. Each roll shall be labeled with the manufacturer's name, type, lot number, roll number, and roll dimensions (length, width, gross weight).
 - 1. LLDPE geomembrane or plastic wrapping damaged as a result of storage or handling shall be repaired or replaced, as directed.
 - 2. LLDPE geomembrane shall not be exposed to temperatures in excess of 60 Deg C (140 Deg F) or less if recommended by the Manufacturer.
- C. No hooks, tongs or other sharp instruments shall be used for handling the LLDPE geomembrane.
 - 1. Rolls shall not be lifted by use of cables or chains in contact with the LLDPE geomembrane.
 - 2. LLDPE geomembrane shall not be dragged along the ground.

1.6 PROJECT CONDITIONS

- A. When the weather is of such a nature as to endanger the integrity and quality of the installation, whether this is due to rain, high winds, cold temperatures, or other weather elements, the installation of the geomembrane shall be halted at the direction of, or with the concurrence of, the Owner until the weather conditions are satisfactory.
- B. The contractor shall ensure that adequate dust control methods are in effect to prevent the unnecessary accumulation of dust and dirt on geosynthetic surfaces which hamper the efficient field seaming of geosynthetic panels or performance.
- C. Maintain natural surface water drainage diversions around the work area and provide for the disposal of water which may collect in the work area directly from precipitation falling within the area or from inadequate diversion structures or practices.
- D. All materials shall be placed and spread with low ground pressure equipment (10 psi ground pressure or less) as approved by the CQA Engineer to reduce potential damage to the geosynthetics. The geosynthetics surface shall be off limits to construction traffic. Hard turning of tracked equipment on the protective cover and stone must be avoided.
 - 1. At least 12 IN of separation between the geosynthetics and all low ground pressure equipment shall be maintained.
 - 2. Stockpiling of materials within the limits of Phase I shall be subject to advanced approval by the CQA Inspector. Any hauling equipment (dump trucks, etc.) operating within the Phase I limits (and including access ramps), shall have a minimum of 4 feet of separation between the vehicle wheels and the geosynthetics.
 - 3. No vehicle shall access the completed Work unless it can be demonstrated that its weight, movement or activities will not damage the Work.
 - 4. When damage is suspected, uncover area, repair damage if required, and recover area at no cost to Owner.
 - 5. Suspect areas may be identified by Owner or Engineer.

1.7 WARRANTIES

- A. Written warranties addressing LLDPE geomembrane material and installation workmanship shall be furnished by the Contractor and shall be made to the Owner.
- B. Submit material samples and warranties prior to shipment.
- C. Suitability of geosynthetic liner system shall be subject to Owner's approval of warranty.
 - 1. The Manufacturer's warranty shall be against manufacturing defects and workmanship and against deterioration due to ozone, ultra- violet, and other exposure to the elements, for a period of 5 years on a pro rata basis. The warranty shall be limited to replacement of material, and shall not cover installation of replacement geomembrane.
 - 2. The Installer's warranty shall state that the materials were properly installed, properly (field and factory) welded, seamed and jointed and will not fail within two years of the date of final acceptance of the Work by the Owner.
 - a. Warranty shall not be prorated.
- D. Warranties shall provide for complete repair/replacement excluding installation costs at no additional cost to the Owner for the warranty period.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS AND/OR GEOMEMBRANE INSTALLERS

- A. Subject to compliance with the Contract Documents, the following manufacturers and installers are acceptable:
 - 1. LLDPE Geomembrane liners manufacturers:
 - a. Agru/America, Inc.
 - b. GSE, Inc.
 - c. Poly-Flex Inc.
 - 2. LLDPE Geomembrane Liner Installers:
 - a. Authorized installers of approved manufacturers.
 - b. Other installers may qualify by providing references for a minimum of 10,000,000 SF of liner installations.

2.2 MATERIALS

- A. LLDPE Geomembrane Liner:
 - 1. Consist of unreinforced polyethylene.
 - a. Thickness: 40 mils.
 - b. Manufactured from virgin, first quality resin designed and formulated specifically for liquid containment in hydraulic structures.
 - c. Reclaimed polymer shall not be added to the resin; except use of polymer recycled during the manufacturing process shall be allowed provided that recycled polymer shall be clean and shall not exceed 10 percent by weight.
 - d. No additives or fillers may be added to the resin prior to or during manufacture of the LLDPE geomembrane.
 - 2. Manufactured to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter.
 - a. Any such defects shall be cause for rejection of the material.
 - b. Minor defects may be repaired in accordance with Manufacturer's recommendations if approved by the Engineer.
 - 3. Manufactured as seamless rolls.
 - a. Minimum width: 22 FT as delivered to the site.
 - 4. Prior to shipment, the geomembrane manufacturer will provide the CQA Engineer and the Installer's CQC Consultant with a quality control certificate for each roll of geomembrane provided. The quality control certificate will be signed by a responsible party employed by the geomembrane manufacturer and will include:

- a. Roll numbers and identification; and
- b. The results of quality control tests performed under the MQC program.
5. The Installer's CQC Consultant and the CQA Inspector will verify that a control certificate has been received for each roll and that the certified roll properties meet the requirements of these Specifications.
6. LLDPE sheet with **texture** on both sides shall be used for top, north, and east sideslopes including drainage terrace.
7. The geomembrane liner material shall consist of **40 MIL NOMINAL LLDPE** and meet or exceed GRI GM17 and the following requirements:

PROPERTY	TEST METHOD	<u>TEST VALUE</u> TEXTURED LLDPE
a. Sheet Thickness, Mils • Minimum Average • Lowest Individual 8 of 10 • Lowest Individual 10 of 10	ASTM D5994 (textured)	nominal \pm 5% nominal \pm 10% nominal \pm 15%
b. Sheet Density (<u>min.-avemax.</u>)	ASTM D1505 <u>D792</u> , <u>Method B</u>	\geq 0. 92 <u>939</u> g/cc
c. Melt Flow Index (g/10 min.)	ASTM D1238 Condition 190/2.16	\leq 1.00
d. Minimum Tensile Properties (each direction) • Break Stress • Elongation at Break	ASTM D6693 Type IV Dumb-bell 2 ipm G.L. = 2.0 in (51 mm)	60 psi 250%
e. Min. Tear Resistance Initiation	ASTM D1004	22 lbs
f. Carbon Black Content	ASTM D1603 or ASTM D4218	2.0-3.0%
g. Carbon Black Dispersion • Minimum 9 of 10 • All 10 of 10	ASTM D5596	Category 1 or 2 1, 2, or 3
h. Puncture Resistance, Minimum Average	ASTM D4833	44 lbs
i. Oxidative Induction Time, Minimum Average	ASTM D3895 200°, O ₂ , 1 atm	>100 min.
j. Asperity Height, Minimum Average • Minimum Average • Lowest Individual 8 of 10 • Lowest Individual 10 of 10	GRI GM12	10 mil 7 mil 5 mil

8. Rolls may be rejected if they appear damaged upon delivery or if they have been rejected or returned from another project.

- B. Geomembrane Manufacturing Quality Assurance (QA): The geomembrane liner shall be manufactured in accordance with a written quality assurance/quality control program (QC). This QA/QC program shall be submitted to the Engineer or Inspector, together with shop drawings showing the layout of geomembrane liner in the containment facility. After this QA/QC program has been approved by the Engineer or Inspector, the Manufacturer shall not deviate from the program without written approval of the Engineer or Inspector. All testing shall be performed by the manufacturer and results shall be submitted to CQA Inspector for review. The QA/QC program shall include:
1. Routine testing of incoming resin prior to manufacture of geomembranes. This testing shall include tests for density, melt index, and oxidative induction time, at a frequency of not less than one per 200,000 LB.
 2. Routine testing of the manufactured sheet for physical parameters. This testing shall include tests for carbon black, tensile strength, and elongation properties, at a frequency of not less than one per 20,000 LB of manufactured geomembrane; tear and puncture resistance and carbon black dispersion at a frequency of not less than one per 45,000 LB of manufactured geomembrane. Thickness shall be monitored continuously through the manufacturing process, or measured physically at a frequency of not less than one per roll of manufactured geomembrane. For textured sheet only, asperity height shall be measured every other roll.
 3. Extrusion rod shall be manufactured from identical resin to that used in geomembrane manufacture. Manufactured extrusion rod shall be tested for carbon black, specific gravity and melt index at a frequency of not less than one test per batch.
 4. The Manufacturer shall reject resin shipments which do not conform with the density and melt index requirements of the approved QA/QC program. The Manufacturer shall reject manufactured geomembrane which does not conform to the sheet physical requirements of the approved QA/QC program
 5. The LLDPE textured geomembrane shall conform to the requirements prescribed in GRI Test Method GM17.
- C. Manufacturing QC data shall accompany the geomembrane shipment.
- D. Independent testing of geomembrane shall be conducted in accordance with the CQA Plan.

2.3 INTERFACE FRICTION TESTS

- A. Laboratory friction tests shall be conducted, on behalf of the OWNER by the CQA Laboratory, with representative samples of the materials selected by the Contractor for use in the Work. The CQA Inspector is responsible for shipping materials to the testing laboratory. The initial set of testing and subsequent conformance tests (if any) shall be paid for by the Owner. If any interface doesn't meet the requirements, or if the Contractor changes geosynthetic materials, then the additional cost to qualify those materials shall be borne by the Contractor. Testing will include the interfaces between the following adjacent materials.

B.	D. Specification
C. Material	Section
E. Intermediate Cover	F. 02200
G. 40 mil Textured LLDPE Geomembrane	H. 02775
I. Drainage Composite: Final Cover	J. 02777
K. Protective Cover	L. 02200
	M.

- N. The testing shall be performed in accordance with ASTM D5321.

1. The materials shall be tested at normal stressed of 250, 500, and 1,000 psf. Displacement rates shall be in accordance with ASTM D5321 Procedure A for geosynthetic to geosynthetic interfaces and Procedure B for soil to geosynthetic interfaces. Soil components shall be compacted to the same moisture-density requirements specified for full-scale field placement and saturated prior to shear. All geosynthetic interfaces shall be tested in a wet condition. Geosynthetics shall be oriented such that the shear force is parallel to the downslope orientation of these components in the field. The testing laboratory shall confirm these criteria with the CQA Inspector prior to performing the tests.
- O. A minimum friction angle of 26 degrees is required for each interface in the system defined in Paragraph A.
- P. Interface shear strength of the actual components which will be used in the liner system shall be tested with method ASTM D5321 or an equivalent test method. The interface shall be tested in a water-saturated state.
- Q. This material is part of a system. The system shall meet the requirements before the component material can be deemed acceptable.
- R. Interface friction tests will be conducted by the Owner.

2.4 EQUIPMENT AND ACCESSORIES

- A. Welding and Seaming Equipment:
1. Equipped with gages showing temperatures at the nozzle (extrusion welder) or at the wedge (wedge welder).
 2. Maintained in adequate numbers to avoid delaying work.
 3. Supplied by a power source capable of providing constant voltage under a combined-line load.
 4. Electric generator shall not be placed on the LLDPE geomembrane.
- B. Field Tensiometer:
1. Provide a tensiometer for on-site shear and peel testing of LLDPE geomembrane seams.
 - a. Tensiometer shall be in good working order.
 - b. Built to ASTM specifications.
 - c. Accompanied by evidence of calibration of equipment and gages within the past six months.
 2. Tension meter:
 - a. Motor driven.
 - b. Jaws capable of traveling a measure rate of 2 IN per minute.
 - c. Equipped with a gauge that measures the force in unit pounds exerted between the jaws.
 - d. Digital readout.
- C. Punch Press:
1. Provide a punch press for the onsite preparation of specimens for testing.
 2. Capable of cutting specimens in accordance with ASTM D4437.
- D. Vacuum Box:
1. Provide a vacuum box for onsite testing of LLDPE geomembrane seams in accordance with ASTM D5641.
- E. Equipment necessary to perform "Pressurized Air Channel Evaluation of Dual Seamed Geomembranes" in accordance with ASTM D5820.
- F. Gages:
1. Calibrated within past six months.
 2. Specified test values reading near mid-range of the gage scale.
- G. Equipment necessary to perform "Non-Destructive Testing of Geomembrane Seams Using The Spark Test" in accordance with ASTM D6365.

2.5 FABRICATION

- A. The Manufacturer is responsible for producing geomembrane sheet that complies with this Specification. These responsibilities include but are not limited to:
 - 1. Resin and additive quality control:
 - a. Acceptance of the resin and additives from chemical formulators.
 - b. Testing of the raw resin and additives to ensure compliance with the Manufacturer's specifications and with this Specification.
 - 2. Formulation of the resin and additives into sheeting using mixing and extrusion equipment.
 - 3. Testing of the sheet material to ensure compliance with Manufacturer's specifications and this Specification.
 - 4. Shipping of the sheet material to Installer.
 - 5. Certification of the raw materials and finished sheet to comply with this Specification.
 - 6. Certification of Installer's training (unless Installer is certified by other acceptable manufacturer list herein), experience and methods for welding, seaming, joining and inspecting geosynthetic materials installations in compliance with Manufacturer's standards and with Quality Assurance requirements of this Specification Part 1.2.

PART 3 - EXECUTION

3.1 GEOSYNTHETIC LINER SYSTEM

- A. Geomembrane Subgrade:
 - 1. Protect subgrade at all times from damage until such time as the placement of LLDPE geomembrane liner and other components of the geosynthetic liner system are complete.
 - 2. The subgrade shall be prepared in a manner consistent with proper subgrade preparation techniques for the installation of LLDPE Geomembrane.
 - a. The subgrade shall be properly compacted so as not to settle and cause excessive strains in the LLDPE Geomembrane or other synthetic liner materials.
 - b. Prior to installation, ensure a surface free of debris, roots, or angular stones larger than 1/2 inch.
 - c. In addition, ensure that the subgrade has been rolled to provide a uniform surface.
 - d. During installation, ensure that rutting or ravelling is not caused by installation equipment or weathering.
- B. Anchor Trenches:
 - 1. Geosynthetic materials placed on side slopes shall be anchored into trenches as detailed on the Contract Drawings.
 - 2. Excavation, backfill and compaction shall be in accordance with Section 02200.
- C. LLDPE Geomembrane:
 - 1. General:
 - a. Installer of LLDPE geomembranes is responsible for handling, fitting, welding, seaming, jointing and testing of geosynthetic materials sheets or blankets in the field in accordance with the Construction Quality Assurance (CQA) Plan.
 - b. These responsibilities include but are not limited to:
 - 1) Acceptance (in writing) of the geosynthetic materials sheets or blankets from the transporter.
 - 2) Acceptance (in writing) of the surface which will serve as a base for the LLDPE geomembrane.
 - a) This acceptance shall precede installation of the LLDPE geomembrane.
 - b) Shall state that the Installer has inspected the surface, and reviewed the Specifications for material and placement, and finds all conditions acceptable for placement of LLDPE geomembrane liners.
 - c) Shall explicitly state any and all exceptions to acceptance.

- 3) Handling, welding, seaming, jointing, testing and repair of LLDPE geomembrane liners and other geosynthetic materials in compliance with this Specification and with written procedures manuals prepared by the Manufacturer or Fabricator.
 - a) Manual shall be submitted to the Engineer together with Shop Drawings showing the layout of LLDPE geomembrane within the facility.
 - (1) Do not deviate from the procedures included in the manual.
 - b) LLDPE Geomembrane shall not be placed upon frozen foundation, standing water or other conditions which will result in deterioration of the foundation.
 - c) LLDPE Geomembrane liner materials shall be laid out according to plans previously approved by the Engineer.
 - d) Adjacent rolls of LLDPE geomembrane shall overlap a minimum of 3 IN.
 - 4) Repair or replacement of defects in the geosynthetic materials as required by the Inspector or the Owner.
 - 5) Installer and Manufacturer may be the same firm.
2. Panel deployment:
- a. Subgrade Preparation:
 - 1) Prepare subgrade in a manner consistent with proper subgrade preparation techniques for the installation of LLDPE geomembrane liner.
 - 2) Properly compact the subgrade so as not to settle and cause excessive strains in the LLDPE geomembrane liner.
 - 3) Prior to installation, ensure a surface free of debris, roots, or angular stones larger than 1/2 IN.
 - 4) Subgrade soils proof-rolled with a ten (10) ton drum roller, two (2) passes parallel to slope or as directed by CQA Inspector. The subbase shall be compacted and proof-rolled under observation of the CQA Inspector to assure the maximum practical compaction under the existing field conditions has been achieved. See specification Section 02200 for project specific compaction requirement.
 - 5) Ensure rutting or raveling is not caused by installation equipment or weather.
 - 6) Ensure that lines and grades have been verified by the Contractor and a subgrade acceptance form has been submitted.
 - b. Construct and backfill anchor trenches
 - c. Deploy LLDPE geomembrane liner in a manner to ensure it is not damaged
 - d. On slopes, anchor the LLDPE geomembrane liner securely and deploy it down the slope in a controlled manner.
 - e. Weight the LLDPE geomembrane liner with sandbags or equivalent in the presence of wind.
 - f. Minimize cutting the LLDPE geomembrane liner. Whenever possible, overlap instead of cutting material. If cutting is required, cut LLDPE geomembrane liner with a cutter or other approved device. Seal all cut edges, as recommended by Manufacturer.
 - g. Only those panel/sheets that can be seamed in 1 day shall be deployed.
 - h. Place panels with minimal handling.
 - 1) No horizontal seams on side slopes.
 - 2) Protect panels from tear, puncture or abrasion.
 - i. Equipment used to deploy the geomembrane shall not damage the LLDPE geomembrane.
 - j. Minimize foot traffic.
 - 1) Do not allow personnel access to wet or slippery liners without adequate safety precautions.
 - 2) Do not allow footwear that may damage the geomembrane.
 - k. Ballast with sandbags to prevent wind uplift as recommended by Manufacturer based on local climatic conditions.
 - 1) Remove and replace all wind damaged panels at no additional cost to Owner.
 - 2) If wind causes panels to be displaced, displaced panel may not be reused.
 - l. Install LLDPE geomembrane in stress free, tension free and relaxed condition.
 - 1) Account for temperature and weather-related impacts when deploying and covering.

- 2) Stretching to fit and folding are not permitted.
- m. Do not allow LLDPE geomembrane to bubble, fold, or create ripples as a result of deployment of drainage layer or protective soil cover placement.
 - 1) Except as noted on Contract Drawings no folds in LLDPE geomembrane will be allowed.
- n. Any panel exhibiting stretching caused by placement, covering techniques, or wind shall be removed and may not be incorporated in the final construction.
- o. Field seaming:
 - 1) Field seaming shall be done in accordance with seaming recommendations furnished by the geomembrane Manufacturer, referenced EPA documents, and this specification.
 - 2) Each piece of seaming equipment and each operator shall perform trial seams at the start of a shift, whenever equipment has broken down or seaming is interrupted for more than 30 minutes, and at other times at the discretion of the Installer and Inspector.
 - 3) Trial seams shall use the same seaming materials and methods to be used in the actual construction.
 - 4) Surfaces to be seamed shall be clean and dry at the time of seaming.
 - a) Precipitation and ponding of water on the LLDPE geomembrane shall cause termination of seaming operations.
 - b) LLDPE geomembrane shall not be seamed when ambient temperatures are below 41 Deg F or above 104 Deg F, without written consent of LLDPE geomembrane Manufacturer and Engineer.
 - 5) LLDPE geomembrane sheets shall be seamed continuously without fishmouths or breaks in the seam.
 - a) Where fishmouths are unavoidable, the sheet shall be slit to a point such that the sheet lies flat and with no remaining wrinkle.
 - b) The two edges of the slit shall be seamed together provided that the overlap for this seam shall be a minimum of 6 IN.
 - c) Areas of the slit which do not achieve an overlap of 6 IN, including the terminus of the slit, shall be provided with a patch as discussed below.
 - 6) All LLDPE geomembranes shall be seamed by thermal fusion methods as recommended by the LLDPE geomembrane Manufacturer.
 - a) LLDPE geomembrane seaming shall be either extrusion or double wedge welded as approved by the Engineer.
 - 7) Manufacturer's seaming instructions shall specifically address seaming materials, temporary and permanent jointing, seaming temperatures including temperatures for seaming materials, seam finishing and curing.
 - 8) A copy of Manufacturer's seaming instructions shall be available on site at all times and shall not be deviated from without written approval of the Manufacturer and Engineer.
 - 9) All panels/sheets should be overlapped a minimum of 3 IN.
 - a) No horizontal seams will be permitted on the side slopes. Horizontal seams will be allowed on flat area of the terraces/benches.
 - 10) Seaming shall not be conducted in the presence of standing water.
 - a) The seamed area shall be cleaned of dust, dirt and foreign material prior to and during the seaming operation.
 - 11) Seaming shall extend to the outside edge of panels/sheets to be placed in anchor and/or drainage trenches.
 - 12) Tack welds shall conform with manufacturers seaming techniques and shall not damage underlying membrane.
- p. Patching:
 - 1) Defects in and damage to LLDPE geomembrane sheets shall be repaired by seaming a patch over the defect.

- a) The patch material shall consist of an undamaged piece of LLDPE geomembrane cut to provide a minimum of 6 IN of overlap in all directions from the defect.
 - b) Round corners shall be utilized on all patches. No bead or spot patching will be accepted.
 - c) Torn or permanently twisted LLDPE geomembrane shall be replaced at no expense to the Owner.
- 2) Test all patch seams non-destructively using a vacuum box test
- a) Test patch seams destructively if the seam is greater than 100 feet in contiguous length (i.e. a single seam greater than 100 feet).
 - b) Perform a destructive test for every 100 feet of contiguous seam over 200 total feet of contiguous seam. For example if a patch seam is 340 feet, 2 destructive tests would be required for the seam.
- q. Smoking is not permitted while on the geomembrane.
 - r. No vehicles which may damage the material are allowed on the geomembrane.
 - s. Field Panel Identification: The Installer's CQC Consultant will document that the Geomembrane Installer labels each field panel with an "identification code" consistent with the approved panel layout plan. The location of the label and the color of marker used must be as agreed to in the QA/QC Preconstruction Meeting.

3.2 FIELD QUALITY CONTROL

- A. The CQA Inspector shall not be a part of the installation program and shall not serve as a substitute for performing the duties or certification required of the Manufacturer and Installer.
 - 1. The CQA Inspector's responsibilities include, but are not limited to:
 - a. Inspection of the material and the handling and field installation of the geomembranes. Inspection of all welds, repairs and quality control test results.
 - b. All exceptions to material or installation shall be documented and furnished to the CQA firm in writing within 48 HRS of discovery.
 - c. Inspection and Certification of LLDPE geomembrane integrity until completion of placement of protective soil cover.
- B. Trial Seam Testing:
 - 1. Trial seams shall be at the start of a shift, whenever equipment has broken down or seaming is interrupted for more than 30 minutes, and at other times at the discretion of the Installer and Inspector.
 - a. The location of trial seam shall be in an area proposed for the day's production seaming.
 - b. Equipment, methods and personnel shall be the same as proposed for the day's seaming.
 - 2. Test four replicates (1 IN wide specimens) cut from trial seam.
 - a. To be acceptable, four of four replicate test specimens must meet specified seam strength requirements and all failures shall be Film Tear Bond.
 - b. A minimum of 2 specimens shall be tested for shear strength and 2 for peel adhesion using an approved field quantitative tensiometer. Jaw separation speed shall be 2 IN per minute.
 - c. If the field trial seam tests fail to meet these requirements, the entire operation shall be repeated.
 - d. If the additional test seams fail, the seaming apparatus or seamer shall not be accepted or used for seaming until the deficiencies are corrected and two consecutive successful test seams are achieved.
- C. Non-Destructive Seam Testing:
 - 1. All field seams shall be non-destructively tested over their full length.
 - a. Seam testing shall be performed as the seaming work progresses, not at the completion of field seaming.
 - b. All testing shall be documented. Any seams which fail shall be repaired and documented.
 - 2. Non-destructively test all field seams continuously using one of the following nondestructive seam tests:

- a. Vacuum box (ASTM D5641). Test at 5psi for 10 seconds. Any loss in vacuum, as indicated by bubbling of soap solution, is a failing test.
 - b. Spark tests (ASTM D6365). Test at uniform rate between 6 and 9 meters per minute. A spark indicates a failing test.
 - c. Pressurized air channel test (ASTM D5820). For 40 mil geomembrane, test at between 24 and 30 psi for at least 5 minutes. A pressure drop of more than 4psi is a failing test.
3. All tests should be conducted in accordance with their corresponding ASTM method.
- 3.4. All field seams that cannot be continuously non-destructively tested by pressurized air channel test or vacuum box test shall be visually inspected and all welds, where possible, will be vacuum box tested.

D. Destructive Seam Testing:

- 1. A minimum of one destructive test per 500 LF of seam, and as many other samples as CQA firm determines appropriate, shall be obtained at locations specified by the CQA firm.
 - a. Sample locations shall not be identified prior to seaming.
 - b. The samples shall be a minimum of 12 IN wide by 48 IN long with the seam centered lengthwise.
 - c. Each sample shall be cut into three equal pieces with one piece retained by the Installer, one piece given to a CQA Testing Laboratory, and the remaining piece given to the CQA Engineer for quality assurance testing and/or permanent record.
 - d. Each sample shall be numbered and recorded on the final panel layout record drawing, and cross-referenced to a field log which identifies:
 - 1) Panel/sheet number.
 - 2) Seam number.
 - 3) Top sheet.
 - 4) Date and time cut.
 - 5) Ambient temperature.
 - 6) Seaming unit designation.
 - 7) Name of seamer.
 - 8) Seaming apparatus temperature and pressures (where applicable).
- 2. A minimum of four 1 IN wide replicate specimens shall be cut from the Installer's sample.
 - a. A minimum of 2 specimens shall be tested for shear strength and 2 for peel adhesion using an approved field quantitative tensiometer. Jaw separation speed shall be 2 IN per minute.
 - b. To be acceptable, all field test specimens must meet the specified seam strength requirements and all must fail as Film Tear Bond.
 - c. If all field tests pass, 5 specimens shall be tested at the CQA Testing Laboratory for shear strength and 5 for peel adhesion in accordance with ASTM D6392.
 - d. To be acceptable, 4 out of 5 replicate test specimens must meet the specified seam strength requirements and fifth sample must meet 80% required strength and fail at Film Tear Bond.
 - e. Shear elongation and Peel separation shall not exceed values given in GRI GM19
- 3. The minimum required seam strengths for 40 mil LLDPE are:

<u>Description</u>	<u>Test Method</u>	<u>Seam Type</u>	<u>Required Value (lbs/in width)</u>
LLDPE Peel	ASTM D6392	Extrusion	48
LLDPE Peel	ASTM D6392	Fusion	50
LLDPE Shear	ASTM D6392	All	60

- 4. For destructive samples which have failed the passing criterion, the Contractor will reconstruct all the field seams between any two previous passed seam locations which include the failed seam or will go on both sides of the failed seam location (10 feet minimum), take another sample each side and test both. If both pass, the Contractor may patch or cap strip the seam between the passed samples. If either fails, the Contractor will

remove and replace the entire seam. In all cases, acceptable field seams must be bounded by two passed test locations. The decision of the CQA Engineer will be final.

- a. In addition, all destructive seam sample holes shall be repaired the same day as cut.
 - b. Certified test results on all field seams shall be submitted to and approved by the CQA Engineer prior to acceptance of the seam.
5. All repaired areas shall be non-destructively tested and destructively tested as described in Part 3.1B.2.p (2) of this specification.
 6. Destructive testing shall be performed by a CQA Testing Laboratory not employed by the Installer.
 7. A map showing the locations, number and type of all patches shall be prepared and provided to the Owner.
 8. Documentation: The following documentation must be maintained at the project site for review by the CQA Engineer or Inspector.
 - a. Geomembrane Installer's Documentation:
 - 1) Daily Log: daily record that summarizes panels deployed, seams completed, seam testing, seam repair, personnel on site, weather conditions, and equipment on site.
 - 2) Material Conformance: maintain original conformance certificate(s) from geomembrane manufacturer.
 - 3) Subgrade Acceptance Log: maintained originals of subgrade acceptance forms for each panel and signed by the Geomembrane Installer.
 - 4) Panel Log: provides geomembrane roll number used and subgrade acceptance for each panel deployed.
 - 5) Seam Testing Log: provides a complete record of all nondestructive and destructive seam tests performed as part of the Geomembrane Installer's QC program.
 - 6) Seam/Panel Repair Log: provides a complete record of all repairs and vacuum box testing of repairs made to defective seams or panels.
 - 7) As-Built Drawing: maintain an as-built drawing updated on a weekly basis.

3.3 GEOSYNTHETIC LINER SYSTEM ACCEPTANCE

- A. Contractor shall retain all ownership and responsibility for the geosynthetic liner system until final acceptance by the Owner.
 1. Owner will accept the geosynthetic liner system installation when the installation is finished and all required warranties, test results, and documentation from the Contractor, Manufacturer, Inspector and Installer has been received and approved, and verification of the adequacy of all field seams and repairs, including associated testing, is complete.

END OF SECTION

SECTION 02776
HDPE GEOMEMBRANE LINER SYSTEM

PART 1 - GENERAL

1.01 SUMMARY

- A. Section Includes:
1. Furnishing, installation, quality control, and testing of a textured HDPE geomembrane liner. HDPE geomembrane liner will be used as part of the Overlay Liner System overlay liner system for the Phase I / II connection.
- B. Related Sections include but are not necessarily limited to:
1. Section 02200 – Earthwork: Landfill.
 2. Section 02240 – Drainage Sand Layer - Overlay Liner System
 3. Section 02777A – Drainage Composite: Overlay Liner System
 4. Central County Solid Waste Disposal Complex Class I Landfill Expansion Construction Quality Assurance Plan.

1.2 QUALITY STANDARDS

- A. Referenced Standards:
1. ASTM International (ASTM).
 - a. ASTM D638, Standard Test Method for Tensile Properties of Plastics.
 - b. ASTM D792, Standard Test Method for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
 - c. ASTM D1004, Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting.
 - d. ASTM D1238 Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.
 - e. ASTM D1603 Standard Test Method for Carbon Black in Olefin Plastics.
 - f. ASTM D3015 Standard Practice for Microscopic Examination of Pigment Dispersion in Plastic Compounds. Refer to Subpart 2.2 for property to be tested.
 - g. ASTM D3895 Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis.
 - h. ASTM D4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique.
 - i. ASTM D4437 Determining the Integrity of Field Seam Used in Joining Flexible Polymeric Sheets of Geomembrane
 - j. ASTM D4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
 - k. ASTM D5199 Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.
 - l. ASTM D5321, Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method.
 - m. ASTM D5397 Procedure to Perform a Single Point Notched Constant Tensile Load – Appendix (SP-NCTL) Test.
 - n. ASTM D5596 Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics.
 - o. ASTM 5641 Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber.
 - p. ASTM D5721 Practice for Air-Oven Aging of Polyolefin Geomembranes.
 - q. ASTM D5820, Standard Practice for Pressured Air Channel Evaluation of Dual Seamed Geomembrane.
 - r. ASTM D5885 Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry.

- s. ASTM D5994 Test Method for Measuring the Core Thickness of Textured Geomembranes.
 - t. ASTM D 6365 Non-Destructive Testing of Geomembrane Seams Using the Spark Test
 - u. ASTM D 6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods
 - v. ASTM D 6693 Standard Test Method for Determining Tensile Properties of nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes ASTM E-96-00, Procedure BW, Standard Test Methods for Water Vapor Transmission of Materials.
2. The Geosynthetic Research Institute (GRI).
 - a. GRI GM6 Pressurized Air Channel Test for Dual Seam Geomembranes.
 - b. GRI GM10 Specification for the Stress Crack Resistance of Geomembrane Sheet.
 - c. GRI GM11 Accelerated Weathering of Geomembranes Using a Fluorescent UVA-Condensation Exposure Device.
 - d. GRI GM12 Measurement of the Asperity Height of Textured Geomembranes Using a Depth Gauge.
 - e. GRI GM13 Standard Specification for Test Properties, Testing Frequency, and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembrane.
 - f. GRI GM14 Selection Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes.
- B. Qualifications:
1. Each manufacturing and fabricating firm shall demonstrate 5 years continuous experience with a minimum of 10,000,000 SF of HDPE geomembranes.
 2. Installer:
 - a. Demonstrate 5 years continuous experience with a minimum 10,000,000 SF of HDPE geomembranes.
 - b. Certified by at least one of the named manufacturers in this Specification (not necessarily the manufacturer supplying materials for this Project).
 - c. Geomembrane Installer Personnel Qualifications:
 - 1) Installation Superintendent shall have worked in a similar capacity on at least five HDPE geomembrane liner jobs similar in size and complexity to the project described in the Contract Documents.
 - 2) The Master Welder shall have completed a minimum of 5,000,000 sf of HDPE geomembrane seaming work using the type of seaming apparatus proposed for use on this Project.
 - 3) Other welders shall have seamed a minimum of 1,000,000 sf of HDPE geomembrane.
 3. CQC Testing Laboratory shall demonstrate 3 years of continuous experience in similar geosynthetic materials testing.
- C. Construction Quality Assurance / Control:
1. The Owner or Engineer's representative will conduct independent testing to support Construction Quality Assurance (CQA) program and to provide documentation of such to appropriate regulatory agencies.
 2. Unless specifically superseded by these contract documents or approved plans submitted by the Contractor, the geosynthetic materials shall be manufactured, stored, placed, seamed, tested and protected as described in EPA/600/R-93/182 and EPA/530/SW-91/051.
 - a. This specifically includes:
 - 1) Material Composition.
 - 2) Manufacturing.
 - 3) Handling and Packaging.
 - 4) Shipment.
 - 5) Storage (Manufacturer and Site).

- 6) Placement:
 - a) Seaming and Joining.
 - b) Destructive and Non Destructive Testing.
 - c) Protection, Backfilling and Covering.
 - 7) Conformance Testing.
 - 8) Anchoring and Anchor Trenches.
 - 9) Access Roads/Ramps.
- D. CQA Plan Implementation: Construction Quality Control will be performed in accordance with the CQA Plan prepared for the Class I Landfill Expansion project. The Contractor and Geomembrane Installer should familiarize themselves with the CQA Plan.
- E. Certifications:
- 1. Certifications are required for various aspects of the project related to the HDPE geomembrane liner system construction.
 - a. Utilize certification forms approved for use on this Project by the Owner and Engineer.
- F. Installer's Construction Quality Control (CQC) programs to include, but not be limited to, product acceptance testing, installation testing, including both nondestructive and destructive quality control field testing of the sheets and seams during installation of the geomembrane, proposed methods of testing geosynthetic joints and connections at appurtenances for continuity, documentation and changes, alterations, repairs, retests, and acceptance.
- G. Geomembrane Installer's installation manual to include:
- 1. Ambient temperature at which the seams are made
 - 2. Control of panel lift up by wind
 - 3. Acceptable condition of the subsurface beneath the geomembrane
 - 4. Quality and consistency of the welding material
 - 5. Proper preparation of the liner surfaces to be joined
 - 6. Cleanliness of the seam interface (e.g., the amount of airborne dust and debris present)
 - 7. Proposed details for connecting the HDPE liner to appurtenances, i.e. penetrations of the containment facilities
 - 8. A complete description of seaming by extrusion welding and hot-wedge welding
 - 9. Requirements of the Manufacturer's Installation Manual unless exceptions are noted and approved by the Engineer

1.3 DEFINITIONS AND RESPONSIBILITIES

- A. Geomembrane Manufacturer: Manufacturer of geomembranes producing geomembrane sheets from resin and additives. The manufacturer is responsible for producing geomembrane sheet which complies with these Specifications and conducting Manufacturer's Quality Control (MQC) testing to document the material's compliance with these Specifications. These responsibilities include but are not limited to:
- 1. Acceptance of the resin and additives from chemical formulators. Testing of the raw resin and additives to ensure compliance with the manufacturer's specifications and with this Specification.
 - 2. Formulation of the resin and additives into geomembrane sheeting using mixing and extrusion equipment.
 - 3. Testing of the geomembrane sheet to ensure compliance with manufacturer's specification and this Specification.
 - 4. Shipping of the geomembrane sheet to installer designated facilities and to the Project.
 - 5. Certification of the raw materials and finished geomembrane sheet to comply with this Specification.
 - 6. Certification of installer's training, experience, and methods for welding and inspection of geomembrane installations in compliance with manufacturer's standards.

- B. Geomembrane Installer. Installer of geomembranes are responsible for handling, fitting, welding, and testing of geomembrane sheets in the field. These responsibilities include but are not limited to:
 - 1. Acceptance (in writing) of the geomembrane from the manufacturer.
 - 2. Acceptance (in writing) of the surface which will serve as a base for the geomembrane. This acceptance shall precede installation of the geomembrane, and shall state that the installer has inspected the surface, and reviewed the Specifications for material and placement, and finds all conditions of the surface upon which the geomembrane is to be placed are acceptable for placement of geomembrane liners. The written acceptance shall explicitly state any and all exceptions to acceptance.
 - 3. Handling, storage, welding, testing, and repair geomembrane liners in compliance with this Specification and the Geomembrane Installer's Installation Procedures Manual.
 - 4. Performance of QC testing and record keeping as required by the approved Geomembrane Installer's Field Installation Procedures Manual.
 - 5. Repair or replacement of defects in the geomembrane as required by the Installer's CQC Consultant or the CQA Inspector.
- C. CQA Inspector:
 - 1. Inspectors of HDPE geomembrane are the individuals, independent of the geomembrane manufacturer, Installer, and Contractor, who is retained by the Owner and is responsible for observing field installation of the geosynthetic materials and providing the Manufacturer, Installer, CQA Engineer, and Owner with verbal and written documentation of the compliance of the installation with this specification and with written procedures manuals prepared by the Manufacturer or Installer.
- D. CQA Testing Laboratory shall:
 - 1. Perform destructive testing of the HDPE geomembrane.
 - 2. Perform conformance testing of HDPE geomembrane in accordance with the Central County Solid Waste Disposal Complex (CCSWDC) Class I Landfill Expansion Construction Quality Assurance Plan. CQA conformance testing frequency shall be same as Manufacturer Quality Control (MQC) testing frequency unless otherwise noted in CQA Plan or this specification.
- E. Installer's CQC Consultant: A firm or individuals, who is retained by the Installer and/or Contractor and is responsible for observing field installation of the geomembrane and performance of material conformance and CQC testing to provide the Contractor with verbal and written documentation of the compliance of the installation with these Specifications.
- F. CQA Engineer: Responsible for implementing CQA Plan including overseeing material conformance testing, field installation of the geomembrane, and CQC activities, and to perform CQA conformance testing to provide Owner with verbal and written documentation of the compliance of the installation with these Specifications. The CQA Engineer will use the written results of the CQC program and the CQA program in the preparation of the Project Certification Document. The CQA Engineer reports to the Owner and is not part of this contract.
- G. Refer to the accompanying CCSWDC Class I Landfill Expansion CQA Plan for additional definitions.

1.4 SUBMITTALS

- A. Shop Drawings:
 - 1. Submit for Engineer's approval Shop Drawings, including:
 - a. Manufacturer's certification that raw materials and sheet materials comply with required materials, mil thickness, and material properties.
 - 1) Original certificates are required.
 - 2) A list of all geomembrane rolls to be actually delivered to the Project that correlates the resin lot numbers to geomembrane roll numbers produced from that resin lot.

- 3) Production dates of the geomembrane rolls will be provided and confirmation from the manufacturer that the geomembrane rolls meet the Project specifications.
 - b. Manufacturer/Fabricator/Installer quality control program requirements.
 - c. Qualifications and experience of key personnel per 1.2 B of this section.
 - d. Manufacturer's written acceptance of Geomembrane Installer's qualifications for installation of the HDPE geomembrane.
 - e. The manufacturer's/installer's recommendation for shipping, handling, and storage of materials.
 - f. Written description of recommended heavy equipment machines (to include model number and/or handling capacity) for use of the equipment and the handling of the geomembrane materials. If special
 - g. HDPE Geomembrane layout plan with proposed size, number, position and sequencing of liner panels and showing the location and direction of all field or factory joints.
 - 1) Proposed details for connecting the geosynthetic materials to appurtenances.
 - 2) Proposed methods of welding, seaming or jointing geosynthetic materials.
 - 3) Proposed method and sequencing for placement of drainage layer on top of the HDPE geomembrane liner.
 - 4) Proposed method of testing HDPE geomembrane and other geosynthetic materials, joints and connections at appurtenances for continuity.
 - 5) Location and configuration of haul roads and access points.
 - 6) Proposed details for anchor trench if different than included in Contract Documents.
- B. Miscellaneous:
1. Test results:
 - a. Resin test, tests of sheet material and factory seam tests at frequency specified in respective quality control manuals.
 - 1) Results shall include or bracket the rolls delivered for use in the Work.
 - b. Daily test seaming logs.
 - c. Seam pre-weld test results.
 - d. Daily results of non-destructive and destructive seam testing.
 2. Warranties as described in Section 1.7 of these Specifications.
 3. Submit written certifications that:
 - a. Utilize certification forms approved for use on this project by the Owner and Engineer. Make appropriate number of copies, as required.
 - b. The HDPE geomembrane material delivered to site meets the requirements of this Specification.
 - c. The HDPE geomembrane were received and accepted in undamaged condition from shipper.
 - d. The HDPE geomembrane liner was installed in accordance with this Specification and with approved Shop Drawings.
 - e. The HDPE geomembrane joints were inspected, tested for strength and continuity, and passed all inspections and tests.
 - 1) All test and inspection data shall be incorporated into this certification.
 - f. The drainage layer, geotextiles and protective soil cover layer on top of the HDPE geomembrane liner was placed properly and carefully.
 4. Manufacturer/Installer's Field Installation Procedures Manual shall clearly identify any exceptions taken to the specified execution of the Work; however, these Specification should be considered as the minimum level of installation required to be acceptable for approval and compliance with the Project Documents.
 5. Record Drawings: Submit reproducible drawings of record showing changes from the approved installation drawings. The record drawings shall include the identity and location of each repair, cap strip, penetration, boot, and test sample taken from the installed geosynthetic for testing. The record drawings shall show locations of each type of material, anchor trenches and the construction baseline.

- C. Provide all submittals in a single coordinated transmittal. Partial submittals will not be accepted. All submittals must be submitted prior to the Geomembrane Preconstruction Meeting and a minimum of four weeks prior to installation.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Unused or stockpiled HDPE geomembrane shall be stored in accordance with the manufacturer's recommendations.
- B. Each roll shall be labeled with the manufacturers name, type, lot number, roll number, and roll dimensions (length, width, gross weight).
 - 1. HDPE geomembrane or plastic wrapping damaged as a result of storage or handling shall be repaired or replaced, as directed.
 - 2. HDPE geomembrane sheet surface temperatures in excess of 60 Deg C (140 Deg F), or less, if recommended by the Manufacturer shall not be exceeded.
- C. No hooks, tongs or other sharp instruments shall be used for handling the HDPE geomembrane.
 - 1. Rolls shall not be lifted by use of cables or chains in contact with the HDPE geomembrane.
 - 2. HDPE geomembrane shall not be dragged along the ground.

1.6 PROJECT CONDITIONS

- A. When the weather is of such a nature as to endanger the integrity and quality of the installation, whether this is due to rain, high winds, cold temperatures, or other weather elements, the installation of the geomembrane shall be halted at the direction of, or with the concurrence of, the Owner until the weather conditions are satisfactory.
- B. Ensure that adequate dust control methods are in effect to prevent the unnecessary accumulation of dust and dirt on geosynthetic surfaces which hamper the efficient field seaming of geosynthetic panels or performance.
- C. Maintain surface water drainage diversions around the work area and provide for the disposal of water which may collect in the work area directly from precipitation falling within the area or from inadequate diversion structures or practices of the Contractor. The Contractor shall also maintain adequate dewatering controls for keeping groundwater tables below the Work areas.
- D. All materials shall be placed and spread with low ground pressure equipment (8 psi ground pressure or less) as approved by the CQA Engineer to reduce potential damage to the geosynthetics. The geosynthetics surface shall be off limits to tracked or rubber tired construction equipment, with the exception of small low ground pressure ATV or multi-tired ATV traffic (John Deere 4x4 620i, or equal). Hard turning of tracked equipment on the protective cover and stone over the geomembrane must be avoided.
 - 1. At least 12 -inch of separation between the geosynthetics and all low ground pressure equipment shall be maintained.
 - 2. Stockpiling of materials within the limits of Phase I shall be subject to advanced approval by the CQA Inspector. Any hauling equipment (dump trucks, etc.) operating within the Phase I limits (and including access ramps), shall have a minimum of 3 feet of separation between the vehicle wheels and the geosynthetics.
 - 3. No vehicle shall access the completed Work unless it can be demonstrated that its weight, movement or activities will not damage the Work.
 - 4. When damage is suspected, uncover area, repair damage if required, and recover area at no cost to Owner.
 - 5. Suspect areas may be identified by Owner or Engineer.

1.7 WARRANTIES

- A. Written warranties addressing HDPE geomembrane material and installation workmanship shall be furnished by the Contractor and shall be made to the Owner.
- B. Submit material samples and warranties prior to shipment.

- C. Suitability of geosynthetic liner system shall be subject to Owner's approval of warranty.
1. The Manufacturer's warranty shall be against manufacturing defects and workmanship and against deterioration due to ozone, ultra- violet, and other exposure to the elements, for a period of 20 years on a pro rata basis. The warranty shall be limited to the manufacturer producing, testing, shipping, loading/unloading, and providing all labor, equipment, and associated costs necessary to delivery replacement of material to the project. The warranty shall specifically outline all exclusions and in general shall not cover installation of replacement geomembrane unless failure of the material is determined to be at fault. Installation costs for replacement geomembrane will be at no cost to the Owner if the material fails.
 2. The geomembrane supplied shall be capable of chemically compatible to prevent the leachate and LFG condensate produced by the solid waste (refuse) from reaching the underlying soil. The material supplied shall have a manufacturer's warranty that it will remain impermeable when exposed over five (5) years to a raw landfill leachate having the following range of values*:

LEACHATE & LFG CONDENSATE QUALITY

<u>Component</u>	<u>Range of Values**</u>	
pH	3.6	8.5
Hardness (Carbonate)	35	8,120
Alkalinity (Carbonate)	310	9,500
Calcium	240	2,570
Magnesium	64	410
Sodium	85	3,800
Iron (Total)	6	1,640
Chloride	96	2,350
Sulfate	40	1,220
Organic Nitrogen	2.4	550
Ammonia Nitrogen	0.2	845
Conductivity	100	1,200
BOD	7,050	32,400
COD	800	50,700
Suspended Solids	13	26,500

* Gewsein, Allen J., USEPA: EPA/530/SE-137, March 1975

** Values are in milligrams per liter except pH (pH units) and conductivity (Micromhos per cubic centimeter).

3. The Installer's warranty shall state that the materials were properly installed, properly (field and/or factory) welded, seamed and jointed and the installed welds, seams, joints will not fail within two years of the date of final acceptance of the Work by the Owner.
 - a. Warranty shall not be prorated.

D. Warranties shall provide for complete repair (for Installer's Warranty) / replacement for Manufacturer's Warranty) at no additional cost to the Owner for the warranty period.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS AND/OR GEOMEMBRANE INSTALLERS

- A. Subject to compliance with the Contract Documents, the following manufacturers and installers are acceptable:
1. HDPE Geomembrane liners manufacturers:
 - a. Agru/America, Inc.
 - b. GSE, Inc.
 - c. Poly-Flex Inc.

2. HDPE Geomembrane Liner Installers:
 - a. Authorized installers of approved manufacturers.
 - b. Other installers may qualify by providing references for a minimum of 10,000,000 SF of liner installations; however, the manufacturer shall be notified, and approval received from the manufacturer, that states no warranty issues will occur with selection of this installer.

2.2 MATERIALS

- A. HDPE Geomembrane Liner:
 1. Consist of unreinforced polyethylene.
 - a. Thickness: 60 mils.
 - b. Manufactured from virgin, first quality resin designed and formulated specifically for liquid containment in hydraulic structures.
 - c. Reclaimed polymer shall not be added to the resin; except use of polymer recycled during the manufacturing process shall be allowed provided that recycled polymer shall be clean and shall not exceed 10 percent by weight.
 2. Manufactured to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter.
 - a. Any such defects shall be cause for rejection of the material.
 - b. Minor defects may be repaired in accordance with Manufacturer's recommendations if approved by the Engineer.
 3. Manufactured as seamless rolls.
 - a. Minimum width: 22 feet as delivered to the site.
 4. Prior to shipment, the geomembrane manufacturer will provide the CQA Engineer and the Installer's CQC Consultant with a quality control certificate for each roll of geomembrane provided. The quality control certificate will be signed by a responsible party employed by the geomembrane manufacturer and will include:
 - a. Roll numbers and identification; and
 - b. The results of quality control tests performed under the MQC program.
 5. The Installer's CQC Consultant and the CQA Inspector will verify that a control certificate has been received for each roll and that the certified roll properties meet the requirements of these Specifications.
 6. HDPE sheet with **texture** on both sides shall be used for the Phase I / II overlay liner system including west drainage terrace.
 7. The geomembrane liner material shall consist of **60 MIL NOMINAL HDPE** and meet or exceed GRI GM13 and the following requirements:

PROPERTY	TEST METHOD	<u>TEST VALUE</u> TEXTURED HDPE
a. Sheet Thickness, Mils	ASTM D5994	
• Minimum Average		nominal - 5%
• Lowest Individual 8 of 10		nominal - 10%
• Lowest Individual 10 of 10		nominal - 15%
b. Sheet Density (min. ave.)	ASTM D792 or D1505	≥ 0.940 g/cc
c. Melt Flow Index (g/10 min.)	ASTM D1238 Condition 190/2.16	≤ 1.00
d. Minimum Tensile Properties	ASTM D638, Type IV,	
• Yield Stress	Dumb-bell at 2 imp.	126 ppi
• Break Stress	(each direction)	90 ppi
• Elongation at Yield	Or ASTM D6693	12%
• Elongation at Break		100%

PROPERTY (2-inch gage length)	TEST METHOD	<u>TEST VALUE</u> TEXTURED HDPE
e. Min. Avg. Tear Resistance Initiation	ASTM D1004, Die C	42-45 lbs
f. Carbon Black	ASTM D1603 or ASTM D4218	2.0-3.0%
g. Carbon Black Dispersion <ul style="list-style-type: none"> • Minimum 8 of 10 • All 10 of 10 	ASTM D5596	Category 1 or 2 1, 2, or 3
h. Puncture Resistance, Minimum Average	ASTM D4833	90 lbs
i. Oxidative Induction Time, Minimum Average	ASTM D3895 or ASTM D5885	100 min. 400 min.
j. Asperity Height, Minimum Average	GRI GM12	15 mil
k. Max. Water Vapor Transmission Rate	ASTM E96	0.24 g/m ² per day
l. Stress Crack Resistance	ASTM D 5397 App A	300 hours

8. Rolls may be rejected if they appear damaged upon delivery or if they have been rejected or returned from another project.

B. Geomembrane Manufacturing Quality Assurance (QA): The geomembrane liner shall be manufactured in accordance with a written quality assurance/quality control program (QC). This QA/QC program shall be submitted to the Engineer or Inspector, together with shop drawings showing the layout of geomembrane liner in the containment facility. After this QA/QC program has been approved by the Engineer or Inspector, the Manufacturer shall not deviate from the program without written approval of the Engineer or Inspector. All testing shall be performed by the manufacturer and results shall be submitted to CQA Inspector for review. The QA/QC program shall include:

1. Routine testing of incoming resin prior to manufacture of geomembranes. This testing shall include tests for density, melt index, environmental stress crack, oxidative-induction time and water vapor transmission at a frequency of not less than one per 200,000 LB.
2. Routine QC testing of the manufactured sheet for physical parameters. This QC testing shall include tests for carbon black, asperity height, tensile strength, and elongation properties, at a frequency of not less than one per 20,000 LB (approximately every 10 rolls) of manufactured geomembrane; tear and puncture resistance at a frequency of not less than one per 45,000 LB (approximately every 25 rolls) of manufactured geomembrane. Thickness shall be monitored continuously through the manufacturing process, or measured physically at a frequency of not less than one per roll of manufactured geomembrane.
3. Extrusion rod shall be manufactured from identical resin to that used in geomembrane manufacture. Manufactured extrusion rod shall be tested for carbon black, specific gravity and melt index at a frequency of not less than one test per batch.
4. The Manufacturer shall reject resin shipments which do not conform with the density and melt index requirements of the approved QA/QC program. The Manufacturer shall reject manufactured geomembrane which does not conform to the sheet physical requirements of the approved QA/QC program.

5. The HDPE textured geomembrane shall conform to the requirements prescribed in GRI Test Method GM13 or these specification which ever is more stringent.
- C. Manufacturing QC data shall accompany the geomembrane shipment.
- D. Independent testing of geomembrane shall be conducted in accordance with the CCSWDC Class I Landfill Expansion CQA Plan.

2.3 INTERFACE FRICTION TESTS

- A. Laboratory friction tests shall be conducted, on behalf of the OWNER by the CQA Laboratory, with representative samples of the materials selected by the Contractor for use in the Work. The CQA Inspector is responsible for shipping materials to the testing laboratory. The initial set of testing and subsequent conformance tests (if any) shall be paid for by the Owner. If any interface doesn't meet the requirements, or if the Contractor changes geosynthetic materials, then the additional cost to qualify those materials shall be borne by the Contractor. Testing will include the interfaces between the following adjacent materials.

<u>Material</u>	<u>Specification Section</u>
Cover Soil	02200
60 mil Textured HDPE Geomembrane	02776
Drainage Composite: Overlay Liner System	02777A
Drainage Sand Layer: Overlay Liner System	02240

- B. The testing shall be performed in accordance with ASTM D5321.
 1. The materials shall be tested at normal stressed of 5,000, 10,000, and 20,000 psf. Displacement rates shall be in accordance with ASTM D5321 Procedure A for geosynthetic to geosynthetic interfaces and Procedure B for soil to geosynthetic interfaces. Soil components shall be compacted to the same moisture-density requirements specified for full-scale field placement and saturated prior to shear. All geosynthetic interfaces shall be tested in a wet condition. Geosynthetics shall be oriented such that the shear force is parallel to the downslope orientation of these components in the field. The testing laboratory shall confirm these criteria with the CQA Inspector prior to performing the tests.
- C. A minimum friction angle of 23 degrees is required for each interface in the system defined in Paragraph A.
- D. Interface shear strength of the actual components which will be used in the liner system shall be tested with method ASTM D5321 or an equivalent test method. The interface shall be tested in a water-saturated state.
- E. This material is part of a system. The system shall meet the requirements before the component material can be deemed acceptable.
- F. Interface friction tests (initial CQA testing) will be conducted by the Owner.

2.4 EQUIPMENT AND ACCESSORIES

- A. Welding and Seaming Equipment:
 1. Equipped with gages showing temperatures at the nozzle (extrusion welder) or at the wedge (wedge welder).
 2. Maintained in adequate numbers to avoid delaying work.
 3. Supplied by a power source capable of providing constant voltage under a combined-line load.

4. Electric generator shall not be placed directly on the HDPE geomembrane unless protective boots or rubber tires are placed no generators and no damage to the geomembrane is observed. In addition, fuel cans will not be allowed to be stored directly on the geomembrane unless a spill container is provided outside of the fuel container.
- B. Field Tensiometer:
1. CQC will provide a tensiometer for on-site shear and peel testing of HDPE geomembrane seams.
 - a. Tensiometer shall be in good working order.
 - b. Built to ASTM specifications.
 - c. Accompanied by evidence of calibration of equipment and gages within the past six months.
 2. Tension meter:
 - a. Motor driven.
 - b. Jaws capable of traveling a measure rate of 2 -inch per minute.
 - c. Equipped with a gauge that measures the force in unit pounds exerted between the jaws.
 - d. Digital readout.
- C. Punch Press:
1. Provide a punch press for the onsite preparation of specimens for testing.
 2. Capable of cutting specimens in accordance with ASTM D4437.
- D. Vacuum Box:
1. Provide a vacuum box for onsite testing of HDPE geomembrane seams in accordance with ASTM D5641.
- E. Equipment necessary to perform "Pressurized Air Channel Evaluation of Dual Seamed Geomembranes" in accordance with ASTM D5820.
- F. Gages:
1. Calibrated within past six months.
 2. Specified test values reading near mid-range of the gage scale.
- G. Equipment necessary to perform "Non-Destructive Testing of Geomembrane Seams Using The Spark Test" in accordance with ASTM D6365.

2.5 FABRICATION

- A. The Manufacturer is responsible for producing geomembrane sheet that complies with this Specification. These responsibilities include but are not limited to:
1. Resin and additive quality control:
 - a. Acceptance of the resin and additives from chemical formulators.
 - b. Testing of the raw resin and additives to ensure compliance with the Manufacturer's specifications and with this Specification.
 2. Formulation of the resin and additives into sheeting using mixing and extrusion equipment.
 3. Testing of the sheet material to ensure compliance with Manufacturer's specifications and this Specification.
 4. Shipping of the sheet material to Installer.
 5. Certification of the raw materials and finished sheet to comply with this Specification.
 6. Certification of Installer's training (unless Installer is certified by other acceptable manufacturer list herein), experience and methods for welding, seaming, joining and inspecting geosynthetic materials installations in compliance with Manufacturer's standards and with Quality Assurance requirements of this Specification Part 1.2.

PART 3 - EXECUTION

3.1 GEOSYNTHETIC LINER SYSTEM

- A. Geomembrane Subgrade:

1. Protect subgrade at all times from damage until such time as the placement of HDPE geomembrane liner and other components of the geosynthetic liner system are complete.
 2. The subgrade shall be prepared in a manner consistent with proper subgrade preparation techniques for the installation of HDPE Geomembrane.
 - a. The subgrade shall be properly compacted so as not to settle and cause excessive strains in the HDPE Geomembrane or other synthetic liner materials.
 - b. Prior to installation, ensure a surface free of debris, roots, or angular stones larger than 1/2 inch.
 - c. In addition, ensure that the subgrade has been rolled to provide a uniform surface.
 - d. During installation, ensure that rutting or ravelling is not caused by installation equipment or weathering.
- B. Anchor Trenches:
1. Geosynthetic materials placed on side slopes shall be anchored into trenches as detailed on the Contract Drawings.
 2. Excavation, backfill and compaction shall be in accordance with Section 02200.
- C. HDPE Geomembrane:
1. General:
 - a. Installer of HDPE geomembranes is responsible for handling, fitting, welding, seaming, jointing and testing of geosynthetic materials sheets or blankets in the field in accordance with the CCSWDC Class I Expansion Construction Quality Assurance (CQA) Plan.
 - b. These responsibilities include but are not limited to:
 - 1) Acceptance (in writing) of the geosynthetic materials sheets or blankets from the transporter.
 - 2) Acceptance (in writing) of the surface which will serve as a base for the HDPE geomembrane.
 - a) This acceptance shall precede installation of the HDPE geomembrane.
 - b) Shall state that the Installer has inspected the surface, and reviewed the Specifications for material and placement, and finds all surface conditions acceptable for placement of HDPE geomembrane liners. Installer shall coordinate with the Contractor or surveyor to ensure the geomembrane surface is to the appropriate elevation.
 - c) Shall explicitly state any and all exceptions to acceptance.
 - 3) Handling, welding, seaming, jointing, testing and repair of HDPE geomembrane liners and other geosynthetic materials in compliance with this Specification and with written procedures manuals prepared by the Manufacturer or Fabricator.
 - a) Manual shall be submitted to the Engineer together with Shop Drawings showing the layout of HDPE geomembrane within the Project.
 - (1) Do not deviate from the procedures included in the manual unless approved by the Owner/Engineer.
 - b) HDPE Geomembrane shall not be placed upon frozen foundation, standing water or other conditions which will result in deterioration of the foundation.
 - c) HDPE Geomembrane liner materials shall be laid out according to plans previously approved by the Engineer.
 - d) Adjacent rolls of HDPE geomembrane shall overlap a minimum of 3 -inch.
 - 4) Repair or replacement of defects in the geosynthetic materials as required by the Inspector or the Owner.
 - 5) Installer and Manufacturer may be the same firm.
 2. Panel deployment:
 - a. Subgrade Preparation:
 - 1) Prepare subgrade in a manner consistent with proper subgrade preparation techniques for the installation of HDPE geomembrane liner.
 - 2) Properly compact the subgrade so as not to settle and cause excessive strains in the HDPE geomembrane liner.

- 3) Prior to installation, ensure a surface free of debris, roots, or angular stones larger than 1/2 -inch.
 - 4) Subgrade soils proof-rolled with a ten (10) ton drum roller, two (2) passes parallel to slope or as directed by CQA Inspector. The subbase shall be compacted and proof-rolled under observation of the CQA Inspector to assure the maximum practical compaction under the existing field conditions has been achieved. See specification Section 02200 for project specific compaction requirement.
 - 5) Ensure rutting or raveling is not caused by installation equipment or weather.
 - 6) Ensure that lines and grades have been verified by the Contractor and a subgrade acceptance form has been submitted.
- b. Construct and backfill anchor trenches
 - c. Deploy HDPE geomembrane liner in a manner to ensure it is not damaged
 - d. On slopes, anchor the HDPE geomembrane liner securely and deploy it down the slope in a controlled manner.
 - e. Weight the HDPE geomembrane liner with sandbags or equivalent in the presence of wind.
 - f. Minimize cutting the HDPE geomembrane liner. Whenever possible, overlap instead of cutting material. If cutting is required, cut HDPE geomembrane liner with a cutter or other approved device. Seal all cut edges, as recommended by Manufacturer.
 - g. Only those panel/sheets that can be seamed in 1 day shall be deployed.
 - h. Place panels with minimal handling.
 - 1) No horizontal seams on side slopes.
 - 2) Protect panels from tear, puncture or abrasion.
 - i. Equipment used to deploy the geomembrane shall not damage the HDPE geomembrane.
 - 1) A rut is defined as a 1/4 -inch depression over a 10 FT straight-edged length.
 - j. No vehicular traffic, except low ground pressure equipment necessary for the deployment and installation of verlying geosynthetic layer, is permitted on unprotected HDPE geomembrane.
 - k. Minimize foot traffic.
 - 1) Do not allow personnel access to wet or slippery liners without adequate safety precautions.
 - 2) Do not allow footwear that may damage the geomembrane.
 - l. Ballast with sandbags to prevent wind uplift as recommended by Manufacturer based on local climatic conditions.
 - 1) Remove and replace all wind damaged panels at no additional cost to Owner.
 - 2) If wind causes panels to be displaced, displaced panel may not be reused.
 - m. Install HDPE geomembrane in stress free, tension free and relaxed condition.
 - 1) Account for temperature and weather-related impacts when deploying and covering.
 - 2) Stretching to fit and folding are not permitted.
 - n. Do not allow HDPE geomembrane to bubble, fold, or create ripples as a result of deployment of drainage layer or protective soil cover placement.
 - 1) Except as noted on Contract Drawings no folds in HDPE geomembrane will be allowed.
 - o. Any panel exhibiting stretching caused by placement, covering techniques, or wind shall be removed and may not be incorporated in the final construction.
 - p. Field seaming:
 - 1) Field seaming shall be done in accordance with seaming recommendations furnished by the geomembrane Manufacturer, referenced EPA documents, and this specification.
 - 2) Each piece of seaming equipment and each operator shall perform pre-weld trial seams at the start of a shift, whenever equipment has broken down or seaming is interrupted for more than 30 minutes, and at other times at the discretion of the Installer and Inspector.

- 3) Trial seams shall use the same seaming materials and methods to be used in the actual construction.
 - 4) Surfaces to be seamed shall be clean and dry at the time of seaming.
 - a) Precipitation and ponding of water on the HDPE geomembrane shall cause termination of seaming operations.
 - b) HDPE geomembrane shall not be seamed when ambient temperatures are below 41 DegF or above 104 DegF, without written consent of HDPE geomembrane Manufacturer and Engineer.
 - 5) HDPE geomembrane sheets shall be seamed continuously without fishmouths or breaks in the seam.
 - a) Where fishmouths are unavoidable, the sheet shall be slit to a point such that the sheet lies flat and with no remaining wrinkle.
 - b) The two edges of the slit shall be seamed together provided that the overlap for this seam shall be a minimum of 6 -inch.
 - c) Areas of the slit which do not achieve an overlap of 6 -inch, including the terminus of the slit, shall be provided with a patch as discussed below.
 - 6) All HDPE geomembranes shall be seamed by thermal fusion methods as recommended by the HDPE geomembrane Manufacturer.
 - a) HDPE geomembrane seaming shall be either extrusion or double wedge welded as approved by the Engineer.
 - 7) Manufacturer's seaming instructions shall specifically address seaming materials, temporary and permanent jointing, seaming temperatures including temperatures for seaming materials, seam finishing and curing.
 - 8) A copy of Manufacturer's seaming instructions shall be available on site at all times and shall not be deviated from without written approval of the Manufacturer and Engineer.
 - 9) All panels/sheets should be overlapped a minimum of 3 -inch.
 - a) No horizontal seams will be permitted on the side slopes. **Horizontal seams will be allowed on flat area of the terraces/benches.**
 - 10) Seaming shall not be conducted in the presence of standing water.
 - a) The seamed area shall be cleaned of dust, dirt and foreign material prior to and during the seaming operation.
 - 11) Seaming shall extend to the outside edge of panels/sheets to be placed in anchor and/or drainage trenches.
 - 12) Tack welds shall conform with manufacturers seaming techniques and shall not damage underlying membrane.
- q. Patching:
- 1) Defects in and damage to HDPE geomembrane sheets shall be repaired by seaming a patch over the defect. All repairs will be numbered by the CQC consultant and shown on the as-builts.
 - a) The patch material shall consist of an undamaged piece of HDPE geomembrane cut to provide a minimum of 6 -inch of overlap in all directions from the defect.
 - b) Round corners shall be utilized on all patches. No bead or spot patching will be accepted.
 - c) Torn or permanently twisted HDPE geomembrane shall be replaced at no expense to the Owner.
 - 2) Test all patch seams using one of the following nondestructive tests: vacuum tests or spark tests.
 - a) Test patch seams destructively at a frequency of ten percent or a minimum of one test per seaming personnel per day.
 - b) This destructive testing may be accomplished using demonstration seams performed adjacent to the liner installation.
- r. Smoking is not permitted while on the geomembrane.

- s. Field Panel Identification: The Installer's CQC Consultant will document that the Geomembrane Installer labels each field panel with an "identification code" consistent with the approved panel layout plan. The location of the label and the color of marker used must be as agreed to in the QA/QC Preconstruction Meeting.

3.2 FIELD QUALITY CONTROL

- A. The CQA Inspector shall not be a part of the installation program and shall not serve as a substitute for performing the duties or certification required of the Manufacturer and Installer.
 - 1. The CQA Inspectors responsibilities include, but are not limited to:
 - a. Inspection of the material and the handling and field installation of the geomembranes. Inspection of all welds, repairs and quality control test results.
 - b. All exceptions to material or installation shall be documented and furnished to the CQA firm in writing within 48 HRS of discovery.
 - c. Inspection and Certification of HDPE geomembrane integrity until completion of placement of protective soil cover.
- B. Trial Seam Testing:
 - 1. Trial seams shall be at the start of a shift, whenever equipment has broken down or seaming is interrupted for more than 30 minutes, and at other times at the discretion of the Installer and Inspector.
 - a. The location of trial seam shall be in an area proposed for the day's production seaming.
 - b. Equipment, methods and personnel shall be the same as proposed for the day's seaming.
 - 2. Test four replicates (1 -inch wide specimens) cut from trial seam.
 - a. To be acceptable, four of four replicate test specimens must meet specified seam strength requirements and all failures shall be Film Tear Bond.
 - b. A minimum of 2 specimens shall be tested for shear strength and 2 for peel adhesion using an approved field quantitative tensiometer. Jaw separation speed shall be 2 -inch per minute.
 - c. If the field trial seam tests fail to meet these requirements, the entire operation shall be repeated.
 - d. If the additional test seams fail, the seaming apparatus or seamer shall not be accepted or used for seaming until the deficiencies are corrected and two consecutive successful test seams are achieved.
- C. Non-Destructive Seam Testing:
 - 1. All field seams shall be non-destructively tested over their full length.
 - a. Seam testing shall be performed as the seaming work progresses, not at the completion of field seaming.
 - b. All testing shall be documented. Any seams which fail shall be repaired and documented.
 - 2. Non-destructively test all field seams continuously using one of the following nondestructive seam tests:
 - a. Vacuum box (ASTM D5641). Test at 6psi for 10 seconds. Any loss in vacuum, as indicated by bubbling of soap solution, is a failing test.
 - b. Spark tests (ASTM D6365). Test at uniform rate between 6 and 9 meters per minute. A spark indicates a failing test.
 - c. Pressurized air channel test (ASTM D5820). Test at 35 psi for at least 5 minutes. A pressure drop of more than 2psi is a failing test.
 - 3. All tests should be conducted in accordance with their corresponding ASTM method.
 - 3.4. All field seams that cannot be continuously non-destructively tested by pressurized air channel test or vacuum box test shall be visually inspected and all welds, where possible, will be vacuum box tested.
- D. Destructive Seam Testing:
 - 1. A minimum of one destructive test per 500 LF of seam, and as many other samples as CQA firm determines appropriate, shall be obtained at locations specified by the CQA firm.
 - a. Sample locations shall not be identified prior to seaming.

- b. The samples shall be a minimum of 12 -inch wide by 48 -inch long with the seam centered lengthwise.
 - c. Each sample shall be cut into three equal pieces with one piece retained by the Installer, one piece given to a CQA Testing Laboratory, and the remaining piece given to the CQA Engineer for quality assurance testing and/or permanent record.
 - d. Each sample shall be numbered and recorded on the final panel layout record drawing, and cross-referenced to a field log which identifies:
 - 1) Panel/sheet number.
 - 2) Seam number.
 - 3) Top sheet.
 - 4) Date and time cut.
 - 5) Ambient temperature.
 - 6) Seaming unit designation.
 - 7) Name of seamer.
 - 8) Seaming apparatus temperature and pressures (where applicable).
2. A minimum of four 1 -inch wide replicate specimens shall be cut from the Installer's sample.
- a. A minimum of 2 specimens shall be tested for shear strength and 2 for peel adhesion using an approved field quantitative tensiometer. Jaw separation speed shall be 2 -inch per minute.
 - b. To be acceptable, all test specimens must meet the specified seam strength requirements and all must fail as Film Tear Bond.
 - c. If all field tests pass, 5 specimens shall be tested at the CQA Testing Laboratory for shear strength and 5 for peel adhesion in accordance with ASTM D6392.
 - d. To be acceptable, 4 out of 5 replicate test specimens must meet the specified seam strength requirement and fifth sample must meet 80% required strength and fail at Film Tear Bond.
3. The minimum required seam strengths for 60 mil HDPE are:

<u>Description</u>	<u>Test Method</u>	<u>Seam Type</u>	<u>Required Value (lbs/in width)</u>
HDPE Peel	ASTM D6392	Extrusion	78
HDPE Peel	ASTM D6392	Fusion	91
HDPE Shear	ASTM D6392	Extrusion	120
HDPE Shear	ASTM D6392	Fusion	120

4. For destructive samples which have failed the seam strength criterion, the Contractor will reconstruct all the field seams between any two previous passed seam locations which include the failed seam or will go on both sides of the failed seam location (10 feet minimum), take another sample each side and test both. If both pass, the Contractor may patch or cap strip the seam between the passed samples. If either fails, the Contractor will remove and replace the entire seam. In all cases, acceptable field seams must be bounded by two passed test locations. The decision of the CQA Engineer will be final.
- a. In addition, all destructive seam sample holes shall be repaired the same day as cut.
 - b. Certified test results on all field seams shall be submitted to and approved by the CQA Engineer prior to acceptance of the seam.
5. Ten percent of all repaired areas **that are large enough to obtain a destructive patch** shall be destructively tested. **A destructive test shall be approximately 4 feet long for the test.**
- a. All repaired areas shall be non-destructively tested.
6. Destructive testing shall be performed by a CQA Testing Laboratory not employed by the Installer.
7. A map showing the locations, number and type of all destructive samples, patches, repairs, and penetrations shall be prepared and provided to the Owner.
8. Documentation: The following documentation must be maintained at the project site for review by the CQA Engineer or Inspector.
- a. Geomembrane Installer's Documentation:

- 1) Daily Log: daily record that summarizes panels deployed, seams completed, seam testing, seam repair, personnel on site, weather conditions, and equipment on site.
- 2) Material Conformance: maintain original conformance certificate(s) from geomembrane manufacturer.
- 3) Subgrade Acceptance Log: maintained originals of subgrade acceptance forms for each panel and signed by the Geomembrane Installer.
- 4) Panel Log: provides geomembrane roll number used and subgrade acceptance for each panel deployed.
- 5) Seaming Pre-weld Log: provided a complete record of all pre-weld start-up test results.
- 6) Seam Testing Log: provides a complete record of all nondestructive and destructive seam tests performed as part of the Geomembrane Installer's QC program.
- 7) Seam/Panel Repair Log: provides a complete record of all repairs and vacuum box testing of repairs made to defective seams or panels.
- 8) As-Built Drawing: maintain an as-built drawing updated on a weekly basis.

3.3 GEOSYNTHETIC LINER SYSTEM ACCEPTANCE

- A. Contractor shall retain all ownership and responsibility for the geosynthetic liner system until final acceptance by the Owner.
 1. Owner will accept the geosynthetic liner system installation when the installation is finished and all required warranties, test results, and documentation from the Contractor, Manufacturer, Inspector and Installer has been received and approved, and verification of the adequacy of all field seams and repairs, including associated testing, is complete.

END OF SECTION

SECTION 02777
DRAINAGE COMPOSITE – FINAL COVER

PART 1 - GENERAL

1.1 SUMMARY

- A. Section includes the bonded geotextile-geonet drainage composite used as part of the final cover system.
- B. Related sections include but are not necessarily limited to:
 - 1. Section 02778 - Geotextiles.

1.2 QUALITY ASSURANCE

- A. Referenced Standards:
 - 1. ASTM International (ASTM):
 - a. D1238, Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer.
 - b. D1505, Standard Test Method for Density of Plastics by the Density-Gradient Technique.
 - c. D1603, Standard Test Method for Carbon Black in Olefin Plastics.
 - d. D1987 Test Method for Biological Clogging of Geotextile or Soil/Geotextile Filters.
 - e. D4716, Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products.
 - f. D4873, Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples.
 - g. D5199, Standard Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.
 - h. D5321, Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method
 - i. D7005, Determining the Bond Strength (Ply Adhesion) of Geocomposites.
 - j. D5035, Standard Test Method for Breaking Force and Elongation of Textile Fabrics (strip method).
 - 2. Geosynthetic Research Institute (GRI).
 - a. GRI GC8 – Determination of the Allowable Flow Rate of a Drainage Geocomposite.
- B. Qualifications:
 - 1. Each manufacturing and fabricating firm shall demonstrate five (5) years continuous experience, including a minimum of 5,000,000 SF of drainage composite production in the past three (3) years.
 - 2. Installer shall attend pre-installation conference.

1.3 DEFINITIONS

- A. Manufacturer: Manufacturer producing drainage composites from geonet cores and geotextiles.
- B. Installer: The Installers are the individuals actually performing the hands-on work in the field.

1.4 SUBMITTALS

- A. Shop Drawings:
 - 1. Manufacturer's documentation that raw materials and roll materials comply with required drainage composite physical properties.
 - 2. Manufacturer and Installer quality control manuals.
 - 3. Original test results for resins and roll material at frequency specified in respective quality control manuals.
 - a. Include or bracket the rolls delivered for use in the Work.

4. Proposed details of anchor trench if different than included in Contract Documents.

B. Miscellaneous Submittals:

1. Qualification documentation specified in Article 1.2.
2. Transmissivity test.
3. Interface friction test.

1.5 DELIVERY, STORAGE AND HANDLING

- A. Label, handle, and store drainage composites in accordance with ASTM D4873 and as specified herein.
- B. Wrap each roll in an opaque and waterproof layer of plastic during shipment and storage.
 1. Do not remove the plastic wrapping until deployment.
- C. Label each roll with the manufacturer's name, drainage composite type, lot number, roll number, and roll dimensions (length, width, gross weight).
- D. Repair or replace, as directed by the Engineer, drainage composite or plastic wrapping damaged as a result of storage or handling.
- E. Do not expose drainage composite to temperatures in excess of 71 DegC (160 DegF) or below 0 DegC (32 DegF) unless recommended by the Manufacturer.
- F. Do not use hooks, tongs or other sharp instruments for handling the drainage composite.
- G. Do not lift rolls by use of cables or chains in contact with the drainage composite.
- H. Do not drag drainage composite along the ground or across textured geomembranes.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

- A. Subject to compliance with the Contract Documents, the following Manufacturers are acceptable:
 1. CETCO
 2. GSE Lining Technology.
 3. Polyflex Inc.
 4. Skaps Industries.
 5. Tenax Corp.

2.2 MATERIALS AND MANUFACTURE

- A. Geonet Core:
 1. Use nonthermally degraded polyethylene polymer which is clean and free of any foreign contaminants.
 2. Manufactured geonet to conform to the property requirements listed in Table 1 and be free of defects including tears, nodules or other manufacturing defects which may affect its serviceability.

TABLE 1 - GEONET PROPERTIES

PROPERTY	TEST METHOD	REQUIRED VALUE	MIN. MQC TEST FREQUENCY
Specific Gravity/ Density (g/cm ³) (min)	ASTM D1505	>0.94 g/cc (<u>min. average value</u>)	1 per 50,000 ft ² and every resin lot
Thickness (mil)	ASTM D5199	300 mil (<u>min. average value</u>)	1 per 50,000 ft ² and every resin lot
Carbon Black Content	ASTM D1603	2 percent	1 per 50,000 ft ² and every resin lot
Tensile Strength	ASTM D5035	75 lbs/in MD	1 per 50,000 ft ² and every resin lot

- B. Geotextile:
 1. Cover geonet core on both sides or single side, as shown on Drawings, with a geotextile complying with requirements specified in Section 02778: Geotextiles, Drainage.
- C. Drainage Composite:
 1. Create a composite by heat bonding geotextiles to the geonet.
 2. Transmissivity = 1.3×10^{-3} m²/sec @ 100 hrs and 1,000 psf by ASTM D4716 (see Paragraph 2.3 A).
 3. Ply adhesion ASTM D7005 MARV of 1 lb/in.
- D. Independent conformance testing shall be performed in accordance with CQA Plan.

2.3 SOURCE QUALITY CONTROL

- A. Transmissivity Testing:
 1. Measure transmissivity using water at 68 DegF with a normal compressive load of 1,000 psf. and a hydraulic gradient of 0.33
 2. Attach geotextiles to the geonet in the same configuration as will be used in the field.
 3. Boundary conditions are soil interface on the upper geotextile and textured 40 mil LLDPE geomembrane against the lower geotextile.
 4. Maximum design normal load testing shall be conducted for a minimum period of 100 hours unless data equivalent to the 100-hour period is provided in which case the test shall be conducted for a minimum period of one hour.
 5. Testing frequency: 1 test for every 540,000 SF of installed product
- B. Interface Friction Tests.
 1. Laboratory friction tests shall be conducted, on behalf of the Owner by the CQA Laboratory, with representative samples of the materials selected by the Contractor for use in the Work. The Contractor is responsible for shipping materials to the testing laboratory. The initial set of testing and subsequent conformance tests (if any) shall be paid for by the Owner. If any interface doesn't meet the requirements, or if the Contractor changes geosynthetic materials, then the additional cost to qualify those materials shall be borne by the Contractor. Testing will include the interfaces between the following adjacent materials.

<u>Material</u>	<u>Specification Section</u>
Protective Cover	02200
Drainage Composite – Final Cover	02777
40 mil Textured LLDPE Geomembrane	02775
Intermediate Cover	02200

2. The testing shall be performed in accordance with ASTM D5321.
3. The materials shall be tested at normal stressed of 250, 500, and 1,000 psf. Displacement rates shall be in accordance with ASTM D5321 Procedure A for geosynthetic to geosynthetic interfaces and Procedure B for soil to geosynthetic interfaces. Soil components shall be compacted to the same moisture-density requirements specified for full-scale field placement and saturated prior to shear. All geosynthetic interfaces shall be tested in a wet condition. Geosynthetics shall be oriented such that the shear force is parallel to the downslope orientation of these components in the field. The testing laboratory shall confirm these criteria with the CQA Inspector prior to performing the tests.
4. A minimum friction angle of 26 degrees is required for each interface in the system defined in Paragraph B.1.
5. Interface shear strength of the actual components which will be used in the liner system shall be tested with method ASTM D5321 or an equivalent test method.
6. This material is part of a system. The system shall meet the requirements before the component material can be deemed acceptable.

7. Interface friction tests will be conducted by the CQA Testing Laboratory.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Prior to placement of the drainage composite, clean the substrate of all soil, rock, and other materials which could damage the composite.
- B. The geocomposite drainage media shall be placed only on geomembrane that has been approved by the Geomembrane Installer and accepted by the CQA Inspector.

3.2 INSTALLATION

- A. Install geocomposite drain in accordance with manufacturer's written recommendations.
- B. Deploy the drainage composite ensuring that the drainage composite and underlying materials are not damaged.
 1. Replace or repair faulty or damaged drainage composite as directed by Engineer.
- C. Unroll drainage composite downslope keeping in slight tension to minimize wrinkles and folds.
- D. Maintain free of dirt, mud, or any other foreign materials at all times during construction.
 1. Clean or replace rolls which are contaminated.
- E. Place adequate ballast to prevent uplift by wind.
- F. Overlap adjacent rolls a minimum of 6 IN.
 1. Overlap new drainage composite over existing as shown on the Drawings.
 2. Shingle all edges of geocomposite downslope
- G. Use manufacturer's fasteners to join adjacent rolls.
 1. Metallic fasteners will not be allowed.
 2. Space fasteners a maximum of 5 FT along downslope roll overlaps and a maximum of 1 FT along cross slope roll overlaps.
 3. Use fasteners of contrasting color from the drainage composite to facilitate visual inspection.
 4. Do not weld drainage composite to geomembranes.
 5. Install geotextile cap strip wherever ends of geocomposite are exposed to soil intrusion.
- H. See Section 02778, Geotextiles, for information on seaming the upper geotextile to the upper geotextile of the adjacent rolls.
- I. Repairs holes or tears in the drainage composite by placing a patch of drainage composite extending a minimum of 2 FT beyond the edges of the hole or tear.
 1. Use approved fasteners, spaced every 6 IN around the patch, to fasten the patch to the original roll.

3.3 FIELD QUALITY CONTROL

- A. Prior to installation of the drainage composite, the Installer's CQC Consultant shall provide the Engineer quality control certificates signed by the manufacturer's quality assurance manager for every 540,000 SF of geocomposite drainage media to be installed illustrating satisfactory transmissivity tests among other attributes.

END OF SECTION

SECTION 02777A
DRAINAGE COMPOSITE - OVERLAY LINER SYSTEM

PART 1 - GENERAL

1.1 SUMMARY

- A. Section includes the bonded geotextile-geonet drainage composite used as part of the overlay liner system for the Phase I / II connection.
- B. Related sections include but are not necessarily limited to:
 - 1. Section 02778 - Geotextiles.
 - 2. Central County Solid Waste Disposal Complex Class I Landfill Expansion Construction Quality Assurance Plan.

1.2 QUALITY ASSURANCE

- A. Referenced Standards:
 - 1. ASTM International (ASTM):
 - a. D1238, Flow Rates of Thermoplastics by Extrusion Plastometer.
 - b. D1505, Density of Plastics by the Density-Gradient Technique.
 - c. D1603, Carbon Black in Olefin Plastics.
 - d. D1987 Test Method for Biological Clogging of Geotextile or Soil/Geotextile Filters.
 - e. D4716, Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products.
 - f. D4873, Identification, Storage and Handling of Geosynthetic Rolls.
 - g. D5199, Standard Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.
 - h. D7005, Determining the Bond Strength (Ply Adhesion) of Geocomposites.
 - 2. Geosynthetic Research Institute (GRI).
 - a. GRI GC8 – Determination of the Allowable Flow Rate of a Drainage Geocomposite.
- B. Qualifications:
 - 1. Each manufacturing and fabricating firm shall demonstrate 5 years continuous experience, including a minimum of 5,000,000 SF of drainage composite production in the past 3 years.
 - 2. Installer shall attend pre-installation conference.

1.3 DEFINITIONS

- A. Manufacturer: Manufacturer producing drainage composites from geonet cores and geotextiles.
- B. Installer: The Installers are the individuals actually performing the hands-on work in the field.

1.4 SUBMITTALS

- A. Shop Drawings:
 - 1. Shop Drawings:
 - a. Manufacturer's documentation that raw materials and roll materials comply with required drainage composite physical properties.
 - b. Manufacturer and Installer quality control manuals.
 - c. Original test results for resins and roll material at frequency specified in respective quality control manuals. Include or bracket the rolls delivered for use in the Work.
 - d. Proposed details of anchor trench if different than included in Contract Documents.
- B. Miscellaneous Submittals:
 - 1. Qualification documentation specified in Article 1.2.
 - 2. Transmissivity test.
 - 3. Interface friction test.

1.5 DELIVERY, STORAGE AND HANDLING

- A. Label, handle, and store drainage composites in accordance with ASTM D4873 and as specified herein.
- B. Wrap each roll in an opaque and waterproof layer of plastic during shipment and storage. Do not remove the plastic wrapping until deployment.
- C. Label each roll with the manufacturer's name, drainage composite type, lot number, roll number, and roll dimensions (length, width, gross weight).
- D. Repair or replace, as directed by the Engineer, drainage composite or plastic wrapping damaged as a result of storage or handling.
- E. Do not expose drainage composite to temperatures in excess of 71 DegC (160 DegF) or below 0 DegC (32 DegF) unless recommended by the Manufacturer.
- F. Do not use hooks, tongs or other sharp instruments for handling the drainage composite.
- G. Do not lift rolls by use of cables or chains in contact with the drainage composite.
- H. Do not drag drainage composite along the ground or across textured geomembranes.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

- A. Subject to compliance with the Contract Documents, the following Manufacturers are acceptable:
 - 1. CETCO.
 - 2. GSE Lining Technology.
 - 3. Polyflex Inc.
 - 4. Skaps Industries.
 - 5. Tenax Corp.

2.2 MATERIALS AND MANUFACTURE

- A. Geonet Core:
 - 1. Use nonthermally degraded polyethylene polymer which is clean and free of any foreign contaminants.
 - 2. Manufactured geonet to conform to the property requirements listed in Table 1 and be free of defects including tears, nodules or other manufacturing defects which may affect its serviceability.

TABLE 1 - GEONET PROPERTIES

PROPERTY	TEST METHOD	REQUIRED VALUE	MIN. MQC TEST FREQUENCY
Specific Gravity/ Density (g/cm ³) (min)	ASTM D1505	>0.94 g/cc (<u>min. average value</u>)	1 per 100,000 ft ² and every resin lot
Mass per Unit Area (lbs/ft ²)	ASTM D5261		1 per 50,000 ft ² and every resin lot
Carbon Black Content	ASTM D1603	2 percent	1 per 50,000 ft ² and every resin lot
Tensile Strength	ASTM D5035		1 per 50,000 ft ² and every resin lot

- B. Geotextile:
 - 1. Cover geonet core on both sides with a geotextile complying with requirements specified in Section 02778: Geotextiles, Drainage.
- C. Drainage Composite:

1. Create a composite by heat bonding geotextiles to the geonet. The bond between the geotextile and the geonet shall exhibit a minimum peel strength of 1 LBS/IN when tested in accordance with ASTM D413
2. Transmissivity $1.8 \times 10^{-3} \text{m}^2/\text{sec}$ @ 100 hrs and 20,000 psf by ASTM D4716.
3. Ply adhesion ASTM D7005 MARV of 1 lb/in.

2.3 SOURCE QUALITY CONTROL

A. Transmissivity Testing:

1. Measure transmissivity using water at 68 DegF with a normal compressive load of 20,000 psf and a hydraulic gradient of 0.02.
2. Attach geotextiles to the geonet in the same configuration as will be used in the field.
3. Boundary conditions are soil interface on the upper geotextile and HDPE geomembrane against the lower geotextile.
4. Maximum design normal load testing shall be conducted for a minimum period of 100 hours unless data equivalent to the 100-hour period is provided in which case the test shall be conducted for a minimum period of one hour. In the case of the design load from one lift of waste, the minimum period shall be one hour.
5. Testing frequency: 1 test for every 540,000 SF of installed product.

B. Interface Friction Tests.

1. Laboratory friction tests shall be conducted, on behalf of the OWNER by the CQA Laboratory, with representative samples of the materials selected by the Contractor for use in the Work. The Contractor is responsible for shipping materials to the testing laboratory. The initial set of testing and subsequent conformance tests (if any) shall be paid for by the Owner. If any interface doesn't meet the requirements, or if the Contractor changes geosynthetic materials, then the additional cost to qualify those materials shall be borne by the Contractor. Testing will include the interfaces between the following adjacent materials.

<u>Material</u>	<u>Specification Section</u>
Drainage Sand Layer – Overlay Liner	02240
Drainage Composite – Overlay Liner	02777A
60 mil Textured HDPE Geomembrane	02776
Cover Soil	02200

2. The testing shall be performed in accordance with ASTM D5321.
3. The materials shall be tested at normal stressed of 5,000, 10,000, and 20,000 psf. Displacement rates shall be in accordance with ASTM D5321 Procedure A for geosynthetic to geosynthetic interfaces and Procedure B for soil to geosynthetic interfaces. Soil components shall be compacted to the same moisture-density requirements specified for full-scale field placement and saturated prior to shear. All geosynthetic interfaces shall be tested in a wet condition. Geosynthetics shall be oriented such that the shear force is parallel to the downslope orientation of these components in the field. The testing laboratory shall confirm these criteria with the CQA Inspector prior to performing the tests.
4. A minimum friction angle of 23 degrees is required for each interface in the system defined in Paragraph 2.3.B.1.
5. Interface shear strength of the actual components which will be used in the liner system shall be tested with method ASTM D5321 or an equivalent test method.
6. This material is part of a system. The system shall meet the requirements before the component material can be deemed acceptable.
7. Interface friction tests will be conducted by the CQA Testing Laboratory.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Prior to placement of the drainage composite, clean the substrate of all soil, rock, and other materials which could damage the composite.
- B. The geocomponent drainage media shall be placed only on geomembrane that has been approved by the Geomembrane Installer and accepted by the CQA Inspector.

3.2 INSTALLATION

- A. Install geocomposite drain in accordance with manufacturer's written recommendations.
- B. Deploy the drainage composite ensuring that the drainage composite and underlying materials are not damaged. Replace or repair faulty or damaged drainage composite as directed by Engineer.
- C. Unroll drainage composite downslope keeping in slight tension to minimize wrinkles and folds.
- D. Maintain free of dirt, mud, or any other foreign materials at all times during construction. Clean or replace rolls which are contaminated.
- E. Place adequate ballast to prevent uplift by wind.
- F. Overlap adjacent rolls a minimum of 6 IN. Overlap new drainage composite over existing as shown on the drawings.
- G. Use manufacturer's fasteners to join adjacent rolls. Metallic fasteners will not be allowed. Space fasteners a maximum of 5 FT along downslope roll overlaps and a maximum of 1 FT along cross slope roll overlaps. Use fasteners of contrasting color from the drainage composite to facilitate visual inspection. Do not weld drainage composite to geomembranes.
- H. See Section 02778, Geotextiles, for information on seaming the upper geotextile to the upper geotextile of the adjacent rolls.
- I. Repairs holes or tears in the drainage composite by placing a patch of drainage composite extending a minimum of 2 FT beyond the edges of the hole or tear. Use approved fasteners, spaced every 6 IN around the patch, to fasten the patch to the original roll.

3.3 FIELD QUALITY CONTROL

- A. Prior to installation of the drainage composite, the Installer's CQC Consultant shall provide the Engineer quality control certificates signed by the manufacturer's quality assurance manager for every 540,000 SF of geocomposite drainage media to be installed illustrating satisfactory transmissivity tests among other attributes.

END OF SECTION

SECTION 02778

GEOTEXTILES

PART 1 - GENERAL

1.1 SUMMARY

- A. Section Includes:
 - 1. Non-woven geotextile material for use in geocomposite drainage layer and other applications shown on the Drawings.
- B. Related Sections:
 - 1. Section 02200 -Earthwork.
 - 2. Section 02777 - Drainage Composite – Final Cover.
 - 3. Section 02777A – Drainage Composite – Overlay Liner System.
 - 4. Central County Solid Waste Disposal Complex Phase I Closure Construction Quality Assurance Plan (applies to closure areas).
 - 5. Central County Solid Waste Disposal Complex Class I Landfill Expansion Construction Quality Assurance Plan (applies only to Overlay Liner System only).

1.2 QUALITY ASSURANCE

- A. Referenced Standards:
 - 1. American Association of State Highway Transportation Officials (AASHTO):
 - a. M288, Standard Specification for Geotextile Specification for Highway Application.
 - 2. ASTM International (ASTM):
 - a. D1987, Biological Clogging of Geotextile or Soil/Geotextile Filters.
 - b. D3786, Standard Test Method for Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics - Diaphragm Bursting Strength Tester Method.
 - c. D4354, Sampling of Geosynthetics for Testing.
 - d. D4355, Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus).
 - e. D4491, Standard Test Methods for Water Permeability of Geotextiles by Permittivity.
 - f. D4533, Standard Test Method for Trapezoid Tearing Strength of Geotextiles.
 - g. D4632, Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.
 - h. D4751, Standard Test Method for Determining Apparent Opening Size of a Geotextile.
 - i. D4759, Standard Practice for Determining the Specification Conformance of Geosynthetics.
 - j. D4833, Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
 - k. D4873, Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples.
 - l. D4884, Strength of Sewn or Thermally Bonded Seams of Geotextiles
 - m. D5261, Standard Test Method for Measuring Mass per Unit Area of Geotextiles.
 - n. D6193, Standard Practice for Stitches and Seams.
- B. Qualifications:
 - 1. Each manufacturing, fabricating firm shall demonstrate 5 years continuous experience, including a minimum of 10,000,000 SF of geotextile installation in the past three (3) years.
 - 2. Installing firm shall demonstrate that the site Superintendent or Foreman has had responsible charge for installation of a minimum of 1,000,000 SF of geotextile.
 - 3. Installer shall attend pre-installation conference.

1.3 DEFINITIONS

- A. Manufacturer: Manufacturer producing geotextile sheets from resin and additives.

- B. Installer: The Installers are the individuals actually performing the hands-on work in the field.
- C. MARV: Minimum Average Roll Value

1.4 SUBMITTALS

- A. Shop Drawings:
 - 1. Manufacturer's documentation that raw materials and roll materials comply with required geotextile physical properties.
 - 2. Manufacturer and Installer quality control manuals.
 - 3. Original test results for resins, roll material and factory seam tests at frequency specified in respective quality control manuals.
 - a. Results shall include or bracket the rolls delivered for use in the Work.
 - 4. Proposed details of anchoring and overlapping if different than included in Contract Documents.
- B. Miscellaneous Submittals:
 - 1. For needle punched geotextiles, the Manufacturer shall certify that the geotextile has been continuously inspected using permanent on-line full-width metal detectors and does not contain any needles which could damage other geosynthetic layers.
 - 2. Qualification documentation specified in Article 1.2.B

1.5 DELIVERY, STORAGE AND HANDLING

- A. Label, handle, and store geotextiles in accordance with ASTM D4873 and as specified herein.
- B. Wrap each roll in an opaque and waterproof layer of plastic during shipment and storage.
 - 1. Do not remove the plastic wrapping until deployment.
- C. Label each roll with the manufacturer's name, geotextile type, lot number, roll number, and roll dimensions (length, width, gross weight).
- D. Repair or replace geotextile or plastic wrapping damaged as a result of storage or handling, as directed.
- E. Do not expose geotextile to temperatures in excess of 71 Deg C (160 Deg F) or less than 0 Deg C (32 Deg F) unless recommended by the manufacturer.
- F. Do not use hooks, tongs or other sharp instruments for handling geotextile.
 - 1. Do not lift rolls lifted by use of cables or chains in contact with the geotextile.
 - 2. Do not drag geotextile along the ground.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

- A. Subject to compliance with the Contract Documents, the following Manufacturers are acceptable:
 - 1. GSE Lining Technology.
 - 2. Mirafi (TenCate Geosynthetics)
 - 3. Propex.
 - 4. SKAPS Industries.
 - 5. Tenax Corp.
 - 6. Or approved equal

2.2 MATERIALS AND MANUFACTURE

- A. Geotextile:
 - 1. Non-woven and woven pervious sheet of polymeric material.
 - 2. Geotextile fibers:

- a. Long-chain synthetic polymer composed of at least 85 percent by weight polyolefins, polyesters, or polyamides.
- b. Filaments resistant to deterioration by ultraviolet light, oxidation, and heat exposure.
- c. Do not add reclaimed or recycled fibers or polymer to the formulation.
3. Form geotextile into a network such that the filaments or yarns retain dimensional stability relative to each other, including the selvages.
4. The geotextile physical properties shall equal or exceed the minimum average roll values listed below.
 - a. Values shown are for the weaker principal direction unless both values are shown.
 - b. Acceptance of geotextile shall be in accordance with ASTM D4759.

Non-woven Drainage Geotextile: Used in the geocomposite for drainage and other applications shown on Drawings.

PROPERTY	TEST METHOD	MARV	MIN. MQC TEST FREQUENCY
Mass per Unit Area, (oz/sy)	ASTM D5261	6	1 per 90,000 ft ²
Grab Tensile Strength (lbs)	ASTM D4632	170 160	1 per 90,000 ft ²
Puncture Strength (lbs)	ASTM D4833	90	1 per 90,000 ft ²
AOS, US sieve (mm)	ASTM D4751	70	1 per 540,000 ft ²
Permittivity, (sec ⁻¹)	ASTM D4491	1.5	1 per 540,000 ft ²
Flow Rate, gpm/ft ²	ASTM D4491	110	1 per 540,000 ft ²
Ultraviolet Degradation, % retained @ 500 HRS	ASTM D4355	70	1per formulation

Non-woven Drainage Geotextile: Used in underlayment and other applications.

PROPERTY	TEST METHOD	MARV	MIN. MQC TEST FREQUENCY
Mass per Unit Area (oz/sy)	ASTM D5261	8	1 per 90,000 ft ²
Grab Tensile Strength (lbs)	ASTM D4632	205	1 per 90,000 ft ²
Grab Tensile Elongation (%)	ASTM D4632	50	1 per 90,000 ft ²
Puncture Strength (lbs)	ASTM D4833	120	1 per 90,000 ft ²
Trapezoidal Tear Strength (lbs)	ASTM D4533	85	1 per 90,000 ft ²

Non-woven Drainage Geotextile: Used in the EGC anchor trenches.

PROPERTY	TEST METHOD	MARV	MIN. MQC TEST FREQUENCY
Mass per Unit Area (oz/sy)	ASTM D5261	16	1 per 90,000 ft ²
Grab Tensile Strength (lbs)	ASTM D4632	370	1 per 90,000 ft ²
Grab Tensile Elongation (%)	ASTM D4632	50	1 per 90,000 ft ²
Puncture Strength (lbs)	ASTM D4833	170	1 per 90,000 ft ²
Trapezoidal Tear Strength (lbs)	ASTM D4533	145	1 per 90,000 ft ²

B. Thread:

1. High-strength polyester, nylon, or other approved thread type.
2. Equivalent chemical compatibility and ultraviolet light stability as the geotextile.
3. Contrasting color with the geotextile.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Construct the surface underlying the geotextiles smooth and free of ruts or protrusions which could damage the geotextiles.

3.2 INSTALLATION

- A. Install geotextiles in accordance with manufacturer's written recommendations except as follows.
- B. Handling shall be in accordance with ASTM D4873.
 - 1. No equipment will be permitted to traffic in direct contact with the geotextile.
- C. Lay geotextile smooth so as to be free of tensile stresses, folds, and wrinkles.
- D. Seam Construction:
 - 1. Sew all geotextile seams except for geotextile used to wrap drainage stone or used for erosion control purposes. Adjacent panels may be overlapped without sewing as long as the seams do not come apart when material is placed over them.
 - 2. Broom clean existing geotextile and cut off to provide a clean area for seaming with the new geotextile.
 - 3. Sew seams continuously using an SSA flat seam with one (1) row of a two-thread 401 chain stitch unless otherwise recommended by the manufacturer.
 - 4. Minimum distance from the geotextile edge to the stitch line nearest to that edge: 2 IN unless otherwise recommended by the manufacturer.
 - 5. Tie off thread at the end of each seam to prevent unraveling.
 - 6. Construct seams on the top side of the geotextile to allow inspection.
 - 7. Sew skipped stitches or discontinuities with an extra line of stitching with 18 IN of overlap.
 - 8. Overlap adjacent panels a minimum of 6 IN.
 - ~~8.9.~~ All geotextile seams shall be double wedge welded in lieu of sewing.
- E. Protect geotextiles from clogging, tears, and other damage during installation.
- F. Geotextile Repair:
 - 1. Place a patch of the same type of geotextile which extends a minimum of 24-12 IN beyond the edge of the damage or defect.
 - 2. Fasten patches continuously using a sewn seam or other approved method.
 - 3. Align machine direction of the patch with the machine direction of the geotextile being repaired.
 - 4. Replace geotextile which cannot be repaired.
- G. Use adequate ballast (e.g., sand bags) to prevent uplift by wind.
- H. Do not use staples or pins to hold the geotextile in place.
- I. Geotextile left uncovered for more than 14 days shall be removed and replaced at the contractors expense.
- J. Damaged rolls may be rejected. If rejected, verify that rejected material is removed from the site or stored at a location separate from accepted rolls. Geotextile rolls that do not have proper manufacturer's documentation must also be stored at a separate location until all documentation has been received and approved.
- K. The CQA Inspector shall observe that the equipment used to install the geotextile does not damage it during deployment.
- L. Crews working on the geotextile shall not smoke, wear shoes that could damage the geotextile, or engage in activities that could damage the geotextile.

3.3 FIELD QUALITY CONTROL

- A. The CQA Consultant shall confirm that the identification, storage, and handling of geotextiles is in accordance with ASTM D4873. Any deviation from this requirement will be reported to the Engineer.
- B. The CQA Consultant will examine all manufacturer certifications to ensure that the property values listed on the certifications meet or exceed these specifications. Any deviations will be reported to the Engineer.
- C. The CQA Consultant will observe placement of the geotextiles to confirm that the panel overlaps and seams are in accordance with these specifications. Any deviations will be reported to the Engineer.

END OF SECTION

SECTION 02780
GEOSYNTHETIC RAIN COVER

PART 1 - GENERAL

1.1 DESCRIPTION

- A. Furnish all labor, materials, tools, and equipment, and perform all work and services necessary for or incidental to the furnishing and installation, complete, of an impermeable, geosynthetic rain cover as shown on Drawings and specified in accordance with provisions of the Contract Documents.
- B. Related Sections include but are not necessarily limited to:
 - 1. Section 02200 - Earthwork.
 - 2. Section 02221 - Trenching, Backfilling, and Compacting for LFG Piping and Structures.
 - 3. Central County Solid Waste Disposal Complex Class I Landfill Expansion Construction Quality Assurance Plan (applies only to Overlay Liner System only).

1.2 QUALITY ASSURANCE

- A. Refer to the following standard references or specifications as applicable to this section of technical specifications:
 - 1. American Society for Testing and Materials (ASTM).
 - a. ASTM D751 - Standard Test Method for Coated Fabrics.
 - b. ASTM D4533 - Standard Test Method for Trapezoid Tearing Strength of Geotextiles
 - c. ASTM D5199 - Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.
 - d. ASTM D7003 - Standard Test Method for Strip Tensile Properties of Reinforced Geomembranes.
 - e. ASTM D7004 - Standard Test Method for Grab Tensile Properties of Reinforced Geomembranes.
 - f. ASTM E96 - Standard Test Methods for Water Vapor Transmission of Materials.

1.3 SUBMITTALS

- A. The Contractor must provide installation instructions.
- B. The Contractor must certify that the rain cover resin is first use; top grade quality only.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. 20-mil Scrim Reinforced Polyethylene Rain Cover
 - 1. The 20-mil scrim reinforced polyethylene rain cover shall consist of two sheets of high-strength polyethylene film laminated together with a third layer of molten polyethylene. A heavy scrim reinforcement shall be placed between these plies to enhance tear resistance and increase service life.
 - 2. Contractor must supply (in the Bid price) a high strength adhesive tape or equal for waterproofing and sealing the field seams and for performing repair work to the rain cover. Contractor shall minimize field seams.
 - 3. The scrim reinforced rain cover must meet the following specifications or approved equal, as determined by the Engineer.

<u>PROPERTY</u>	<u>TEST METHOD</u>	<u>SCRIM-REINFORCED TEST VALUE</u>
a. Thickness, nominal	ASTM D5199	20 mil
b. Weight		11.2 10.7 oz/yd ²
c. 1" Tensile Strength	ASTM D7003	75 lbf
d. Elongation at Break	ASTM D7003	750 700%
e. Grab Tensile Strength	ASTM D7004	102.9 lbf
f. Trapezoidal Tear Strength	ASTM D4533	102 70 lbf
g. Hydrostatic Resistance	ASTM D751	136 psi
h. Perm Rating	ASTM E96 Method A	0.052 U.S.Perm
i. Water Vapor Transmission	ASTM E96 Method A	0.023 g / 100 in ² / day

B. General Requirements

1. The rain cover must perform as specified for at least 3 years and a manufacturer's warranty must be supplied for at least 3 years.
2. The material must be able to be moved by site personnel as needed. The material must be resilient to damage when moved and/or relocated by site personnel. If necessary, the material may be cut for removal/relocation; however, in this case, must be able to be easily resealed by site personnel.
3. Factory seams must utilize methods that will eliminate excess overlap.
4. The rain cover must be impermeable, capable of repelling water with no absorption.
5. The material must be anchored, when installed, through a system so as to preclude wind damage, traffic damage, and weather.

PART 3 - EXECUTION

3.1 METHODS

- A. The Contractor shall deploy the GRC in a manner consistent with the manufacturer's specifications.
- B. Anchoring methods shall be as per the manufacturer's specifications or as approved otherwise by the Engineer.
- C. Any damage to the GRC during installation will be the Contractor's responsibility to repair/replace at no cost to the Owner.
- D. Field seams shall be of the strongest available method for the approved material except as required for patches or similar limited area applications.

END OF SECTION

APPENDIX B
REVISED CQA PLAN



Sarasota County
Solid Waste Operations

Central County Solid Waste Disposal Complex
Phase I Class I Landfill Closure and Landfill
Gas Collection System
Construction Quality Assurance Plan

October 2010

Revised March 2013

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HDR Project No. 0096-125174-002

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SECTION 1.0 INTRODUCTION

1.1 PURPOSE

This Construction Quality Assurance (CQA) Plan is a document that contains requirements for testing materials and monitoring construction of the Sarasota Central County Solid Waste Disposal Complex Phase I Class I Landfill Closure and Landfill Gas Collection System, including the responsibilities of CQA personnel, documentation control, and reporting procedures.

The plan was prepared to provide the Owner, Design Engineer, CQA Engineer, and the Contractor the means to govern the construction quality; to satisfy environmental protection requirements for current solid waste management regulations; and utilize state-of-the-art construction practices and testing procedures to adequately document proposed construction activities. The proposed construction, testing, and documentation procedures are also intended to provide the necessary safeguards and provisions accepted by the Owner upon completion. The roles of each party have been sufficiently defined and the level of responsibility explained. The proposed final cover system will be constructed in accordance with the design, the construction documented, and respective components approved and certified for acceptance.

More specifically, this CQA Plan addresses the soils and geosynthetics components of the final and temporary final cover system. Specific work elements include the following:

- Initial Cover
- Intermediate Cover
- Final Cover liner which consists, from bottom to top, of
 - 40-mil LLDPE liner (textured),
 - geocomposite drainage layer
- Protective cover
- Pipes and fittings
- Vegetative Layer
- Top Soil
- TPO Geomembrane for Temporary Final Cover
- Landfill Gas Collection System piping and components

The CQA Engineer has the primary responsibility of implementing and managing the CQA program described in this plan. When construction is complete, the CQA organization will prepare a construction certification report that will include information generated through the CQA program and will document the extent to which construction was performed in accordance with the contract documents.

The CQA Plan is intended to be a supporting document to improve the overall implementation of the work. The Contractor is instructed to bring discrepancies in the contract documents to the attention of the Design Engineer or CQA Engineer for resolution. The Design Engineer has the sole authority to determine resolution of discrepancies existing within the Contract Documents. Unless otherwise determined by the Design Engineer, the more stringent requirement shall be the controlling resolution.

1.2 REFERENCE DOCUMENTS

In addition to the methods, procedures and requirements outlined in this CQA Plan refer to the following documents:

- Florida Department of Environmental Protection (FDEP) Chapter 62-701.400; 62-701.600
- Project Plans and Specifications
- Manufacturer's Quality Assurance Manuals (where applicable)
- Contractor's Construction Quality Control Plan
- EPA/600/R-93/182
- ASTM International - Current Edition

1.3 DEFINITIONS

This section provides definitions for terms used in this CQA Plan.

Contract Documents – All contractor submittals, construction plans, as-built plans, construction specifications, QA plan, safety plan and project schedule.

CQA Organization – The company and persons including CQA Engineer, CQA Inspector, and CQA Laboratories whose primary responsibility is to implement the CQA Plan.

CQA Plan – The document contained herein, entitled Central County Solid Waste Disposal Complex Phase I Closure Construction Quality Assurance Plan prepared for Sarasota County Solid Waste Operations by HDR Engineering, Inc.

Project Plans and Specifications - All project related plans and specifications including design modifications and as-built plans.

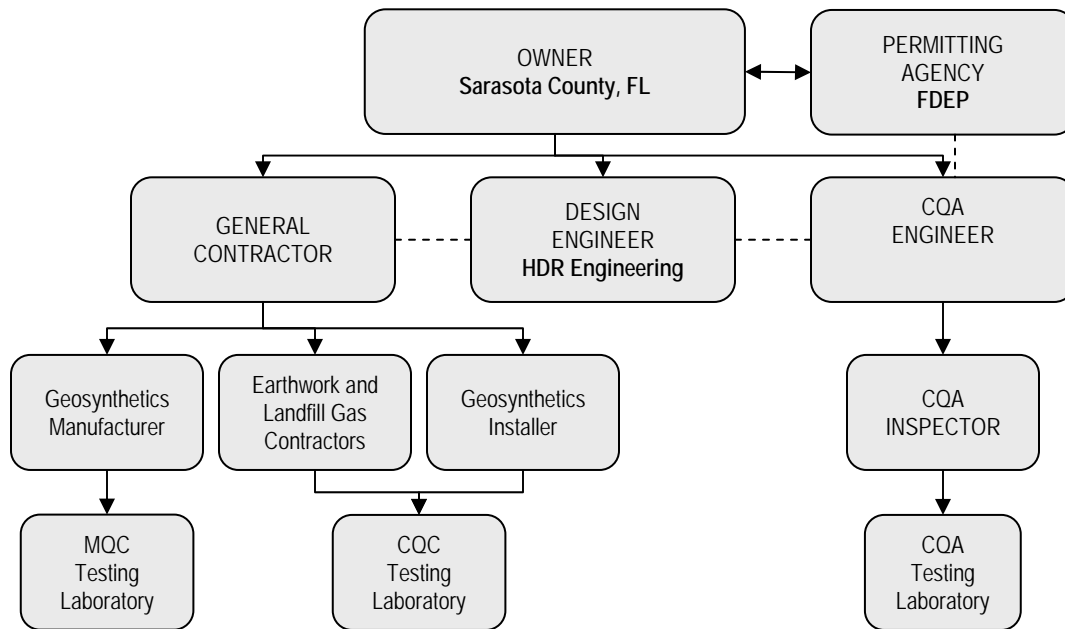
Quality Control - Actions taken by the geomembrane manufacturer and installer to ensure that the geosynthetic materials and workmanship meet the requirements of the Project Plans and Specifications.

Work - All tools, equipment, supervision, labor and material or supplies necessary to complete the project as specified herein and as shown on the Project Plans and Specifications.

SECTION 2.0 RESPONSIBILITY AND AUTHORITY

The principal organizations involved in permitting, designing and construction of the solid waste disposal facility include the permitting agency, facility owner/operator, Design Engineer, CQA organization, and Contractor. The principal organizations, their areas of responsibility and lines of authority as delineated for the CQA Plan are shown in the organization chart below and described fully in this section. This establishes the necessary lines of communication that will facilitate an effective decision making process during implementation of the CQA Plan.

**Figure 1
CQA/CQC Organization Chart**



2.1 PERMITTING AGENCY

The Florida Department of Environmental Protection (FDEP), as permitting agency, is authorized by law to issue a permit for the construction of landfill closure. It is the responsibility of the FDEP to review the facility owner/operator's permit application, including the site-specific CQA Plan, for compliance with FDEP's regulations and to make a decision to issue or deny a permit based on this review. The FDEP has the responsibility and authority to review and accept or reject any design revisions or requests for variance that are submitted by the facility owner/operator after the permit is issued. The FDEP also has the responsibility and authority to review all CQA documentation during or after construction to confirm that the approved CQA Plan was followed and that the construction was completed as specified in the design.

2.2 FACILITY OWNER/OPERATOR

Sarasota County, Florida ("Owner") is the facility owner/operator and is responsible for the design, construction, operation and closure of the solid waste disposal facility. This responsibility includes complying with the requirements of the FDEP in order to obtain a permit and assuring the FDEP, by the

submission of CQA documentation, that the facility was constructed as specified in the design. The Owner has the authority to select and dismiss organizations charged with design, CQA, and construction activities. The Owner also has the authority to accept or reject design plans and specifications, CQA Plans, reports and recommendations of the CQA Engineer, and the materials and workmanship of the contractor.

2.3 DESIGN ENGINEER

HDR Engineering, Inc. is the Design Engineer and is primarily responsible for designing the landfill closure for the solid waste disposal facility that fulfills the requirements from the Owner and the FDEP. Design activities shall not end until construction of the closure is completed. The Design Engineer may be requested to change some component designs if unexpected site conditions are encountered or changes in construction methodology occur that could adversely affect landfill construction. Implementation of the CQA Plan provides assurance that these unexpected changes or conditions will be detected, documented, and addressed during construction.

The Owner has the authority to delegate additional responsibility and authority to the Design Engineer by expressed consent (i.e., a contractual agreement). Additional responsibilities and authority may include formulating and implementing a site-specific CQA Plan, periodic review of CQA documentation, modifying construction site activity, and identifying corrective measures in cases where deviation from the specified design or failure to meet design criteria, plans, and specifications is detected by the CQA Engineer.

2.4 CONSTRUCTION QUALITY ASSURANCE ORGANIZATION

2.4.1 Construction Quality Assurance Engineer (CQA Engineer)

The CQA Engineer is a party, independent of the manufacturer and the contractor, with responsibility for implementing this CQA plan. The CQA Engineer is responsible to the Owner but will function independently of the Owner and Contractor. At a minimum, the CQA Engineer is a Florida Registered Professional Engineer who possesses adequate formal academic training in engineering and managerial experience to successfully oversee and implement construction quality assurance activities for solid waste disposal facilities. The CQA Engineer is responsible for the following:

- Reviewing design criteria, permit conditions, the Contractor's Construction Quality Control (CQC) plan, and project plans and specifications for clarity and completeness so that the CQA plan can be implemented.
- Educating CQA Inspectors on CQA requirements and procedures.
- Scheduling and coordinating CQA activities including sampling for conformance testing.
- Confirming that regular calibration of testing equipment is properly conducted and recorded.
- Reviewing and interpreting test data and reports.
- Rejecting defective work and verifying that corrective measures have been implemented.
- Certifying construction completion.
- Providing signed, sealed final report and record drawings to the FDEP after owner review and approval stating that the final cover and temporary final cover systems have been installed in substantial conformance with the Project Plans and Specifications.

2.4.2 Construction Quality Assurance Inspector (CQA Inspector)

In order to assist the CQA Engineer in providing full-time on-site oversight and monitoring services, a CQA Inspector will be named. The CQA Inspector is a person(s) or firm(s) independent of the Contractor and Geomembrane Installer and authorized by the CQA Engineer and Owner to manage and oversee the execution of the work. The CQA Inspector shall possess formal academic training in soils engineering, engineering geology or other closely associated discipline. All completed work is subject to approval of the CQA Engineer.

The following minimum qualifications must be met by the CQA Inspector:

- The CQA Inspector must have been in business for at least ten (10) continuous years of operation immediately prior to the date of this project.
- The CQA Inspector must have inspected and tested a minimum of five (5) liner projects consisting of at least 10,000,000 square feet of LLDPE, TPO and/or HDPE liner.
- The CQA Inspector shall provide one full-time Qualified Engineering Technician and other trained technicians to perform the required tests and inspections of the liner system.
- The Qualified Engineering Technician is qualified representative of the CQA Inspector, who is an engineering technician with a minimum of four years of directly related experience or a graduate engineer/geologist with one year of directly related experience.
- The CQA Inspector shall provide certified technicians to perform full time observation and documentation of activities related to the CQA of the liner system construction.
- The CQA Inspector must have registered full-time Professional Engineers on staff to sign, seal, and certify that the project was constructed in accordance with the contract documents.

The CQA Inspector's responsibilities include:

- Performing independent on-site inspection of the work in progress to assess compliance with the facility design, Project Plans and Specifications.
- Verifying that the equipment used in testing meets the test requirements and that the tests are conducted according to the standardized procedures defined by the CQA Plan.
- Reviewing design criteria, and Project Plans and Specifications for CQA requirements and procedures.
- Scheduling and coordinating inspection activities.
- Directing and supporting the inspection personnel in performing observations and tests by:
 - submitting test samples for analysis by the CQA laboratory,
 - confirming that regular calibration of testing equipment is properly conducted and recorded,
 - confirming that the testing equipment, personnel, and procedures do not change over time or making sure that any changes do not adversely impact the inspection process,
 - recording and maintaining comprehensive documentation of the liner system construction, and
 - verifying that the raw data are properly recorded, validated, reduced, summarized, and interpreted in accordance with the CQA Plan and the Project Plans and Specifications.
- Providing to the CQA Engineer reports on the inspection results including:

- review and interpretation of all data sheets and reports,
- identification of work that the CQA Inspector believes should be accepted, rejected, or uncovered for observation, or that may require special testing, inspection, or approval,
- rejection of defective work and verification that corrective measures are implemented, and
- verification that the Contractor's construction quality control plan is in accordance with the site-specific CQA Plan.

2.4.3 Construction Quality Assurance Laboratory (CQA Laboratory)

The CQA Laboratory will be independent of the geosynthetic manufacturer and installer. The CQA Laboratory will be qualified and responsible for material conformance testing for soil, geomembrane, geocomposite, and for destructive seam tests on the installed geomembrane. The CQA Engineer and CQA Inspector will be responsible for coordinating with the laboratory, sampling the geosynthetics or arranging for sampling at the manufacturing facility, and reviewing conformance testing.

- The CQA Laboratory shall possess testing equipment which is capable of testing the interface friction between the liner system components in accordance with ASTM standards.
- The CQA Laboratory shall possess testing equipment which is capable of testing LLDPE and TPO liner seams for peel and shear according to ASTM standards.
- The CQA Laboratory shall be familiar with ASTM, NSF and other applicable test standards. It shall have performed a minimum of 100 sets of peel and shear tests on seams of material the same type as specified.

2.5 CONSTRUCTION CONTRACTORS

2.5.1 Construction Contractor

It is the responsibility of the Contractor to construct the landfill final cover and temporary final cover system in strict accordance with design criteria, Project Plans and Specifications, using the required construction procedures and techniques. The chosen Contractor will be registered in accordance with applicable local, state, and federal requirements and will have prior landfill-related experience.

The Construction Contractor's responsibilities include but are not limited to:

- Constructing the final cover and temporary final cover system in strict accordance with the contract documents including Project Plans and Specifications using the necessary construction procedures and techniques.
- Formulating and implementing a Construction Quality Control (CQC) Plan in accord with requirements of the technical specification.
- Contracting with subcontractors, such as manufacturers and specialty installers, and coordinating their activities.
- Supplying required materials and supporting QC documentation either directly or through subcontractors.
- Discussing procedures for locating and protecting construction materials and for implementing methods for preventing damage of the materials from inclement weather or other adverse effects.

- Coordinating activities with the CQA Engineer and CQA Inspector and providing the CQA organization with all necessary documentation as detailed in this plan.
- Updating original construction drawings and specifications to reflect any deviation from the original plans and furnishing as-built record drawings and all required quality control documentation.
- Planning and monitoring construction site health and safety procedures.
- Approving shop drawings prior to submission to the CQA Engineer.
- Determining and verifying:
 - field measurement,
 - field construction criteria,
 - catalog numbers and similar data, and
 - conformance to Project Plans and Specifications.
- Coordinating each submittal with other submittals and with the requirements of work and of the Project Plans and Specifications
- Notifying the CQA Engineer in writing, at time of submission, of any variance in the submittals from the requirements of the Project Plans and Specifications. Any such deviations permitted by the Design Engineer will require modifications to the Project Plans and Specifications.

2.5.2 Site Supervisor

The Construction Contractor will be represented in the field by a Site Supervisor. The Site Supervisor is responsible for the following:

- Scheduling and coordinating work including subcontractors.
- Informing the CQA Inspector and CQA Engineer of any discrepancies between the Project Plans and Specifications and field conditions.
- Coordinating with the CQA Inspector and CQA Engineer.
- Attending project meetings.
- Maintaining a daily log of construction and quality control activities.
- Implementing and verifying CQC procedures.
- Submitting proposed alternative materials or construction methods for approval before acquisition and use.
- Construction.

2.5.3 Geomembrane Installation Contractor (Geomembrane Installer)

The Geomembrane Installer may be a general contractor, a subcontractor to the general construction contractor, or a specialty contractor hired directly by the Owner. The Geomembrane Installer has not been chosen at this time. The selected contractor will have experience in installing at least 10 million square feet of geosynthetics.

The Geomembrane Installer or their CQC Consultant will be responsible for the following:

- Coordinating with the general contractor and CQA Inspector.
- Handling, storing, placing, and installing manufactured materials.
- Implementing and verifying a manufacturer and installer QC plan.

2.5.4 Thermoplastic Polyolefin Geomembrane Installer

Thermoplastic Polyolefin (TPO) geomembrane installer will demonstrate 5 years continuous experience with a minimum 10,000,000 square feet of geomembranes. The installer will be trained and certified by at least one of the named manufacturers in this Specification (not necessarily the manufacturer supplying materials for this Project).

Geomembrane Installer Personnel Qualifications:

- Installation Superintendent shall have worked in a similar capacity on at least five geomembrane liner jobs similar in size and complexity to the project described in the Contract Documents.
- The Master Welder shall have completed a minimum of 5,000,000 square feet of geomembrane seaming work using the type of seaming apparatus proposed for use on this Project.
- Other welders shall have seamed a minimum of 1,000,000 square feet geomembrane.

SECTION 3.0
INTERMEDIATE AND PROTECTIVE SOIL COVER

This section contains procedures and tests, which must be implemented in order to ensure the soil components of the final and temporary final cover systems meet the design standards. This is a critical component of the Construction Quality Assurance Plan. All required tests and sampling procedures within this section shall be performed in accordance with generally accepted engineering procedures. Table 3-1 contains a listing of applicable test procedure standards for the intermediate and protective cover soils.

3.1 INTERMEDIATE SOIL COVER

3.1.1 Preconstruction

Soil materials to be used as intermediate cover shall consist of select borrow material meeting all requirements specified in Specification Section 02200, Earthwork. The borrow material for intermediate cover must be of approved regular on-site borrow or borrow excavation unless otherwise specified or noted on drawings. In addition, soil provided by the Owner, from an off-site soil recovery project may be provided for use in the lower 6-inches of intermediate cover. The off-site soil must pass the material requirements of this plan and technical specifications. For all other soils from an off-site location, Contractor must submit the source test data to the CQA Inspector for approval a minimum of 48 hours prior to intended use.

Table 3- 1
Intermediate and Protective Cover Test Procedure Standards

STANDARD	TEST DESCRIPTION
ASTM D422	Method for Particle-Size Analysis of Soils
ASTM D698	Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12, 400 ft-lb/ft ²)
ASTM D2922	Test Methods for Density of Soil and Soil-Aggregate In-Place by Nuclear Methods (Shallow Depth)
ASTM D2487	Test Method for Classification of Soils for Engineering Purposes (United Soil Classification System)
ASTM D2488	Practice for Description and Identification of Soils (Visual-Manual Procedure)
ASTM D3017	Test Method for Water Content of Soil and Rock In-Place by Nuclear Methods (Shallow Depth)
ASTM D2216	Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures
ASTM D2937	Test Method for Density of In-Place Soils by Drive-Cylinder Method

Soil for the intermediate cover should be free of deleterious material (organics, sticks, roots, waste, etc.) and rock fragments, boulders or cobbles greater than three inches in size. Fines content of installed soil shall be a maximum of 50% (passing #200 sieve) and monitored as specified in the Project Plans and Specifications. Soil shall classify as SP, SW, SC, SM, SP-SM, or SP-SC in accordance with ASTM D2487 or ASTM D2488.

The intermediate cover layer shall be placed and compacted in accordance with specification section 02200, Earthwork, Part 3.6.E. The CQA Inspector shall test materials and monitor compliance with requirements of the Project Plans and Specifications. All observations and tests shall be conducted at locations selected by the CQA Inspector who has been assigned responsibility for verification and documentation of the element in question.

3.1.2 Construction

The following is an outline of the minimum construction requirements for the intermediate cover. For more detailed information, see the specification Sections 02200, Earthwork, 02775, LLDPE Geomembrane Liner System, and 02771 TPO Geomembrane .

- Strip vegetation from existing cover soils and dispose at a location designated by Owner.
- Verify that a minimum of 18 inches of cover soils exist after stripping operations. Add additional soil as needed to fill surface depressions and achieve a minimum thickness of 18 inches. Surface shall be smooth without irregularities unless shown on the drawings.
- Approval from CQA Inspector with regard to suitability of soils and acceptable subgrade.
- Atmospheric conditions observed and recorded by the CQA Inspector and appropriate actions taken when unsuitable weather conditions exist.
- Dust control continuous throughout the intermediate cover operations.
- Verify grade control is established to control thickness of material placed.
- Verify final grading completed in accordance with specification Section 02200, Earthwork.
- Intermediate cover compacted to specified requirements provided in Section 02200.
- Surface of intermediate cover soils proof-rolled in accordance with technical specification Section 02200 Part 3.2.F.
- Verify minimum thickness of the soils and geomembrane materials is achieved in accordance with the specifications.
- Provide as built survey of intermediate cover sealed by a professional land surveyor illustrating construction of all design features.
- Approval from CQA Inspector with regard to final surface smoothness and uniformity. Any objects protruding from the final surface or coarse fragments within the surface material that may damage the geomembrane will be removed.
- The required thickness of intermediate cover will be verified, as described in Specification 02200 – Earthwork, on an established grid system with not less than one verification point per 10,000 square feet of surface.

**Table 3- 2
Intermediate Cover Conformance and Construction Testing**

TEST DESCRIPTION	STANDARD	TEST FREQUENCY
Intermediate Cover		
Density, Nuclear Method	ASTM D2922	1 per 1,500 yd ³
Moisture Content, Nuclear Method	ASTM D3017	1 per 1,500 yd ³
Sand Cone or Drive Cylinder Method	ASTM D2937	1 per 20 nuclear tests
Oven Moisture Content Verification	ASTM D2216	1 per 20 nuclear tests
Moisture Density Relations	ASTM D698	1 per 20,000 yd ³ *
Sieve Analysis	ASTM D422	1 per 20,000 yd ³ *

* Increase frequency as needed to ensure each soil type is tested.

3.2 PROTECTIVE COVER

3.2.1 Preconstruction

Soil materials to be used as the 24-inch thick protective cover over the geomembrane (including 6-inch thick topsoil cover) shall consist of select borrow material meeting all requirements specified in Specification Section 02200, Earthwork. The borrow material for protective cover must be of approved regular on-site borrow or borrow excavation unless otherwise specified or noted on the drawings. If cover soil comes from off-site location, the Contractor must submit the source test data to the CQA Inspector for approval a minimum of 48 hours prior to intended use.

Soil for the bottom 18 inches of protective cover should be free from deleterious material (organics, sticks, roots, etc.) and rock fragments, boulders or cobbles greater than three inches in size. The upper 6 inches of protective cover shall meet the same criteria except that the soil shall contain sufficient organics to promote vegetative growth.

The protective cover layer shall be placed and compacted in accordance with the specification Section 02200, Earthwork, Parts 3.1 G through M and 3.6.E. The CQA Inspector will observe that placement of the soil material is done in a manner to protect the geocomposite. The CQA Inspector shall test materials and monitor compliance with requirements of the Project Plans and Specifications. All observations and tests shall be conducted at locations selected by the CQA Inspector who has been assigned responsibility for verification and documentation of the element in question.

**Table 3- 3
Protective Cover Conformance and Construction Testing**

TEST DESCRIPTION	STANDARD	TEST FREQUENCY
Intermediate Cover		
Density, Nuclear Method	ASTM D2922	1 per 1,500 yd ³
Moisture Content, Nuclear Method	ASTM D3017	1 per 1,500 yd ³
Sand Cone or Drive Cylinder Method	ASTM D2937	1 per 20 nuclear tests
Oven Moisture Content Verification	ASTM D2216	1 per 20 nuclear tests
Moisture Density Relations	ASTM D698	1 per 20,000 yd ³ *
Sieve Analysis	ASTM D422	1 per 20,000 yd ³ *

* Increase frequency as needed to ensure each soil type is tested

Note: Testing is not required for topsoil layer

3.2.2 Construction

Protective cover should be stable for construction and maintenance traffic. Care will be exercised in placement so as not to shift, wrinkle or damage the underlying geosynthetic layers, and the placement methods will be documented by the Contractor and CQA Inspector.

The protective cover shall be placed under the direct supervision of the CQA Inspector. The Contractor shall utilize care to avoid damage to the geocomposite. No vehicular traffic will be permitted on the unprotected liner system except low ground pressure equipment necessary for the deployment and installation of liner system. The loose thickness of the initial lift of protective cover shall not be less than 12 inches and spread with low ground pressure equipment (maximum pressure 10psi). Fill shall be placed by equipment starting at the toe of slope and spreading toward the top of slope. Material shall not be placed over standing water or ice.

The following is an outline of the minimum construction requirements for the protective cover. For more detailed information, see specification section 02200, Earthwork:

- Approval from CQA Inspector with regard to suitability of soils.
- Atmospheric conditions observed and recorded by the CQA Inspector and appropriate actions taken when unsuitable weather conditions exist.
- Dust control continuous throughout protective cover operations.
- Verify the underlying geocomposite construction is complete before material installation.
- Verify grade control is established to control thickness of material placed.
- For placement of material over geosynthetics, monitor 12-inch minimum thickness of material below spreading equipment and the spreading equipment has a ground pressure rating equal to or less than 10psi. During placement of material, identify geocomposite damaged during material installation and establish that the damage is repaired.
- Monitor haul road thickness over geocomposite and verify that equipment hauling and placing material over geocomposite meets equipment specifications.

- Monitor placement of material over piping and verify that pipe is not damaged by occasionally uncovering piping.
- Monitor equipment speed over material.
- Verify lower 18 inches of protective cover compacted to specified requirements. Do not compact topsoil layer beyond tracking it in.
- Verify final grading completed in accordance with specification section 02200, Earthwork.
- Verify minimum thickness is achieved in accordance with specifications.
- Install sod in accordance with specifications.
- Approval from CQA Inspector with regard to final surface smoothness and uniformity.
- Provide as-built survey of protective cover sealed by a professional land surveyor illustrating construction of all design features.

The required thickness of protective cover will be verified, as described in Specification 02200 – Earthwork, on an established grid system with not less than one verification point per 10,000 square feet of surface.

SECTION 4.0 GEOMEMBRANE LINER

This section covers the work necessary to construct and test the geomembrane lining system, which will consist of a 40 mil Linear Low Density Polyethylene (LLDPE) liner material (top, north and east slopes) in accordance with specification Section 02775, LLDPE Geomembrane Liner Systems and a 60 mil Thermoplastic Polyolefin (TPO) Geomembrane (south slope) in accordance with specification Section 02771, TPO Geomembrane. The geomembrane material and installation will be in accordance with specification Sections 02775 and 02771. The LLDPE and TPO liner materials shall be new, first quality products designed and manufactured specifically for the purposes of the Work and shall have satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes. All LLDPE geomembranes will be textured on both sides and shall be an unmodified LLDPE containing no plasticizers, fillers, chemical additives, or extenders. The only other compound ingredients to be added to the LLDPE geomembrane resin shall be anti-oxidants and heat stabilizers required for manufacturing. The LLDPE geomembranes shall be supplied as a single ply continuous sheet with no factory seams and in rolls with a minimum width of 22 feet. The roll length shall be maximized to provide the largest manageable sheet for the fewest field seams. The requirements for the TPO geomembrane will meet the minimum requirement as illustrated in specification Section 02771.

Extrusion resin used for fusion welding with extrudate to make field seams between geomembrane sheets and for repairs shall be LLDPE or TPO produced from, and the same as, the geomembrane sheet resin. Physical properties shall be the same as LLDPE or TPO geomembrane sheets.

The geomembrane liner shall conform to the testing requirements of GRI Standard GM17 - *“Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes”* (Geosynthetic Research Institute; Philadelphia, PA) and requirements of Section 02771 for TPO geomembrane.

4.1 PRECONSTRUCTION

4.1.1 Certification of CQA Plan Conformance

Prior to start of work, the Geosynthetics Manufacturer and the Geomembrane Installer, each, shall submit for approval by the CQA Inspector documented evidence of its ability and capacity to perform this Work. Each shall have successfully manufactured and/or installed a minimum of ten (10) million square feet of similar lining material in solid waste containment structures.

The Contractor shall submit written certification by the Geosynthetics Manufacturer that the lining materials conform to the requirements of the CQA Plan. The Contractor shall submit the name and qualifications of its project superintendent that will be on the project whenever lining materials are being handled and/or installed plus the names and qualifications of senior installation personnel on the project. All manufacturer and Geomembrane Installer qualifications shall be submitted in accordance with technical specification Sections 02775 and 02771 Part 1.2.B.

4.1.2 Geomembrane Installer's and Manufacturer's QC Program

The Geosynthetics Manufacturer and the Geomembrane Installer, each, shall submit a complete description of its quality control (QC) program, as applicable, for manufacturing, handling, installing, testing, repairing and providing a completed lining in accordance with requirements of the CQA Plan and contract documents. The description shall include, but not be limited to, polymer resin supplier, product identification, acceptance testing, fabrication and production testing, installation testing, documentation of changes, alterations and repairs, retests and acceptance.

The following quality control tests will be performed on the geomembrane.

**Table 4- 1
MQC Conformance Testing for LLDPE Geomembranes**

STANDARD	TEST DESCRIPTION	FREQUENCY OF TESTING
ASTM D6693, Type IV, 2 ipm	Standard Test Method for Determining Tensile Properties of Non-reinforced Polypropylene and Non-reinforced Flexible Polypropylene Geomembranes	Every 20,000 lbs
ASTM D1004	Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting	Every 45,000 lbs
ASTM D1505/D792	Standard Test Method for Density of Plastics by the Density-Gradient Technique	Every 200,000 lbs
ASTM D1238	Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer	One per rail car compartment
ASTM D1603	Standard Test Method for Carbon Black Content in Olefin Plastics	Every 20,000 lbs
ASTM D3895	Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry	Every 200,000 lbs
ASTM D4833	Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products	Every 45,000 lbs
ASTM D5596	Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics	Every 45,000 lbs
ASTM D5994 ¹	Standard Test Method for Measuring Core Thickness of Textured Geomembrane	Every roll
GRI GM12	Asperity Height	Every other roll

1. Textured Geomembrane Only.

**Table 4- 2
MQC Conformance Testing for TPO Geomembranes**

STANDARD	TEST DESCRIPTION	FREQUENCY OF TESTING
ASTM D751	Thickness	Per roll
ASTM D4885	Tensile Properties	Once per day or 20,000 lb
ASTM D751	Tear Resistance	Once per day or 45,000 lb
Visual	Scrim Orientation	Every Lot or Every Scrim Roll

4.1.3 Geomembrane Installer's Installation Plan

The Installer shall submit installation drawings, the Manufacturer's written Field Installation Procedure Manual, and a schedule for performing/completing the Work. Installation drawings shall show a lining sheet layout with proposed size, number, position, and sequence of placing of all sheets and indicating the location of all field seams. Installation drawings shall also show complete details and/or methods for anchoring the lining at its perimeter, making field seams, and making anchors/seals to pipes and structures.

The Installer shall submit a complete description of welding procedures for making field seams and repairs. The welding procedures shall conform to the latest procedures recommended by the lining Manufacturer.

The Contractor and Geomembrane Installer shall submit for approval, by the CQA Inspector, certification that the surface(s) on which the lining will be placed is acceptable. Installation of the lining shall not commence until this certification is furnished to the CQA Inspector.

The Geomembrane Installer shall provide on-site technical supervision and assistance at all times during installation of the lining system. The Geomembrane Installer and Contractor, as applicable to each, shall submit for approval by the CQA Inspector written certification that the lining system was installed in accordance with the Manufacturer's recommendation, the CQA Plan, Project Plans, Specification Sections 02775 and 02771, and approved submittals.

The CQA Engineer will initiate a pre-installation meeting with the Geomembrane Installer, Contractor, and CQA Inspector prior to installation of the lining system. Topics for review/discussion shall include, as a minimum, Project Plans and Specifications, approved submittals, and training and qualification procedures for Contractor personnel.

Prior to installation of the lining system, the Geomembrane Installer shall instruct the workmen of the hazards of installation, such as handling sheets of lining material in high winds; use of equipment; application of solvents, adhesives and caulks; and walking on lining surfaces. Work gloves, safety glasses, hard hats, and smooth-soled shoes are minimum safety wear requirements when working on the geomembrane. Safety shoes must be worn when handling heavy objects.

The Owner shall have authority to order an immediate stoppage of work because of improper installation procedures, safety infractions, or for any reason which may result in a defective liner.

4.1.4 Contractor's Geomembrane Preconstruction Material Submittals

The Contractor will provide the CQA organization with the following items for review and testing:

- Results of interface friction testing for the geomembrane proposed for the project as outlined in this CQA Plan.
- Manufacturer's description (cut sheet) of the proposed geomembrane documenting it will meet or exceed specified requirements.
- Available historical data documenting that the proposed geomembrane will meet specified interface friction angle.

- Written instructions for storage, handling, installation, seaming, and repair of the proposed geomembrane consistent with the technical specifications, project plans, and the manufacturer’s recommendations.

Before shipment of the geomembrane, the CQA organization shall review all approved pre-construction submittals. Pre-construction submittals should be submitted a minimum of four weeks in advance to allow time for review and approval by the CQA organization.

The Contractor shall submit certifications that the LLDPE and TPO geomembrane material delivered to the site meets the requirements of the Specification and that the LLDPE and TPO geomembrane was received and accepted in undamaged condition from shipper.

4.1.5 CQA Conformance Testing

The geomembrane material will be sampled at the site by the CQA Inspector or at the manufacturing plant by a third party under the direction of the CQA organization. The sample will be taken across the entire roll width and will be 3 feet long. Samplers will mark the machine direction and the manufacturer’s roll identification number on the sample. Samplers will also assign a conformance test number to the sample and mark the sample with that number. The samples will be forwarded to a CQA testing laboratory for the conformance testing. The CQA Inspector will review all conformance test results and report any nonconformance to the Owner and CQA Engineer.

The following conformance tests will be performed on the LLDPE geomembrane at the frequencies indicated in Table 4-3.

**Table 4- 3
CQA Conformance Testing for LLDPE Geomembranes**

STANDARD	TEST DESCRIPTION	FREQUENCY OF TESTING
ASTM D6693	Standard Test Method for Determining Tensile Properties of Non-reinforced Polypropylene and Non-reinforced Flexible Polypropylene Geomembranes	Every 20,000 lbs
ASTM D6392	Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.	Every 500 LF of seam
ASTM D5321	Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic Friction by the Direct Shear Method	One per project

**Table 4- 4
CQA Conformance Testing for TPO Geomembranes**

STANDARD	TEST DESCRIPTION	FREQUENCY OF TESTING
ASTM D 4637 751	Thickness	1 test per 100,000 ft ²
ASTM D 4885	Tensile Strength at Break	1 test per 100,000 ft ²
ASTM D 4885	Elongation at Break	1 test per 100,000 ft ²
ASTM D 5884	Tear Strength	1 test per 100,000 ft ²

STANDARD	TEST DESCRIPTION	FREQUENCY OF TESTING
ASTM D 4833FTM 101C Method 2031	Puncture Resistance	1 test per 100,000 ft ²
ASTM G 155	Resistance to Xenon-Arc Weathering	Manufacturer's Certification Only
ASTM D 1149	Ozone Resistance	1 test per 100,000 ft ²
ASTM D5321	Interface Friction	One for each interface identified for the project by the Engineer

Laboratory interface friction tests shall be conducted in general accordance with ASTM D5321, on the following interfaces:

- Textured LLDPE liner and geocomposite
- Textured LLDPE liner and intermediate cover soil
- TPO geomembrane and 16 oz/sy geotextile

The CQA Laboratory will perform three (3) direct shear tests at the project specific effective normal stresses. These tests will be performed using the Contractor's proposed geosynthetic materials for above interfaces following award of the construction contract to the selected Contractor. Samples of intermediate cover soil and protective cover soil (if different than the intermediate cover soil material) proposed for the project will also be obtained for testing. A minimum interface friction angle based on the landfill design will be required to maintain stability. The project specific testing parameters for direct shear testing, including the effective normal stresses and minimum required interface friction angles, for the TPO and LLDPE materials are provided in technical specification Section 02771-2.2 Table 2 and Section 02775-2.3, respectively.

The Owner will pay for "Passing" tests. Costs of corrective action, costs of "Failing" tests and all associated costs of testing due to failing tests will be paid by the Owner and the cost reimbursed to the Owner by the Contractor. Materials not meeting the required shear strength will not be approved for use on this project.

4.2 CONSTRUCTION

4.2.1 Delivery, Storage and Handling

Materials will be delivered to the site after the required submittals have been furnished and approved. The delivered roll goods will be marked by the manufacturer to show at a minimum the following information:

- Name of manufacturer.
- Product type.
- Product thickness.
- Manufacturing batch code.
- Date of manufacture.
- Physical dimensions.

- Roll number.

Lining materials delivered to the site shall be inspected for damage, unloaded, and stored with a minimum of handling. Each roll shall be wrapped in an opaque and waterproof layer of plastic during shipment and storage. The plastic wrap shall not be removed until deployment. Materials shall not be stored directly on the ground. The storage area shall be such that all materials are protected from mud, soil, dirt and debris. The stacking of lining shall not be higher than two rolls.

Under no circumstances shall the lining be subjected to materials, sandbags, equipment or other items being dragged across its surface. Nor shall workmen and others slide down slopes atop the lining. All scuffed surfaces resulting from abuse of any kind caused by the Contractor in performance of the Work shall be repaired at the CQA Inspector's direction.

LLDPE or TPO geomembrane or plastic wrapping damaged as a result of storage or handling shall be repaired or replaced, as directed. LLDPE or TPO shall not be exposed to temperatures in excess of 60°C (140°F) or less if recommended by the Manufacturer.

No hooks, tongs or other sharp instruments shall be used for handling the LLDPE or TPO geomembrane. Rolls shall not be lifted by use of cables or chains in contact with the LLDPE or TPO geomembrane. LLDPE or TPO geomembrane shall not be dragged along the ground.

The Contractor shall be completely responsible for shipping, storage, handling, and installation of all lining materials in compliance with the CQA Plan.

4.2.2 Geomembrane Subsurface Preparation

Before geomembrane installation, the CQA Inspector will document that the intermediate cover installation is complete and CQC and CQA documentation verifies that subsurface has been prepared in accordance with specification Sections 02775 and 02771.

4.2.3 Geomembrane Placement and Seaming

Prior to installation of the geomembrane, a site inspection will be conducted by the CQA Inspector and the Contractor to verify measurements, structures and surface conditions to support the geomembrane.

The Contractor and Geomembrane Installer will provide written documentation to the CQA Inspector that surfaces to receive the geomembrane have been inspected and are acceptable for installation of the lining.

Before the work begins, the Contractor will inspect all lining materials for damage from transit. Materials that cannot be repaired will be rejected and removed from the work area and site.

During unwrapping of lining materials for use and placement, the Contractor will visually inspect all materials, particularly surfaces of lining sheets, for imperfections and faulty areas. All such defective places will be marked and repaired in accordance with approved methods.

The geomembrane will be installed as shown on the project plans and approved installation drawings. Placement of the geomembrane will be done such that good fit, without bridging, is provided on all covers and grade changes. Excessive slack will be avoided to minimize rippling during the soil cover operation. Geomembrane liner shall be handled and placed in a manner which minimizes wrinkles, scratches and crimps.

Sheets of geomembrane materials will be of lengths and widths and will be placed in a manner as to reduce field seaming to a minimum. The lining will be anchored in accordance with details shown on approved plans and drawings. The lining will be anchored and sealed to structures, pipes and other types of penetrations, (if any), in accordance with details shown on approved plans and drawings. All changes in approved installation drawings and procedures must be approved by the Design Engineer.

Extreme care will be taken during installation of the lining to be certain no damage is done to any part of the lining. Dragging of the geomembrane material on the prepared subgrade will be prohibited. Smoking will be prohibited for all personnel. All handling and installation procedures will be performed by workers wearing shoes with smooth soles. Shoes with soles that have patterns in relief shall be prohibited. No foot traffic will be allowed on the geomembrane except with approved shoes. No vehicular traffic will be allowed on the geomembrane except low ground pressure equipment necessary for the deployment and installation of the lining system. All motor driven equipment using fuel will have spark arrestors. No gasoline driven generators or cans of gas or solvent will be placed directly on the lining material. Under no circumstances will the lining be used as a work area to prepare patches or to store tools and supplies. If needed, a tarpaulin of approved material will be spread out as a work area.

During installation, the Contractor will be responsible for protecting the lining against adverse effects of high winds such as uplift. Sand bags will be used as required to hold the lining material in position during installation. Sand bags will be sufficiently close-knit to preclude fines from working through the bottom, sides or seams. Paper bags, whether or not lined with plastic, will not be permitted. Burlap bags, if used, must be lined with plastic. Bags that are split, torn, or otherwise losing their contents will be immediately removed from the work area and any spills immediately cleaned up. Metal or wire ties will not be used.

The geomembrane material will not be installed under adverse climatic conditions, unless the Contractor can demonstrate that his installation techniques adequately compensate for such adverse conditions and quality of workmanship is not compromised. Adverse climatic conditions occur when the air temperature measured 6 inches above the geomembrane surface is less than 41°F and decreasing, or more than 104°F; when it is raining; or when there is frost on the ground; or during conditions of excessive winds.

Geomembrane field seams will be lap seams as shown on approved plans and drawings. The lap seams will be formed by lapping the edges of geomembrane sheets a minimum of 3 inches unless otherwise specified in the approved plans and drawings. The contact surfaces of the sheets will be wiped clean to remove dirt, dust, moisture, and other foreign materials. Geomembrane shall not be welded when ambient temperatures are below 41°F or above 104°F without written consent of manufacturer and CQA Engineer or CQA Inspector. For fillet weld seams, bevel edge of geomembrane and clean oxidation from surfaces to receive extrudate by disk grinding or equivalent not more than one hour before seaming.

For the final cover system, lap seam intersections involving more than three thicknesses of lining material will be avoided, and all seam intersections will be offset at least 2 feet. No horizontal field seams will be allowed on the slope and sheets of lining material on the slopes will extend down slope to the perimeter anchor trench as shown on the drawings. For the temporary final cover system, wedge weld end of geomembrane panel to beginning of new geomembrane panel and continue downslope. Flap of wedge weld to be on top in the downslope direction as long as practically feasible. Welds connecting downslope

sheets shall be double wedge welds, and shall have a minimum of 10 feet vertical offset between adjacent panel welds. Wedge welds shall have a minimum of 3 inch overlap.

Geomembrane liners shall be welded using extrusion (LLDPE), hot air (TPO), single wedge or double wedge welding equipment (LLDPE and TPO). Extrusion welding equipment shall be provided with thermocouples and temperature readout devices which continuously monitor the temperature of the extrudate. Wedge welding equipment shall be provided with thermocouples and temperature readout devices which continuously monitor the temperature of the wedge. Geomembrane liners shall be welded continuously without fishmouths or breaks in the weld. Where fishmouths are unavoidable, the geomembrane sheet shall be slit to a point such that the sheet lies flat and with no remaining wrinkle. The two edges of the slit shall be welded together provided that the overlap for this weld shall be a minimum of 6 inches. Areas of the slit that do not achieve an overlap of 6 inches, including the terminus of the slit, shall be provided with a patch.

Any necessary repairs to the geomembrane will be made with the lining material itself, using approved welding systems, equipment and techniques. The patch size will be 6 inches larger in all directions than the area to be patched. All corners of the patch will be rounded. Torn or permanently twisted geomembrane shall be replaced at no expense to the County.

All seams and seals of the geomembrane will be tightly bonded on completion of the work. Any lining surface showing injury due to scuffing or penetration by foreign objects or showing distress will be replaced or repaired as directed by the CQA Inspector.

Cleanup within the work area will be an ongoing responsibility of the Contractor. Particular care will be taken to insure that no trash, tools, and other unwanted materials are trapped beneath the lining. Care will be taken to insure that all scraps of lining material are removed from the work area prior to completion of the installation.

4.2.4 Emergency Gas Vents

Emergency gas vents will provide emergency pressure relief if the active gas collection system is shut down for an extended period of time or due to hotspots within the landfill. The active gas collection system serves as an integral part of the overall performance of the temporary final cover system, and the emergency gas vents are installed to provide backup relief if necessary. The emergency gas vents are designed to be directly connected to the active gas collection system if necessary to provide additional vacuum under the temporary final cover system. Typically, the emergency gas vents are capped until they are needed.

Each of the components of the emergency gas vents will be installed as specified in the Contract Documents. The vent installation observation will be performed during the construction of the cover system.

Post-construction inspection of the emergency gas vents will include the following:

- Observation to ensure that all system components have been installed as specified and according to the approved manufacturer's specifications and the engineering design.

4.2.5 Field Quality Control

Inspection and testing will involve the full time observation of the installation of the geomembrane, including the making and testing of lining seams and patches and periodic measurement of the liner material thickness to insure compliance.

Test welds will be made to verify that adequate conditions exist for field seaming to proceed. Each seamer and seaming equipment will produce a test seam at the beginning of each shift to determine the peel and tensile strength of the seam. The CQA Inspector may require a sample field seam be made at any time during seaming production to verify equipment/operator performance and seam integrity. In addition, if a seaming operation has been suspended for more than 1/2 hour or if a breakdown of the seaming equipment occurs, a test seam will be produced prior to resumption of seaming operations.

The trial weld sample must be a minimum of three feet long and one and a half feet wide, with the seam centered lengthwise. The CQA Inspector must observe all trial welding operations, quantitatively test each trial weld for peel and shear, and record the results. A minimum of two peel and two shear tests will be performed per trial seam. The trial weld shall be completed under the same conditions for which the panels will be welded. The trial weld must meet the requirements for peel and shear as stated in the following paragraph and the break must be a film tear bond (FTB) for a wedge weld.

During the field seaming operation, destructive samples will be removed from field seams by the Installer at locations selected by the CQA Inspector. Repairs to the field seams will be made in accordance with repair procedures specified in this CQA Plan. The samples will have a width of 12 inches plus the seam width and length of 48 inches. A minimum of one stratified sample per 500 feet of field seam will be made. All field seams will have a film tear bond in peel and shear and will meet the minimum pound per inch width seam strength specified in the specification Sections 02775 and 02271, LLDPE and TPO Geomembrane Liner Systems respectively. The bonded shear strength for fusion and extrusion welds must be greater than or equal to the appropriate values shown in the specifications. A sufficient amount of the seam must be removed in order to conduct field testing, independent laboratory testing, and archiving of enough material in order to retest the seam when necessary. The archived material will be kept at the CQA laboratory. Field testing shall include at least two peel tests per sample. CQA laboratory testing shall consist of five shear tests and five peel tests per sample. The Installer shall test the seam destructively at a frequency of one test per 500 linear feet of weld. Destructive seam-testing locations shall be cap-stripped and the cap completely seamed by extrusion welding to the geomembrane (LLDPE) or hot air welding for TPO geomembrane. Capped sections shall be non-destructively tested. Additional destructive test samples may be taken if deemed necessary by the CQA Inspector.

All field-tested specimens from a destructive-test location must be passing in both shear and peel for the seam to be considered as passing. Passing results, as specified in technical specification Sections 02771 and 02775, for both peel and shear for the seam must be received from the CQA laboratory to confirm the field testing and to accept the seam. The CQA testing laboratory will save all test samples including specimens tested until notified by the CQA Engineer relative to their disposal. All specimens which have failed under test will be shipped immediately by express delivery to the CQA Inspector for determination of corrective measures to be taken, which includes retest or repair of failed section.

For destructive samples which have failed the passing criterion, the Installer will reconstruct all the field seams between any two previous passed seam locations which include the failed seam or will go on both sides of the failed seam location (10 feet minimum), take another sample each side and test both. If both pass, the Installer may patch or cap strip the seam between the passed samples. If either fails, the Installer will remove and replace the entire seam. In all cases, acceptable field seams must be bounded by two passed test locations. The decision of the CQA Engineer will be final.

The Installer shall test all patch welds using one of the following nondestructive tests: vacuum tests, air lance (TPO hot air weld) or spark tests.

In the event capping of a field seam is required, the Installer will use a cover strip of the same thickness as the lining (and from the same roll, if available) and a minimum of 6 inch overlap away from the seam in all direction. It will be positioned over the center of the field seam and welded to the lining using a fillet weld each side.

All geomembrane sheets, seams, anchors, seals, and repairs will be visually inspected by the Installer for defects. Depending on seam welding equipment used, all seams and repairs will be tested continuously by a vacuum testing device, air pressure, or spark tests.

A visual inspection of the lining sheets, seams, anchors and seals will be made by the Installer and CQA Inspector as the installation progresses and again on completion of the installation. Defective and questionable areas will be clearly marked and repaired. Final approval of repairs will be given by the CQA Inspector.

If the fillet weld, extrusion lap weld, hot air weld, or single hot-wedge fusion lap weld is used to weld seams, the Installer will further test all seams and repairs in the geomembrane by vacuum box or by air lance test (hot air weld for TPO). All vacuum box testing will be done in the presence of the CQA Inspector. The area to be tested will be cleaned of all dust, debris, dirt and other foreign matter. A soap solution will be applied to the test area with a paint roller and the vacuum of 5 psi air pressure will be induced and held at least ten seconds to mark for repair any suspicious areas as evidenced by bubbles in the soap solution. All air lance testing will be performed in accordance with ASTM 3340.

If the double hot-wedge is used, the Installer will further test all seams in the geomembrane by using the air pressure test which consists of inserting a needle with gauge in the air space between welds. Air will be pumped into space at a pressure and held for a time as indicated in the specifications. If pressure does not drop more than the amount allowed in the specifications, then the seam is acceptable.

All costs of retesting of the geomembrane including reruns of field weld tests and all repairs will be at the Installer's expense.

The Installer shall assemble the quality control data required above into a final report of geomembrane installation. The report will contain all test data and a final layout of geomembrane liner which shows the location of all seams, patches and sample locations. In addition, the Installer shall submit resin tests, tests of sheet material, factory seam tests, daily seam test results, and daily results of production seam testing.

The Contractor will retain responsibility for the integrity of the geomembrane system until acceptance by the CQA Engineer. The geomembrane will be accepted by the CQA Engineer when:

- Written certification letters including as built record drawings, have been received by the CQA Engineer.
- Installation is completed.
- Documentation of completed installation, including all reports, is received and approved.
- Verification of adequacy of field seams and repairs, including associated testing, is complete.

Acceptance of the completed work will include receipt of all submittals and all work completed to the satisfaction of the CQA Engineer.

4.2.6 Geosynthetics Manufacturer's Warranty

The Geosynthetics Manufacturer's warranty shall be against manufacturing defects or workmanship and against deterioration due to ozone, ultraviolet or other normal weather aging. The warranty shall be limited to replacement of material only, and shall not cover installation of said material. It shall not cover damage due to vandalism, acts of animals or unusual acts of God. The warranty shall state that the furnished material meets all requirements of specification Section 02775 or Section 02271 and the Contract Documents, is free from manufacturing defects and is able to withstand normal weathering for a period of five years, prorated. Written warranties addressing the LLDPE and TPO geomembrane material shall be furnished by the contractor and shall be made to Sarasota County.

4.2.7 Installer's Warranty

The Installer shall furnish a written guarantee that the entire lining work constructed by him to be free of defects in material and workmanship and installed pursuant to the CQA Plan for a period of two (2) years following the date of acceptance of the work by the CQA Engineer. During the 23rd month, a pre-guarantee expiration inspection will be conducted to identify any necessary repair work covered by the guarantee. The Installer shall agree to make any repairs or replacements made necessary by defects in materials or workmanship in the Work which become evident within said guarantee period. The Installer shall make repairs and/or replacements promptly, the Owner may do so, and the Installer shall be liable to the Owner for the cost of such repairs and/or replacements. The Installer's warranty shall state that the materials were properly installed, properly welded, seamed and jointed and will not fail within 2 years of installation under similar conditions. The warranty shall provide for complete repair/replacement for the warranty period. Written warranties addressing the LLDPE and TPO geomembrane material shall be furnished by the contractor and shall be made to Sarasota County.

**SECTION 5.0
GEOTEXTILE**

The following section outlines the CQA required for the installation of geotextiles. Non-woven cushion, drainage, and woven separator geotextiles will be used to protect the geomembrane and segregate the soil from drainage stone.

5.1 PRE-CONSTRUCTION

5.1.1 Manufacturer’s Quality Control

Before scheduled manufacturing of the product, the Geosynthetics Manufacturer will provide the following:

- Manufacturer’s description (cut sheet) of the proposed geotextiles documenting it will meet or exceed specified requirements.
- Written instructions for storage, handling, installation, seaming, and repair of the proposed geotextiles.

Before shipment of the geotextile, the CQA organization shall review all pre-construction submittals.

The CQA Inspector will take conformance samples for testing in accordance with this CQA Plan and the specification Section 02778, Geotextiles.

**Table 5-1
Manufacturer’s Quality Control Testing for Geotextiles**

MATERIAL	TYPE OF TEST	STANDARD TEST METHOD	FREQUENCY OF TESTING
Non-Woven Drainage Geotextile	Mass Per Unit Area (oz/yd ²)	ASTM D5261	One per 90,000 ft ²
	Grab Tensile Strength (lbs)	ASTM D4632	One per 90,000 ft ²
	Grab Tensile Elongation (%)	ASTM D4632	One per 90,000 ft ²
	Puncture Strength (lbs)	ASTM D4833	One per 90,000 ft ²
	AOS, US sieve (mm)	ASTM D4751	One per 540,000 ft ²
	Permittivity, (sec ⁻¹)	ASTM D4491	One per 540,000 ft ²
	Trapezoidal Tear Strength, (lbs)	ASTM D4533	One per 90,000 ft ²
	Flow Rate (gpm/ft ²)	ASTM D4491	One per 540,000 ft ²
	UV Degradation, % retained @ 500 hrs	ASTM 4355	1 per formulation
Woven Separator Geotextile	Flow Rate (gpm/ft ²)	ASTM D4491	One per 540,000 ft ²
	UV Degradation, % retained @ 500 HRS	ASTM D4355	1 per formulation
	Permittivity, (sec ⁻¹)	ASTM D4491	One per 540,000 ft ²
	Trapezoidal Tear Strength, (lbs)	ASTM D4533	One per 90,000 ft ²
	Grab Tensile Strength, (lbs)	ASTM D4632	One per 90,000 ft ²
	Elongation, %	ASTM D4632	One per 90,000 ft ²
	AOS, U.S. Sieve (mm)	ASTM D4751	One per 540,000 ft ²
	Puncture Strength, (lbs)	ASTM D4833	One per 90,000 ft ²

5.1.2 CQA Conformance Testing

The CQA Organization will obtain geotextile conformance test samples of each type of material manufactured for the project. Samples will be obtained across the entire roll width and will be 3 feet long. Samplers will mark the manufacturer's roll identification number, as well as the machine direction, on the sample. Samplers will assign a conformance test number to the sample and mark the sample with that number. Each sample will be sent to the CQA Laboratory for conformance testing. The CQA Inspector will review test results and report any nonconformance to the CQA Engineer.

The following conformance tests will be performed on the geotextile at the frequencies indicated in Table 5-2:

**Table 5- 2
CQA Conformance Testing for Geotextiles**

MATERIAL	TYPE OF TEST	STANDARD TEST METHOD	FREQUENCY OF TESTING
Geotextile	Puncture Strength (lbs)	ASTM D4833	One per 90,000 ft ²
	Flow Rate (gpm/ft ²)	ASTM D4491	One per 540,000 ft ²
	AOS, US sieve (mm)	ASTM D4751	One per 540,000 ft ²
	Grab Tensile Strength (lbs)	ASTM D4632	One per 90,000 ft ²
	Mass per Unit Area (oz/yd ²)*	ASTM D5261	One per 90,000 ft ²

* Non-woven geotextile only

5.2 CONSTRUCTION

5.2.1 Delivery, Storage and Handling

During delivery of geotextiles the CQA Inspector will monitor for the following:

- Equipment used to unload the rolls will not damage the geotextile.
- Rolls are wrapped in impermeable and opaque protective covers.
- Care is used to unload the rolls.
- Documentation required by specification Section 02778, Geotextiles has been received.
- Each roll is marked or tagged with manufacturer's name, project identification, lot number, roll number, roll dimensions, and that this information is documented on a geosynthetic receipt form.
- Materials are stored in a location that is protected from ultraviolet light exposure, precipitation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions.

Damaged rolls may be rejected. If rejected, verify that rejected material is removed from the site or stored at a location separate from accepted rolls. Geotextile rolls that do not have proper manufacturer's documentation must also be stored at a separate location until all documentation has been received and approved.

5.2.2 Geotextile Subsurface Preparation

Before geotextile installation, the CQA Inspector will document that the surface where the geotextile will be installed is acceptable and CQC and CQA documentation verifies that its installation meets specified requirements.

5.2.3 Geotextile Placement and Seaming

During geotextile placement and seaming operations, the CQA Inspector will monitor for the following:

- All defects and defect corrective actions are performed in accordance with specification Section 02778, Geotextiles.
- Equipment used to install the geotextile does not damage it during deployment.
- Crews working on the geotextile do not smoke, wear shoes that could damage the geotextile, or engage in activities that could damage the geotextile.
- The geotextile is securely anchored to prevent movement by the wind.
- Adjacent panels are overlapped and seamed in accordance with specification Section 02778, Geotextiles.
- The geotextile is not exposed to direct sunlight for more than the 14 days in accordance with technical specification Section 02778, Geotextiles.
- Final geotextile surface is free of harmful foreign objects.

The CQA Inspector will inform both the CQA Engineer and Contractor if they observe any conditions that do not conform to the requirements of the CQA Plan conditions.

5.2.4 Geotextile Repairs

Where repairs are necessary, the CQA Inspector will monitor for the following:

- Place a patch of the same type of geotextile which extends a minimum of 24 inches beyond the edge of the damage or defect.
- Fasten patches continuously using a sewn seam or other approved method.
- Align machine direction of the patch with the machine direction of the geotextile being repaired.
- Replace geotextile which cannot be repaired.

**SECTION 6.0
GEOCOMPOSITE**

The following section outlines the CQA required for the installation of the single and double-sided geocomposite. The single sided geocomposite will be used as the drainage layer of the final cover system (top slope). The double sided geocomposite will be used as the drainage layer of the final cover system (north and east slopes).

6.1 PRECONSTRUCTION

All HDPE drainage composite shall be manufactured in accordance with specification Section 02777, Drainage Composite. The drainage composite manufacturer will provide the Contractor and the CQA Inspector with a written certification, signed by a responsible party, that the drainage composites actually delivered have properties which meet or exceed the guaranteed properties. The CQA Inspector will examine all manufacturer's certifications to ensure that the property values listed on the certifications meet or exceed the project specifications. Any deviations will be reported to the CQA Engineer.

6.1.1 Manufacturer's Quality Control

Before scheduled manufacturing of the product, the Geosynthetics Manufacturer will provide the CQA organization with the following items for review and testing:

- Manufacturer's description (cut sheet) of the proposed geocomposites documenting that it will meet or exceed specified requirements.
- Available historical data documenting that the proposed geocomposites will meet specified interface residual strength.
- Written instructions for storage, handling, installation, seaming, and repair of the proposed geocomposites.

Before shipment of the geocomposite, the CQA organization will review pre-construction submittals.

**Table 6- 1
Manufacturer's Quality Control Testing for Geonet / Geocomposite**

MATERIAL	TYPE OF TEST	STANDARD TEST METHOD	FREQUENCY OF TESTING
Geonet	Specific Gravity/Density (g/cm ³) (min)	ASTM D 1505	One per 50,000 ft ² and every resin lot
	Thickness (mil)	ASTM D 5199	One per 50,000 ft ² and every resin lot
	Carbon Black Content (% Minimum)	ASTM D 1603	One per 50,000 ft ² and every resin lot
	Tensile Strength (MD), (lb/in)	ASTM D 5035	One per 50,000 ft ² and every resin lot
MATERIAL	TYPE OF TEST	STANDARD TEST METHOD	FREQUENCY OF TESTING
Geocomposite	Transmissivity (m ² /sec)	ASTM D4716	One per 540,000 ft ²
	Ply adhesion (lb/ft ²)	ASTM D7005	One per 50,000 ft ²

1. This is an index transmissivity value measured at stress = 1,000 psf; a gradient = 0.33; time = 100 hours, minimum 1 hour if data equivalent to 100 hours is provided; and boundary conditions = plate/geocomposite/plate

6.1.2 CQA Conformance Testing

The CQA Organization will obtain geocomposite conformance test samples of each type of material manufactured for the project. Samples will be obtained across the entire roll width and will be 3 feet long. Samplers will mark the manufacturer's roll identification number, as well as the machine direction, on the sample. Samplers will assign a conformance test number to the sample and mark the sample with that number. Each sample will be sent to the CQA Laboratory for conformance testing in accordance with the project Specification Section 02777, Part 2.2.C. The CQA Inspector will review all test results and report any non-conformance to the CQA Engineer.

The following conformance tests will be performed on the geocomposite:

**Table 6-2
CQA Conformance Testing for Geocomposite**

MATERIAL	TYPE OF TEST	STANDARD TEST METHOD	FREQUENCY OF TESTING
Geocomposite	Transmissivity (m ² /s)*	ASTM D4716	One per 540,000 ft ²
	Ply Adhesion	ASTM D 7005	One per 50,000 ft ²
	Thickness (Geonet Core Only)	ASTM D5199	One per 50,000 ft ²
	Interface Friction	ASTM D5321	One per Project

NOTE: Geotextiles shall be tested in accordance with Specification Section 02778.

* See specifications for transmissivity testing criteria.

Laboratory interface friction tests shall be conducted in general accordance with ASTM D5321, on the following interfaces (double-sided geocomposite only):

- Textured LLDPE and geocomposite.
- Geocomposite and protective cover soil.

The CQA Laboratory will perform three (3) direct shear tests at the project specific effective normal stresses. These tests will be performed using the Contractor's proposed LLDPE and a sample of geocomposite obtained from the Geosynthetics Manufacturer following award of the construction contract to the selected Contractor. A sample of protective cover soil proposed for the project will also be obtained for testing. A minimum interface friction angle based on the landfill design will be required to maintain stability.

The Owner will pay for "Passing" tests. Costs of corrective action, costs of "Failing" tests and all associated costs of testing due to failing tests are the sole responsibility of the Contractor. Materials not meeting the required shear strength will not be approved for use on this project.

6.2 CONSTRUCTION

The following subsection describes the CQA inspection activities that are necessary during the geocomposite installation. Refer to the specification Section 02777, Drainage Composite, for project specific construction and test requirements.

The CQA Inspector shall observe the geocomposite placement to confirm that specifications Section 02777 is followed, including coverage of all specified areas and adequate material overlap or seaming

6.2.1 Delivery, Storage and Handling

During delivery of geocomposite the CQA Inspector will observe rolls for the following, and any deviation will be reported to the CQA Engineer:

- Equipment used to unload the rolls does not damage the material.
- Rolls are wrapped in impermeable and opaque protective covers.
- Care is used to unload the rolls.
- Documentation required by specification Section 02777, Drainage Composite has been received.
- The drainage composite manufacturer has identified all rolls of drainage composite in accordance with specification Section 02777, Drainage Composite.

Drainage composite cleanliness is essential to its performance; therefore, the shipping and storage or drainage composite must be in strict accordance with specification Section 02777, Drainage Composite. The CQA Inspector will verify the following and report any deviations to the CQA Engineer.

- Materials are stored in a location that will protect the rolls from ultraviolet light exposure, precipitation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions.
- Drainage composites are free of dirt and dust just before installation. If the drainage composites are judged dirty or dusty, they will be washed by the drainage composite installer prior to installation. Washing operations will be observed by the CQA Inspector and improper washing operations will be reported to the CQA Engineer.
- When several layers of drainage composite are stacked, care is taken to ensure that stacked drainage composites are placed in the same direction. A stacked drainage composite will never be laid in a perpendicular direction to the underlying drainage composite (unless otherwise specified by the CQA Engineer.)

Damaged rolls may be rejected. If rejected, it must be verified that rejected material is removed from the site or stored at a location separate from accepted rolls. Geocomposite rolls that do not have proper manufacturer's documentation must also be stored at a separate location until all documentation has been received and approved.

6.2.2 Geocomposite Subsurface Preparation

Before geocomposite installation, the CQA Inspector will observe for the following:

- Lines and grades for the composite liner subgrade have been verified by the Contractor.
- Geomembrane installation is complete.

6.2.3 Geocomposite Placement and Seaming

During deployment and seaming operations, the CQA Inspector will observe for the following:

- All defects and defect corrective actions (panel rejected, patch installed, etc.) are recorded, and corrective actions are performed in accordance with the specifications.
- Equipment used to install geocomposite does not damage it during deployment.

- Crews working on the geocomposite do not smoke, wear shoes that could damage the geocomposite, or engage in activities that could damage the geocomposite.
- The geocomposite is securely anchored to prevent movement by the wind.
- Adjacent panels are overlapped and connected in accordance with Specification Section 02777, Drainage Composite.
- The geotextile component is not exposed to direct sunlight for more than the number of days recommended by the manufacturer.

The CQA Inspector will inform both the CQA Engineer and Contractor if they observe any conditions that do not conform to the requirements of the CQA Plan.

6.2.4 Geocomposite Repairs

Repair any holes or tears in the drainage composite by placing a patch of drainage composite extending a minimum of 2 feet beyond the edges of the holes or tear. Use approved fasteners, spaced every 6 inches around the patch to fasten the patch to the original roll.

6.2.5 Placement of Soil Materials

All soil material placed over the drainage composite will be placed in accordance with specification Section 02200, Earthwork, so as to ensure the following:

- The drainage composite and underlying geomembrane are not damaged.
- Minimal slippage of the drainage composite on the underlying geomembrane occurs.
- No excess tensile stresses occur in the drainage composite.

The CQA Inspector will inform both the CQA Engineer and Contractor if they observe any conditions that do not conform to the requirements of the CQA Plan.

SECTION 7.0
CORRUGATED POLYETHYLENE PIPE AND FITTINGS
CONSTRUCTION QUALITY ASSURANCE

7.1 PRECONSTRUCTION

All Advanced Drainage Systems (ADS) corrugated pipe and fittings for stormwater drainage shall be produced in accordance with specification Section 15079, Pipe – Corrugated Polyethylene.

7.1.1 Manufacturer’s Quality Control

7.1.1.1 Prior to Shipment

Prior to shipment, the Contractor will provide the CQA Engineer and the CQA Inspector with a quality control certification for each lot/batch of ADS material provided. The quality control certificate will be signed by a responsible party employed by the Manufacturer, such as the production manager. The quality control certificate will include:

- lot/batch number and identification; and
- sampling procedures and results of quality control tests.

The CQA Inspector will verify that the quality control certificates have been provided at the specified frequency for all lots/batches of pipe and that each certificate identifies the pipe lot/batch related to it; and review the quality control certificates and verify that the certified properties meet the requirements of specification Section 15079.

7.1.1.2 Prior to Installation

Prior to the installation of ADS corrugated pipes, the Manufacturer will provide to the Contractor and the CQA Inspector the following:

- a properties sheet including, at a minimum, all specified properties, measured using test methods indicated in ASTM D3350;
- a list of quantities and descriptions of materials other than the base resin which comprise the pipe;
- the sampling procedure and results of testing; and
- a certification by the manufacturer that values given in the properties sheet are minimum values and are guaranteed by the Manufacturer.

The CQA Inspector will review these documents and verify that:

- the property values certified by the Manufacturer meet all requirements of ASTM D3350; and
- the measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.
- report any discrepancies with the above requirements to the CQA Engineer.

SECTION 8.0 SURVEYING

Surveying of lines and grades is conducted on an ongoing basis during construction of the final and temporary final cover system. Close construction quality control (CQC) of the surveying is absolutely essential to ensure that slopes are properly constructed. The surveying conducted at the site shall be performed by the Contractor.

8.1 SURVEY CONTROL

Permanent benchmarks and baseline control points are to be established for the site at locations convenient for daily tie-in. The vertical and horizontal controls for this benchmark will be established within normal land surveying standards.

8.2 SURVEYING PERSONNEL

The Contractor's survey crew will consist of a Senior Surveyor, and as many Surveying CQC Monitors as are required to satisfactorily undertake the requirements for the work. All Surveying CQC personnel will be experienced in the provision of these services, including detailed, accurate documentation.

All surveying will be performed under the direct supervision of a Registered Professional Engineer (PE) or Licensed Land Surveyor (PLS) licensed in the state in which the project is located. The Licensed Land Surveyor may be the Senior Surveyor.

8.3 PRECISION AND ACCURACY

A wide variety of survey equipment is available to meet the requirements of this project. The survey instruments used for this work should be sufficiently precise and accurate to meet the needs of the project. All survey instruments should be capable of reading to a precision of 0.01 foot and with a setting accuracy of 20 seconds. (5.6×10^{-3} degrees).

8.4 LINES AND GRADES

The following surfaces shall be surveyed to verify the lines and grades achieved during construction. The survey should at least include (as deemed appropriate by the CQA Engineer and CQA Inspector):

- One or more construction baselines.
- The edges of all surface breaks (ex. toes, crests, ridges and valleys).
- Surface of the intermediate cover.
- Surface of the final cover.
- All structures including gas wells.
- Inverts of drainage pipe inlets and outlets.
- Top/toe of all berms, roads, and channels.
- Location of edge of liner, anchor trenches tie-in seam to adjacent existing liner system (as applicable).
- Major patches of LLDPE liner.

Laser planes are highly recommended for achieving the correct lines and grades during construction of each surface.

8.5 FREQUENCY AND SPACING

All surveying will be carried out immediately upon completion of a given installation to facilitate progress and avoid delaying commencement of the next installation. In addition, spot checks during construction, as determined by the Senior Surveyor, CQA Inspector, or CQA Engineer, may be necessary to assist the Contractor in complying with the required grades.

The following spacings and locations will be provided by the CQC surveyor, as a minimum, for survey points:

- Surfaces with slopes less than 10 percent will be surveyed on a square grid not wider than 50 feet.
- On slopes greater than 10 percent, a square grid not wider than 50 feet will be used, but, in any case, a line of survey points at the crest, midpoint, and toe of the slope will be taken.
- A line of survey points no farther than 50 feet apart will be taken along any slope break (this will include the inside edge and outside edge of any bench on a slope).
- A line of survey points not farther than 50 feet apart will be taken for all piping used for downdrains, in particular, at the end points.
- At a minimum, every 25 feet along the perimeter of the final cover liner system.

8.6 THICKNESS MEASUREMENTS

The CQC surveyor as a representative of the Contractor shall obtain thickness measurements of the intermediate cover and final cover at a maximum ~~50~~100-foot grid points and at all grade break lines prior to placement of the geomembrane liner. The procedure for obtaining thickness measurements of the intermediate cover and final cover shall be agreed to by the CQA Inspector and CQA Engineer prior to construction. The CQC Surveyor shall review the survey information with the Contractor to ensure that the survey demonstrates compliance with the Project Plans and Specifications. The Contractor is responsible for identifying and reporting to the CQA Inspector any areas of non-compliance evidenced by the survey, and for repairing such areas. The CQA Inspector and Contractor shall review the elevation measurements of the intermediate cover prior to placement of the geomembrane liner.

8.7 TOLERANCES

The following are maximum tolerances for survey points:

- On surfaces, the maximum tolerances shall be 0.1 foot. When comparing survey points for surfaces to determine conformance with design, the surveyed elevation and not the design elevation shall be used to determine if the surface meets design and the tolerances required in this section.
- On piping for downdrain lines, the maximum tolerances shall be 0.1 foot. When comparing survey points for surfaces to determine conformance with design, the surveyed elevation and not the design elevation shall be used to determine if the surface meets design and the tolerances required in this section.
- For thickness verifications, no minor tolerances are acceptable.

8.8 DOCUMENTATION

All field survey notes will be retained by the Senior Surveyor. The results from the field surveys will be documented on a set of survey record (as-built) drawings by the Contractor for submittal to the CQA Inspector. The Contractor shall certify to the CQA Inspector and CQA Engineer that the results of the survey demonstrates compliance with the Contract Documents. Sealed surveys depicting the information gathered in Paragraph 8.5 shall be supplied to the CQA Engineer and CQA Inspector in sufficient quantities. The surveys shall depict the information in a topographic format and illustrate actual data points. For thickness verification a table shall be compiled by the CQC surveyor or contractor containing the following information for each point.

- Top of intermediate cover elevation.
- Intermediate cover thickness.
- Top of protective cover elevation.
- Protective cover thickness.

Any deviations in elevation or thickness outside the tolerances allowed by specification shall be corrected.

SECTION 9.0

REPORTING REQUIREMENTS AND DOCUMENTATION

9.1 PROJECT MEETINGS

Conducting periodic project meetings is the responsibility of the Design Engineer who will make physical arrangements for meetings, record minutes and distribute copies to participants and those affected by decisions made at meetings. At a minimum the following meetings will be held.

- Pre-construction CQA meeting
- Problems or Work deficiency meetings

9.1.1 Preconstruction CQA Meeting

This meeting shall be attended by the Owner, Design Engineer, CQA Engineer, CQA Inspector, and Contractor. The topics should include but are not limited to:

- Providing each organization with all relevant CQA documents and supporting information.
- Familiarizing each organization with the site-specific CQA Plan and its role relative to the design criteria.
- Determining any changes to the CQA Plan that are needed to ensure that the facility will be constructed to meet or exceed the specified design.
- Reviewing the responsibilities of each organization.
- Reviewing lines of authority and communication for each organization.
- Discussing the established procedures or protocol for observations and tests including sampling strategies.
- Discussing the established procedures or protocol for handling construction deficiencies, repairs, and retesting.
- Reviewing methods for documenting and reporting inspection data.
- Reviewing methods for distributing and storing documents and reports.
- Reviewing work area security and safety protocol.
- Discussing procedures for the location and protection of construction materials and for the prevention of damage of the materials from inclement weather or other adverse events.
- Conducting a site walk-around to review construction material and inspection equipment storage locations.

The meeting shall be documented by a designated person, and minutes should be transmitted to all parties.

9.1.2 Weekly Progress Meetings

A progress meeting shall be held weekly at the work area at a time determined at the pre-construction meeting. The frequency of progress meetings may be reduced as the project proceeds if agreed to by the Owner, Contractor, and CQA Engineer. At a minimum, the meeting should be attended by the CQA Engineer, CQA Inspector, Contractor and the Owner.

The purpose of the meeting is to:

- Review the previous week's activities and accomplishments.

- Review status of progress schedule.
- Review the work location and activities for the week.
- Identify the contractor's personnel and equipment assignments for the week.
- Discuss any potential construction problems.

This meeting shall be documented by the CQA Engineer.

9.1.3 Problem or Work Deficiency Meetings

A special meeting shall be held when and if a problem or deficiency is present or likely to occur. At a minimum, the meeting shall be attended by the Design Engineer, Owner, Contractor, CQA Engineer, and CQA Inspector. The purpose of the meeting is to define and resolve a problem or recurring work deficiency in the following manner:

- Define and discuss the problem or deficiency.
- Review alternative solutions.
- Implement a plan to resolve the problem or deficiency.

The meeting shall be documented by the CQA Engineer and transmitted to the Owner, Contractor, CQA Inspector and Design Engineer, if applicable.

9.2 DOCUMENTATION

Documentation is an essential element of the CQA Plan. The following documentation and record keeping of inspection activities will be required.

9.2.1 Daily Summary Report

A summary report shall be prepared daily by the CQA Inspector. This report will provide the chronologic framework for identifying and recording all other reports. At a minimum, the summary reports shall include the following information:

- Unique identifying sheet number for cross-referencing and document control.
- Date, project name, location, and other identification.
- Data on weather conditions.
- Reports on any meetings held and their results.
- Unit processes, and locations, of construction under way during the timeframe of the daily summary report.
- Equipment and personnel being worked in each unit process, including subcontractors.
- Descriptions of areas or units of work being inspected and documented.
- Description of off-site materials received, including any quality verification (vendor certification) documentation.
- Calibrations, or recalibrations, of test equipment, including actions taken as a result of recalibration.
- Decisions made regarding approval of units of material or of work (blocks), and/or corrective actions to be taken in instances of substandard quality.

- Unique identifying sheet numbers of inspection data sheets and/or problem reporting and corrective measures reports used to substantiate the decisions described in the preceding item.
- Supporting inspection data sheets.
- Signature of the CQA Inspector.

9.2.2 Inspection Data Sheets and Photographs

All observations, and field and/or laboratory tests, shall be recorded on an inspection data sheet. Required data to be addressed for most of the standardized test methods are included in the pertinent ASTM Standards.

At a minimum, the inspection data sheets shall include the following information:

- Unique identifying sheet number for cross-referencing and document control.
- Description or title of the inspection activity.
- Location of the inspection activity or location from which the same increment was obtained.
- Type of inspection activity; procedure used (reference to standard method when appropriate).
- Recorded observation or test data, with all necessary calculations.
- Results of the inspection activity; comparison with specification requirements.
- Personnel involved in the inspection activity.
- Signature of the appropriate inspection personnel and concurrence by the CQA Engineer.

Items above may be formulated into site-specific checklists and data sheets so that details are not overlooked.

Photographic supporting data sheets also may prove useful. Such data sheets could be cross-referenced or appended to inspection data sheets and/or problem identification and corrective measures reports. At a minimum, photographic reporting data sheets should include the following information:

- A unique identifying number on data sheets and photographs for cross-referencing and document control.
- The date, time, and location where the photograph was taken and weather conditions.
- The size, scale, and orientation of the subject matter photographed.
- Location and description of the work.
- The purpose of the photograph.
- Signature of the photographer and concurrence of the CQA Engineer.
- Photographic supporting data sheets may be in MS Word or PDF format.

These photographs will serve as a pictorial record of work progress, problems, and corrective measures. They should be kept in a permanent protective file in the order in which they were taken.

9.2.3 Problem Identification and Corrective Measures Reports

A problem is defined herein as material or workmanship that does not meet the specified design. Problem identification and corrective measures reports shall be cross-referenced to specific inspection data sheets where the problem was identified. At a minimum, they shall include the following information:

- Unique identifying sheet number for cross-referencing and document control.

- Detailed description of the problem.
- Location of the problem.
- Probable cause.
- How and when the problem was located (reference to inspection data sheets).
- Estimation of how long problem has existed.
- Suggested corrective measure.
- Documentation of correction (reference to inspection data sheets).
- Final results.
- Suggested methods to prevent similar problems.
- Signature of the appropriate CQA inspection personnel and concurrence by the CQA Engineer.

Copies of the report shall be sent to the Design Engineer and the Owner for their comments and acceptance. These reports should not be submitted to the FDEP at that time unless they have been specifically requested. However, a summary of all data sheets and reports will be submitted to the FDEP upon completion of construction.

9.2.4 Acceptance of Completed Components

All daily inspection summary reports, inspection data sheets, and problem identification and corrective measures reports, shall be reviewed by the CQA Engineer.

9.2.5 Final Documentation

At the completion of the project, the Owner will submit a final construction certification report to the FDEP. This report will include all of the daily inspection summary reports, inspection data sheets, problem identification and corrective measures reports, photographic supporting data, acceptance reports, deviations from design and material specifications (with justifying documentation), and record drawings. This document shall be certified correct by the CQA Engineer and included as part of the CQA Plan documentation.

APPENDIX C
CERTIFICATION OF CONSTRUCTION COMPLETION
REPORT

Provided as a separate bound document
