APPENDIX R

CONCEPTUAL DESIGN SPECIFICATIONS
CONCEPTUAL DESIGN SPECIFICATION
MARANA REGIONAL LANDFILL
PIMA COUNTY, ARIZONA

DIVISION 2
SITWORK

Prepared for:
Marana Regional Landfill

Prepared by
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NOTE: The following specifications are prepared for permitting purposes only and are not intended for use as a bidding or construction control document. Construction-level specifications should be developed to match construction design plans for each individual project.
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DIVISION 2

SITEWORK
PART 1 GENERAL

1.1 SECTION INCLUDES

A. Clearing and stripping grass and other organic material from project construction areas including the offsite roadway.

B. Stockpile stripped material.

1.2 RELATED SECTIONS

A. Section 02221 – Excavating and Stockpiling.

B. Section 02222 – Engineered Fill, Drainage Layer, and Anchor Trench Backfill.

PART 2 PRODUCTS

Not used.

PART 3 EXECUTION

3.1 PREPARATION

A. Verify that any existing plant life designated to remain is tagged and identified.

B. Verify plants to be salvaged are tagged or identified.

3.2 PROTECTION

A. Protect survey benchmarks from damage or displacement.

B. Protect area to remain undisturbed located in northeast corner of property or otherwise designated on the Project Plans.

C. Protect existing utilities in the work area.

3.3 STRIPPING FOR LANDFILL CELL

A. Strip grass, roots, organic soils, and other deleterious materials prior to excavating.
B. Strip to a maximum depth of 6 inches below existing ground surface.

END OF SECTION
SECTION 02221
EXCAVATING AND STOCKPILING

PART 1 GENERAL

1.1 WORK INCLUDED

A. The CONTRACTOR shall furnish all labor, materials, tools, supervision, and equipment necessary for excavating to the lines and grades shown on the Drawings and as specified herein.

B. The CONTRACTOR shall construct all stormwater control structures as shown on the Drawings.

C. CONTRACTOR shall transport all excavated materials and stockpile these materials at the stockpile location areas as indicated on Drawings, or as designated by owner.

1.2 RELATED SECTIONS

A. Section 02222 – Engineered Fills, Drainage Layer, and Anchor Trench Backfill.

B. Section 02223 – Liner Subgrade Preparation.

PART 2 PRODUCTS

2.1 ENGINEERED FILL

A. Soil meeting requirements of Section 02222, Part 2.1.

2.2 OPERATIONS LAYER

A. Soil meeting requirements of Section 02222, Part 2.2

2.3 ANCHOR TRENCH BACKFILL

A. Soil meeting requirements of Section 02222, Part 2.3

2.4 SURPLUS SOILS

A. Remaining soils excavated.

PART 3 EXECUTION
3.1 PREPARATION

A. Establish required lines, levels, contours, and datum by construction staking.

B. Notify utility company to locate utilities, if applicable.

C. Provide for dust control including applicable permits.

D. Protect benchmarks and fences from excavation equipment and vehicular traffic.

E. Provide for dewatering as necessary for finish excavation and place fill.

F. Note that topography shown on Drawings may differ from topography at time of construction. A pre-construction survey shall be performed by the CONTRACTOR and provided to the OWNER to document site conditions prior to starting work.

3.2 LANDFILL CELL AREA

A. Excavate soil as required to the lines, grades, and elevations to construct the landfill cell subgrade.

B. Machine grade slopes and base of landfill cell to design grades.

C. Grade top perimeter of excavation to prevent surface water from draining into excavation.

D. Remove lumped subsoil, boulders, and rock greater than 1 inch in largest dimension from completed subgrade elevation.

E. Notify OWNER of unexpected subsurface conditions and discontinue affected work in area until notified to resume work.

F. Correct areas over-excavated by placing engineered fill per Section 02222, and as approved by the OWNER.

G. Place engineered fill per Section 02222.

H. Selectively excavate engineered fill, operations layer, and anchor trench backfill and stockpile near the project area.

I. Haul remaining material, surplus soils, to stockpile(s) designated on the Drawings or approved by OWNER.
3.3 SOIL STOCKPILING

A. Coordinate selective soil stockpiling with OWNER.

B. Place soil such that maximum slope is 3H:1V, and minimum slope is 5 percent.

C. Placement and mass configuration of soil stockpiles shall be performed at the direction of the OWNER.

D. Provide uniform final graded surface for the soil stockpile(s).

E. Provide erosion/sedimentation controls around perimeter of stockpile per requirements of the Stormwater Pollution Prevention Plan (SWPPP).

END OF SECTION
SECTION 02222
ENGINEERED FILL, OPERATIONS LAYER, AND ANCHOR TRENCH BACKFILL

PART 1     GENERAL

1.1 SECTION INCLUDES

A. Engineered Fill.
B. Operations Layer.
C. Backfill material for geosynthetics anchor trench.

1.2 RELATED SECTIONS

A. Section 02221 – Excavating and Stockpiling.
B. Section 02223 – Liner Subgrade and Preparation.

1.3 REFERENCES

Latest ASTM Standards or other recognized agency standards at the time construction documents are issued for the following items:

A. Soil density, Sand Cone Method
B. Compaction Characteristics of Soil
C. Water content of Soil Aggregate Mixtures
D. Permeability
E. Soil Classification
F. Soil Moisture and Density by Nuclear Method
G. Particle Size Analysis of Soils
H. Liquid Limit, Plastic Limit, and Plasticity Index.
I. Unified Soil Classification System.

References and methods/standard numbers included in these specifications will be modified/updated as necessary to be consistent with standards current at the time construction documents are issued.
PART 2  PRODUCTS

2.1 ENGINEERED FILL
   A. Predominantly cohesionless or low-plastic soil obtained from on-site excavations.
   B. Free of organic material.
   C. Maximum particle dimension: 3 inches, 1 inch for near surface material within 6 inches of the top of subgrade.
   D. Free of frozen material, ice, snow, or excessive moisture.

2.2 OPERATIONS LAYER
   A. Operations layer material shall be obtained from on-site sources identified by the OWNER.
   B. Operations layer shall meet the following requirements:
      1. Maximum particle size of 1 inch.
      2. In the opinion of the CQA Monitor, the particles larger than ¼ inch shall be sub-rounded to rounded, and free of sharp edges that could damage underlying geomembrane liner.

2.3 ANCHOR TRENCH BACKFILL
   A. Predominantly cohesionless or low-plastic soil obtained from on-site excavations.
   B. Free of organic material.
   C. Maximum particle size 1 inch.

PART 3  EXECUTION

3.1 ENGINEERED FILL PREPARATION
   A. Scarify subgrade soils to a 6-inch depth and re-compact subgrade soils to a minimum of 95 percent relative compaction as determined by ASTM D 698 prior to soil placement.
   B. Begin engineered fill placement only when underlying subgrade has been accepted by the OWNER.
C. Prior to placement of engineered fill verify that no substantial thickness of loose or uncompacted soil is present in the fill area.

3.2 ENGINEERED FILL PLACEMENT

A. Place Engineered Fill to the lines and grades shown on the Drawings.

B. Place in loose lift thickness not exceeding 8 inches.

C. Compact each lift to a minimum of 95 percent relative compaction at a moisture content from 4 percent below to 4 percent above optimum as determined by ASTM D 698. Completed lifts of fill can not yield under equipment loads.

D. Grade final surface to a vertical tolerance of 0.1 foot.

3.3 OPERATIONS LAYER PREPARATION

A. Verify the liner and leachate collection geocomposite is installed and all CQC and CQA documentation verifies installation in accordance with these specifications.

B. Verify borrow source meets specified requirements of this section and has been approved for use by the OWNER.

3.2 PLACEMENT

A. Backfill and compact geosynthetics anchor trenches prior to placing operations layer on sideslopes.

B. Do not put any equipment on the operations layer unless there is a minimum of 12 inches of operations layer covering the geocomposite.

C. Place in a single lift to the thickness indicated on the drawings.

D. Place and grade material up slope, do not push material downslope.

E. Use as few passes as possible. There are no compaction requirements.

F. Place without damaging underlying installations.

G. Do not exceed allowable ground pressure are specified below:
### 3.4 BACKFILL FOR ANCHOR TRENCH

A. Begin only when geosynthetic installations have been completed in accordance with deployment and seaming criteria.

B. Place earthfill to the lines and grades shown on the Drawings.

C. Place in loose lift thickness not exceeding 12 inches; no scarification is required.

D. Compact each lift to a minimum of 95 percent relative compaction as determined by wheel rolling with rubber-tired equipment, or similar.

E. Do not damage geosynthetic installation.

F. Grade final surface to a vertical tolerance of plus or minus 0.10 feet.

#### TABLE 02222

<table>
<thead>
<tr>
<th>Allowable Equipment Ground Pressure (psi)</th>
<th>Thickness of Material Above Geocomposite (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5</td>
<td>12</td>
</tr>
<tr>
<td>&lt;10</td>
<td>18</td>
</tr>
<tr>
<td>&lt;20</td>
<td>24</td>
</tr>
<tr>
<td>&gt;20</td>
<td>36</td>
</tr>
</tbody>
</table>

H. Construct haul routes over geocomposite having a minimum material thickness of 24 to 36 inches. The 24-inch minimum coverage includes the initial material dumping and spreading areas, haul roads and stockpile areas that cover the geomembrane and are utilized by rubber-tired vehicles.

I. When placing operations layer to its final thickness over the geomembrane use low ground pressure track-mounted equipment with a maximum allowable ground pressure equal to or less than a LGP D-6 dozer.

J. Maximum equipment speed over operations layer: 5 miles per hour.

K. Do not make sharp turns when placing leachate collection layer.
3.5 FIELD QUALITY ASSURANCE (BY OWNER)

A. The facility’s Construction Quality Assurance Plan “CQA Plan”.

B. The OWNER will collect and test samples of soil materials covered in this Section in accordance with the procedures outlined in the CQA Plan. In-place density and moisture content will be measured during construction by the OWNER in accordance with the procedures outlined in the CQA Plan.

END OF SECTION
SECTION 02223
LINER SUBGRADE PREPARATION

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Final grading and compaction of finished subgrade in preparation for GCL placement.

1.2 RELATED SECTIONS

A. Section 02221 – Excavating and Stockpiling.

B. Section 02222 – Engineered Fill, Drainage Layer, and Anchor Trench Backfill.

C. Section 02779 – GCL.

1.3 REFERENCES

Latest ASTM Standards or other recognized agency standards at the time construction documents are issued for the following items:

A. Compaction Characteristics of Soil

B. Density of Soil and Soil-Aggregate in Place

C. Water Content of Soil and Rock in Place

D. Water (Moisture) Content of Soil and Rock

E. Density and Unit Weight of Soil in Place, Sand-Cone Method

F. Density of Soil in Place by the Drive-Cylinder Method

References and methods/standard numbers included in these specifications will be modified/updated as necessary to be consistent with standards current at the time construction documents are issued.

PART 2 PRODUCTS

2.1 ENGINEERED FILL

A. See Section 02222.
PART 3  EXECUTION

3.1  EXAMINATION

A. Verify that excavation is complete and in compliance with slopes and dimensions shown on the Drawings.

B. If excavation of unsuitable material is required prior to replacement with engineered fill, coordinate excavation with OWNER.

C. Verify surface is free of ponded water before engineered fill or GCL is placed.

3.2  FINISHED GRADING AND COMPACTION OF LINER SUBGRADE

A. Moisture condition engineered fills or liner subgrade soils from 4 percent below to 4 percent over optimum moisture, then compact to a minimum of 95 percent relative compaction as determined by ASTM D 698.

B. Finish grade compacted within a vertical tolerance of plus or minus 0.1 feet of design grade.

C. Subgrade shall be rolled with a smooth-drummed compactor to a smooth and level surface.

D. Surface shall be free of stones or protrusions greater than 0.50-inch diameter and organics or other deleterious material.

E. Fill voids and cracks.

F. Ruts shall be limited to 1-inch maximum depth.

G. The CONTRACTOR may use a scraper or other heavy equipment to verify compaction of subgrade materials by proof-rolling. The subgrade surface will be accepted by the ENGINEER if the specified compaction is obtained, and no materials greater than one inch in dimension are visible. It should be noted that areas of the subgrade may be unsuitable and require removal and replacement with engineered fill. No additional compensation will be provided by the OWNER for the removal and replacement of unsuitable subgrade materials.

3.3  FIELD QUALITY ASSURANCE (BY OWNER)

A. The OWNER will collect samples of liner subgrade materials to determine the material’s optimum moisture content and maximum density (ASTM D-698).

B. The OWNER will measure in-place density and moisture content of the liner subgrade (by one or more of the following methods: ASTM D 2922, ASTM D
1556, ASTM D 2216, and ASTM D 3017), at the frequencies outlined in the CQA Plan.

C. For in-situ liner subgrade conditions, if in the opinion of the CQA Monitor the in-situ liner subgrade is comprised of unyielding, firm soils, the testing requirements listed above in paragraph (B) may be replaced with the following field verification test:

1. Following smooth drum compaction of the subgrade, the CQA Monitor and OWNER shall observe the CONTRACTOR “proof-rolling” the subgrade with a fully-loaded scraper. If the subgrade appears firm and no “pumping” or soft spots areas are observed, the CQA Monitor can certify that the subgrade soils are approved for GCL placement.

D. Contractor shall cooperate fully with the OWNER in performing compaction control tests. Include costs for assistance in unit or lump sum prices.

END OF SECTION
SECTION 02225
GEOCOMPOSITE

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Placement of single-sided geocomposite as part of leachate collection system for the landfill. Double-sided geocomposite may be utilized if so noted on Project Drawings.

1.2 RELATED SECTIONS

A. Section 02222 – Engineered Fill, Drainage Layer, and Anchor Trench Backfill.
B. Section 02711 – Polyethylene Pipe.
C. Section 02771 – Geotextile.
D. Section 02778 – Geomembrane.

1.3 REFERENCES

Latest ASTM Standards or other recognized agency standards at the time construction documents are issued for the following items:

A. Coated Fabrics
B. Density and Specific Gravity (Relative Density) of Plastics
C. Density of Plastics by the Density-Gradient Technique
D. Carbon Black in Olefin Plastics
E. Compressive Properties of Rigid Cellular Plastics
F. Water Permeability of Geotextiles by Permittivity
G. Trapezodial Tearing Strength of Geotextiles
H. Grab Breaking Load and Elongation of Geotextiles
I. Constant Head Hydraulic Transmissivity of Geotextiles
J. Index Puncture Resistance of Geotextiles
K. Determining Apparent Opening Size of a Geotextile

References and methods/standard numbers included in these specifications will be modified/updated as necessary to be consistent with standards current at the time construction documents are issued.

1.4 DEFINITIONS
A. Manufacturer: Responsible for the production of geocomposite rolls.
B. Installer: The party responsible for field handling, storing, deploying, repairing, anchoring, and any other aspects of installing the geocomposite. The installer is also responsible for the transportation of the material to the site.
C. Construction Quality Assurance Consultant (CQAC): The party, independent from the manufacturer or installer, responsible for observing and documenting activities related to the quality assurance of the production and installation of the geosynthetic components of the geocomposite. Also responsible for issuing a construction management report and certification sealed by a Registered Professional Engineer.

1.5 MANUFACTURE SUBMITTALS FOR REVIEW
A. Submit the following 14 days prior to scheduled manufacturing of products for this project:

1. Samples of geocomposites proposed for this project. Include with the sample the roll number, lot number, and MQC test data documented for the particular production run from which the sample was taken.

2. Manufacturer’s description of proposed geocomposites documenting they will meet or exceed specified product requirements.

3. Available and historical data documenting proposed drainage layer geocomposite will meet specified interface residual shear strength.

4. Provide written instructions for storage, handling, installation, seaming, and repair of proposed geocomposites.

B. Submit the following 7 days prior to scheduled installation:

1. Manufacturer’s certificates of compliance with specified product requirements.
2. Manufacturer’s Quality Control (MQC) test results performed on materials produced for this project.

1.6 TRANSMISSIVITY VERIFICATION MQC TESTING (PERFORMED BY MANUFACTURER)

A. The Manufacturer must provide transmissivity test results for the geocomposite proposed for the primary leachate collection system to qualify its use on this project. Refer to paragraph 2.1 of this Section for other product requirements for the components of the geocomposite (geotextile and geonet) as well as the geocomposite itself.

B. Testing: Test with liner system components in contact with each side of the geocomposite as shown on the drawings. Tests must be performed by a GRI accredited lab or as approved by the ENGINEER.

C. Test as described below:

1. Test Method – [To be specified in Specification issued for construction]

2. Normal Load: [To be specified for each liner cell based on maximum waste depth for that cell and 65 psf waste density]

3. Gradient – 0.03

4. Test Duration – 100 hours. Report results at 15 minutes, 1 hour and then every 24 hours.

5. Boundary Conditions – replicate proposed liner materials above and below geocomposite for the test:

   a. Below the geocomposite: 60-mil thickness HDPE smooth geomembrane underlain by the GCL to be used on the project and a 1 inch minimum thickness on-site soil compacted as specified for subgrade preparation.

   b. Above the geocomposite: a 1 inch minimum thickness of operations layer soil that will be used on the project.

6. Minimum transmissivity required:

   a. Primary Leachate Collection: [To be specified for each liner cell based on anticipated (HELP Model) leachate generation rate and floor area for that cell flowing to leachate collection line/sump]

1.7 CONFORMANCE TESTING (PERFORMED BY OWNER)

A. The OWNER will perform conformance testing on geocomposites as outlined in the CQA Plan.
B. Allow a minimum of 7 calendar days for conformance tests to be performed and data to be reviewed.

1.8 DELIVERY, STORAGE, AND HANDLING

A. Protect geocomposite from ultraviolet light exposure, precipitation, inundation, mud, dirt, dust, puncture, cutting, and other damaging or deleterious conditions.

B. Ship geocomposite in a closed trailer.

C. Immediately restore damaged protective covering.

PART 2 PRODUCTS

2.1 GEOCOMPOSITE PRIMARY LEACHATE COLLECTION SYSTEM

A. Description: A drainage geocomposite manufactured by heat-bonding non-woven needle punched geotextile to both sides of a polyethylene geonet.

B. Description: A drainage geocomposite manufactured by heat-bonding non-woven needle punched geotextile to one side of a polyethylene geonet.

C. Provided in roll lengths that accommodate the maximum slope lengths on 3:1 or steeper slopes without requiring butt seams.

D. Manufactured with a thickness adequate to meet specified flow capacity.

E. Manufactured with a non-collapsible waterway for unrestricted flow.

F. Manufactured with core material made of polyethylene that maintains the required flow under specified loads.

G. Manufactured with geotextile overlapped at the upstream end of the geocomposite drain to prevent soil intrusion.

H. Interface shear strength for the geocomposite as part of the liner system shall be tested per the requirements of Section 02779.2.2.

I. Manufactured to meet or exceed the following product requirements based on minimum average roll values:
2.2 GEONET COMPONENT OF GEOCOMPOSITE PRIMARY LEACHATE COLLECTION SYSTEM

**TABLE 02225-1**
GEONET COMPONENT PROPERTIES AND TESTING FREQUENCIES

<table>
<thead>
<tr>
<th>Test(2)</th>
<th>ASTM Test Designation</th>
<th>Minimum MQC Test Frequency(2)</th>
<th>Required Test Values (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (min. avg.)</td>
<td>D751 or D5199</td>
<td>1/100,000 sf</td>
<td>160 mil or as necessary to meet transmissivity requirements of Section 1.6.C.6.</td>
</tr>
<tr>
<td>Melt Flow Index</td>
<td>D1238, E</td>
<td>1 per resin batch</td>
<td>1.0 g/10 min</td>
</tr>
<tr>
<td>Density (min. avg.)</td>
<td>D792 or D1505</td>
<td>1/100,000 sf</td>
<td>0.940 g/cm³</td>
</tr>
<tr>
<td>Carbon Black Content (range)</td>
<td>D1603</td>
<td>1/100,000 sf</td>
<td>2-3%</td>
</tr>
<tr>
<td>Polymer Composition</td>
<td>1/resin batch</td>
<td></td>
<td>95% Polyethylene by weight</td>
</tr>
</tbody>
</table>

2.3 GEOTEXTILE COMPONENT OF GEOCOMPOSITE FOR PRIMARY LEACHATE COLLECTION SYSTEM

A. Per paragraph 2.1, Section 02771.

2.4 MANUFACTURED GEOCOMPOSITE FOR PRIMARY LEACHATE COLLECTION SYSTEM

**TABLE 02225-2**
GEOCOMPOSITE PROPERTIES AND TESTING FREQUENCIES

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Test Designation</th>
<th>Minimum MQC Test Frequency(2)</th>
<th>Required Test Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peel Strength (min. avg.)</td>
<td>F904</td>
<td>1/100,000 sf</td>
<td>500 g/in</td>
</tr>
<tr>
<td>Transmissivity (1)</td>
<td>D4716</td>
<td>1/200,000 sf</td>
<td>See Paragraph 1.6</td>
</tr>
</tbody>
</table>

Notes:

1. Transmissivity shall be measured in a 12-inch x 12-inch box using the same boundary conditions, load, duration and gradient as those used by the manufacturer to establish the min. avg. for the required test value.
2. Testing the geonet component shall be performed in accordance with the upper portion of this table. The geotextile component shall meet the required test values and the manufacturer’s QC test frequency requirements from the Geotextile Separator (see Section 02771, 2.1). Tracking of the frequency of the Manufacturers QC testing and Conformance QA testing shall be based on the geocomposite roll numbers.
3. Unless otherwise noted, all values represent minimum average roll values (MARV), (i.e. any roll in a lot should meet or exceed the values in this table).
2.5   MANUFACTURER SOURCE QUALITY CONTROL

A. Perform Manufacturer’s Quality Control (MQC) tests for geocomposites manufactured for this project. Perform tests necessary to verify geocomposites meet specified product requirements. Perform each MQC test at a minimum of the frequencies defined in this Section.

B. Provide the following information with MQC test data:
   1. Roll numbers and identification
   2. Results of quality control tests, including a description of test methods used.

C. OWNER will reject rolls for which quality control requirements are not met.

2.6   LABELING

A. Mark or tag geocomposite rolls with the following information:
   1. Manufacturer’s name
   2. Product identification
   3. Lot number
   4. Roll number
   5. Roll dimensions

B. Mark special handling requirements on rolls.

PART 3   EXECUTION

3.1   EXAMINATION

A. Prior to installation of geocomposite, examine underlying construction for conformance with specifications. Verify the following:
   1. Underlying installations are complete, installed as designed, and as-built documentation has been obtained.
   2. There is no debris, excessive dust or rocks on the geomembrane in areas where geocomposite will be deployed.

3.2   PROTECTION

A. When placing other geosynthetics over the geocomposite ensure the following:
1. No damage occurs to the geocomposite.
2. The geocomposite does not slip on the underlying geosynthetics.
3. There are no excessive tensile stresses in the geocomposite.

3.3 DEPLOYMENT

A. Follow manufacturer’s recommendations, standards, and guidelines.
B. Deploy geocomposite as indicating in Drawings.
C. Do no entrap excessive dust, stones or moisture in geocomposite that could damage or clog drains or filters or hamper subsequent seaming.
D. Deploy rolls down slope not across slope.
E. Lay smooth with no wrinkles and free of stresses.
F. Examine geocomposite over entire installed surface to ensure that no potentially harmful foreign objects, such as needles, are present. Remove any foreign objects.
G. Do not drag geocomposite across rough or textured surfaces to avoid damage to the geocomposite. Use a smooth geosynthetic slip sheet or rub sheet as necessary to reduce friction damage during deployment.

3.4 PANEL SEAMS (IF REQUIRED)

A. Ensure that no soil is present between geocomposite seams.
B. Overlap geonet 3 inches along panel edges and tie at five-foot intervals with plastic ties of contrasting color to the geonet material.
C. Overlap geotextile and sew or heat bond.

3.5 BUTT SEAMS (IF REQUIRED)

A. Overlap geonet 3 inches along panel ends and tie at 12-inch intervals with plastic ties of contrasting color to the geonet material.
B. Overlap geotextile and sew or heat bond.

3.7 REPAIRS

A. Repair with same geocomposite product overlapped 12 inches beyond the repair area and secure with plastic ties of contrasting color to the geonet material spaced 12 inches on center. Overlap geotextile and sew or heat bond.
3.8 FIELD QUALITY ASSURANCE

A. The CQAC will collect sample of geocomposite delivered to the site, for conformance testing at a minimum frequency of one (1) per hundred thousand (250,000) square feet of geocomposite and perform tests as outlined in the CQA Plan to determine product compliance with specified values.

3.9 ACCEPTANCE

A. CONTRACTOR retains all ownership and responsibility for geocomposite until acceptance by OWNER.

B. OWNER accepts geocomposite when:

1. The installation is complete.
2. Conformance tests verify product requirements.
3. Documentation of installation is complete including the CQAC’s final report.
4. Verification of the adequacy of all seams and repairs, including associated testing, is completed.
5. Written certification documents have been received by the OWNER.

END OF SECTION
SECTION 02275
RIP-RAP

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Installation of rip-rap (and associated geotextile) where indicated on the project drawings.

1.2 RELATED SECTIONS

A. Section 02223 – Subgrade Preparation.

B. Section 02771 – Geotextiles.

1.3 SUBMITTALS

The CONTRACTOR shall submit to the ENGINEER the Manufacturer's certification of compliance for geotextiles used for rip-rap placement, and shall comply with the Manufacturer's recommendations for handling, storing, and installing geotextile material.

1.4 PROTECTION

The CONTRACTOR shall protect trees, shrubs, rock outcroppings and other features remaining as part of final landscaping.

PART 2 PRODUCTS

2.1 RIP-RAP

A. Rip-rap shall be obtained from off-site sources selected by the CONTRACTOR and shall be approved by the ENGINEER. The rip-rap shall be hard, durable, angular to sub-rounded in shape; resistant to weathering and to water action; free from overburden, spoil, and organic material; and shall meet the gradation requirements for the size specified. Rounded shaped stone such as “river rock” shall not be acceptable for use as rip-rap material. Neither the width nor thickness of a single stone should be less than one-third its length. Not more than 25 percent of the stone reasonably distributed throughout the gradation shall have a length of more than 2.5 times the width or thickness. The minimum unit weight of the stone shall be 156 pounds per cubic foot.
B. The gradation requirements for rip-rap will be determined for each phase of construction based on the D$_{50}$ size determined by the erosion control calculations.

2.2 GEOTEXTILE

A. As described in Section 02771.

PART 3 EXECUTION

3.1 RIP-RAP PLACEMENT

A. The subgrade shall be prepared as described in Section 02223, and as shown on the project drawings.

3.2 GEOTEXTILE HANDLING

A. The CONTRACTOR shall handle all geotextile in such a manner as to ensure they are not damaged in any way.

B. The CONTRACTOR shall take care not to entrap stones, excessive dust, or moisture in the geotextile during placement.

C. The CONTRACTOR shall weight all geotextiles with sandbags, or the equivalent, in the presence of wind. Such sandbags shall be installed during placement and shall remain until replaced with rip-rap.

D. Geotextile shall be overlapped a minimum of 12 inches, “shingled” in the downstream direction. No horizontal seams shall be allowed on slopes steeper than 5 horizontal to 1 vertical (i.e., seams shall be along, not across, the slopes).

E. The CONTRACTOR shall place all rip-rap on top of a geotextile, in such a manner as to ensure that:

1. the geotextile and underlying materials are not damaged;
2. minimum slippage occurs between the geotextile and underlying layers;
3. excess stresses are not produced in the geotextile;
4. rip-rap materials are not segregated by size; and
5. rip-rap stones are “nested” together to minimize future settlement and washout.

F. Any damage to underlying or surrounding material or structures during placement of the rip-rap shall be repaired before proceeding with the work.
G. Place rip-rap to the lines, grades, cross-sections, and dimensions shown on the Drawings.

END OF SECTION
SECTION 02711
POLYETHYLENE PIPE

PART 1  GENERAL

1.1 SECTION INCLUDES

A. Supply and installation of polyethylene (HDPE) pipe in locations shown on the drawings.

B. Supply and installation of all HDPE pipe fittings and appurtenances.

1.2 RELATED SECTIONS

A. Section 02771 – Geotextile.

B. Section 02225 – Geocomposite.

1.3 REFERENCES

Latest ASTM Standards or other recognized agency standards at the time construction documents are issued for the following items:

A. Polyethylene Plastics Molding and Extrusion Materials

B. Polyethylene Plastics Pipe and Fittings Materials

References and methods/standard numbers included in these specifications will be modified/updated as necessary to be consistent with standards current at the time construction documents are issued.

1.4 DEFINITIONS

Standard Dimensional Ratio (SDR): The actual outside pipe diameter divided by the wall thickness.

1.5 SUBMITTALS

A. Submit product data for pipe materials and welding system to be used. Submit 10 days prior to installation.

PART 2  PRODUCTS

2.1 PIPE AND FITTINGS
A. All pipe sizes shown on the Drawings and specified in this Section reference nominal diameter, unless otherwise indicated on the Drawings or in this Section. Pipe sizing in accordance with ASTM F714, and ASTM D3035 83.

B. All pipes: SDR as shown in Drawings.

C. Designated as PE3408 and classified as 345464C(ASTM D3350).

D. Conforming to the following requirements:

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Procedures</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (gm/cm³)</td>
<td>ASTM D1505</td>
<td>0.955</td>
</tr>
<tr>
<td>Melt Index (gm/10 min)</td>
<td>ASTM D1238, (E)</td>
<td>min. 0.1</td>
</tr>
<tr>
<td>Flexural Modules (psi)</td>
<td>ASTM D790</td>
<td>min. 133,000</td>
</tr>
<tr>
<td>Tensile Strength (psi)</td>
<td>ASTM D638</td>
<td>min. 3,200</td>
</tr>
<tr>
<td>Environmental Stress Crack (hrs)</td>
<td>ASTM D1693</td>
<td>&gt; 5,000</td>
</tr>
<tr>
<td>Hydrostatic Design Basis (psi)</td>
<td>ASTM D2837</td>
<td>min. 1,600</td>
</tr>
<tr>
<td>UV Stabilizer (% Carbon Black)</td>
<td>ASTM D1603</td>
<td>2-3%</td>
</tr>
<tr>
<td>Elastic Modulus (psi)</td>
<td>ASTM D638</td>
<td>min. 105,000</td>
</tr>
<tr>
<td>Brittleness Temp. (°F)</td>
<td>ASTM D746</td>
<td>&lt; -180 °F</td>
</tr>
<tr>
<td>Vicat Softening Temp. (°F)</td>
<td>ASTM D1525</td>
<td>255 °F</td>
</tr>
<tr>
<td>Thermal Expansion(in/in/°F)</td>
<td>ASTM D696</td>
<td>1.2 x 10⁻⁴</td>
</tr>
<tr>
<td>Hardness (Shore D)</td>
<td>ASTM D2240</td>
<td>64</td>
</tr>
</tbody>
</table>

E. Containing no recycled compound except that generated in the manufacturer’s own plant and from resin of the same specification as the raw material supplier.

F. Resin for pipe and fittings listed by both N.S.F. and P.P.I. and manufactured in accordance with ASTM D305/F714-81.

G. Homogeneous throughout and free of visible cracks, holes, foreign inclusions, or other injurious defects; Being uniform in color, capacity, density, and other physical properties.

H. Provide the following information continuously marked on the pipe or spaced at intervals not exceeding 5 feet.

1. Name and/or trademark of the pipe manufacturer.
2. Nominal pipe size.
4. PE 3408.
6. A production code from which the date and place of manufacturer can be determined.

2.2 PIPE COUPLINGS

A. Where required, provide HDPE blind flange adapters, molded stub ends, and molded end caps and other fittings in accordance with the drawings.

2.3 FABRICATED FITTINGS

A. Provide fabricated or molded fittings as shown on the drawings.

2.4 PIPE PERFORATIONS AND LEACHATE COLLECTION PIPES

A. Perforate with 3/8-inch diameter holes. Drill four equally spaced holes around pipe perimeter, a minimum of every six inches along the pipe lengths.

B. See Drawings for perforation details for sump collector pipe.

PART 3 EXECUTION

3.1 GENERAL

A. When shipping, delivering, and installing pipe, fittings and accessories, do so to ensure a sound, undamaged installation.

B. Provide adequate storage for all materials and equipment delivered to the job site.

C. Handle and store pipe and fittings in accordance with the manufacturer’s recommendations.

3.2 PLACING AND LAYING PIPE

A. Provide maintenance of all such material and equipment.

B. Follow the manufacturer’s recommendations when hauling, unloading, and stringing of the pipe.

C. Do not push or pull pipe and fittings over sharp projections, drop, or have objects dropped on it.

D. Inspect for defects before installation.
E. Any piping showing kinks, buckles, cuts, gouges, or any other damage which in the opinion of the OWNER will affect performance of the pipe must be removed from the site.

F. Replace material found to be defective before or after laying with sound material without additional expense to the OWNER.

### 3.3 FUSION WELDING PIPE

A. Join the polyethylene pipe by the method of thermal butt or side wall fusion, outlined in ASTM D2657. Perform fusion joining of pipe and fittings in accordance with the procedures established by the pipe manufacturer. Of particular importance is the use of proper interface pressures and heater plate temperatures. Ensure that shavings generated during butt surface preparation are cleaned from interior of piping prior to fusing.

B. Use fusion pressures, temperatures, and cycle times according to pipe manufacturer’s recommendations. Use personnel adequately trained and qualified in the technique involved.

C. Do not perform pipe fusion in water when trench conditions are unsuitable for the work. Keep water out of the trench until joining is completed. Secure open ends of pipe and close valves when work is not in progress, so that no trench water, earth, or other substance will enter the pipe or the fittings. Plug or cap or valve pipe ends left for future connections.

D. Clear welding and grade sites, if necessary, to provide enough space for pipe storage and fusion. Keep the site free of rocks, stumps, and debris which could cut, scar, or gouge the pipe. In order to allow the joining operation to continue in adverse weather conditions, a shelter may be required for the joining machine. Particular caution should be exercised to prevent the pipe from becoming wet, and to prevent the heater plate from coming in contact with water.

E. Polyethylene Fusion Qualification: All pipe fusion must be performed by a supplier, or a factory supplied and/or certified fusion operator.

F. Provide training sessions as required to train welding personnel, and quality control personnel in polyethylene fusion machine operation as applicable for the project. Only fully trained personnel will be allowed to perform the installation, supervision, or inspection of polyethylene-fusion joints. Submit a listing of those authorized/instructed for polyethylene fusion welding for review by the OWNER. Make all on-site training sessions during this contract available to quality assurance personnel at no charge to the OWNER.

G. Training: Provide assistance from the manufacturer/supplier in instructing welding personnel in proper fusion procedures and techniques. Notifications will be required in writing, listing the names of those persons so familiarized. A
manufacturer’s representative shall be certified in writing by the manufacturer to be technically qualified and experienced.

END OF SECTION
SECTION 02771
GEOTEXTILE

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Installation of geotextile around gravel fill, as a separation or cushion medium, or as a component of a geocomposite drainage layer.

1.2 RELATED SECTIONS

A. Section 02278 – Geomembrane.
B. Section 02225 – Geocomposite.
C. Section 02222 – Engineered Fill, Drainage Layer, and Anchor Trench Backfill.

1.3 REFERENCES

Latest ASTM Standards or other recognized agency standards at the time construction documents are issued for the following items:

A. Industrial Filament Yarns Made From Man-Made Organic Base-Fibers
B. Water Permeability of Geotextiles by Permittivity
C. Trapezoid Tearing Strength of Geotextiles
D. Tensile Properties by the Wide-width Strip Method
E. Grab Breaking Load and Elongation of Geotextiles
F. Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products
G. Apparent Opening Size of a Geotextile
H. Measuring Nominal Thickness of Geotextiles and Geomembranes
I. Measuring Mass per Unit Area of Geotextiles

References and methods/standard numbers included in these specifications will be modified/updated as necessary to be consistent with standards current at the time construction documents are issued.
1.4 DEFINITIONS

C. Manufacturer: Responsible for the production of geotextile rolls.

D. Installer: The party responsible for field handling, storing, deploying, repairing, anchoring, and any other aspects of installing the geotextile. The installer is also responsible for transportation of the material to the site.

E. Construction Quality Assurance Consultant (CQAC): The party, independent from the manufacturer or installer, responsible for observing and documenting activities related to the quality assurance of the production and installation of the geosynthetic components of the geotextile. Also responsible for issuing a construction monitoring report, and certification sealed by a Registered Professional Engineer.

1.5 SUBMITTALS DUE 10 DAYS PRIOR TO INSTALLATION

A. Samples and complete description of geotextile fabric proposed for use, that meet or exceed requirements of this section.

B. Written instructions for storage, handling installation, and sewing of proposed geotextile.

C. Written instructions for repair of geotextile.

D. Manufacturer's certificates of compliance with specified product requirements. This submittal includes Manufacturer's Quality Control (MQC) testing.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Protect geotextile from ultraviolet light exposure, precipitation, inundation, mud, dirt, dust, puncture, cutting, and other damaging or deleterious condition.

B. Ship geotextile in closed trailer.

C. Immediately restore damaged protective covering.

PART 2 PRODUCTS

2.1 GEOTEXTILE

A. Products comprised of non-woven, continuous-filament needle punched polypropylene or polyester fabric; oriented into a stable network that maintains its structure during handling, placement, and long-term service.

B. The product can not be heat burnished.

C. Resistant to soil chemicals.
D. New product made from virgin materials.

E. Geotextile used for filtration conforming to the following minimum average roll values (MARV) as defined by the Federal Highway Administration for the properties listed.

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Test Designation</th>
<th>Unit</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass per Unit Area</td>
<td>D 5261</td>
<td>oz/SY</td>
<td>*</td>
</tr>
<tr>
<td>Grab Tensile and Elongation</td>
<td>D 4632</td>
<td>lbs</td>
<td>**</td>
</tr>
<tr>
<td>Puncture Resistance</td>
<td>D 6241</td>
<td>lbs</td>
<td>**</td>
</tr>
<tr>
<td>Trapezoidal Tear</td>
<td>D 4533</td>
<td>lbs</td>
<td>**</td>
</tr>
<tr>
<td>Permittivity</td>
<td>D 4491</td>
<td>sec^{-1}</td>
<td>**</td>
</tr>
<tr>
<td>Apparent Opening Size</td>
<td>D 4751</td>
<td>sieve</td>
<td>&lt;100</td>
</tr>
</tbody>
</table>

*As specified on Drawings, min of 8.0 oz/sy in any application.

** To be specified based on the mass per unit area required

2.2 MANUFACTURER SOURCE QUALITY CONTROL

A. Perform quality control tests of geotextile, at a minimum of once for every one hundred thousand (100,000) square feet to evaluate materials conformance to published material properties.

B. Reject rolls for which quality control requirements are not met.

C. Certify the quality of the rolls of geotextile.

D. Provide quality control certificates for each lot and each shift's production. The quality control certificates shall include:

1. Roll numbers and identification.

2. Sampling procedures

3. Results of quality control tests, including a description of test methods used

2.3 LABELING

A. Mark or tag geotextile rolls with the following information:

1. Manufacturer's name

2. Product identification

3. Lot number
4. Roll number

5. Roll Dimensions

B. Mark special handling requirements on rolls.

PART 3 EXECUTION

3.1 EXAMINATION

A. Prior to installation of geotextile, examine underlying construction for conformance with specifications. Verify the following:

1. Underlying installations are complete, installed as designed, and as-built documentation has been obtained.

3.2 PROTECTION

A. When placing soil materials over geotextile, ensure the following:

1. No damage to geotextile.

2. No slippage of geotextile on underlying layers.

3. No excessive tensile stresses in the geotextile.

3.3 DEPLOYMENT

A. Follow manufacturer’s recommendations, standards, and guidelines.

B. Anchor geotextile in anchor trenches on slopes greater than 20 percent. Roll geotextile down slope in such a manner as to continually keep the geotextile sheet in sufficient tension to preclude folds and wrinkles.

C. Weight geotextile with sandbags or equivalent as ballast during deployment. Leave ballast in place until geotextile is covered with succeeding construction layer.

D. Cut geotextile using approved cutter only. Take care to protect other in-place geosynthetic materials when cutting geotextile.

E. Do not entrap in geotextile excessive dust, stones, or moisture that could damage or clog drains of filters or hamper subsequent seaming.

F. Examine geotextile over entire completed surface to ensure that no potentially harmful foreign objects, such as needles, are present. Remove any foreign objects.
3.4 SEAMS AND OVERLAPS

A. Overlap a geotextile a minimum of 18 inches. No seaming is necessary unless otherwise specified on the Drawings or in these specifications.

3.5 REPAIRS

A. Repair holes or tears in a geotextile with a patch from the same geotextile material, seamed in place with a minimum seam overlap of 12 inches in all directions.

B. Remove any soil or other material that may have penetrated the torn geotextile.

3.6 FIELD QUALITY ASSURANCE

A. The CQAC will collect samples of geotextile delivered to the site for conformance testing at a minimum frequency as identified in the CQA Plan, and perform tests to determine product compliance with specified values.

B. Samples will be taken across the entire width excluding the first three feet of the roll unless otherwise approved. Sample size will be three feet long by the roll width.

3.7 ACCEPTANCE

A. CONTRACTOR retains all ownership and responsibility for geotextile until acceptance by OWNER.

B. OWNER accepts geotextile when:

1. The installation is complete.
2. Conformance tests verify product requirements.
3. Documentation of installation is complete, including the CQAC’s final report.
4. Verification of the adequacy of all seams and repairs, including associated testing, is complete.
5. Written certification documents have been received by the OWNER.

END OF SECTION
SECTION 02778
GEOMEMBRANE

PART 1 GENERAL

1.1 SUMMARY

A. Section includes furnishing and installing textured surface HDPE geomembrane for the landfill composite liner.

1.2 REFERENCES

Latest ASTM Standards or other recognized agency standards at the time construction documents are issued for the following items:

A. Tensile Properties of Plastics
B. Brittleness Temperature of Plastics and Elastomers
C. Specific Gravity (Relative Density) and Density of Plastics
D. Initial Tear Resistance of Plastic Film and Sheeting
E. Flow Rates of Thermoplastics
F. Plastics by the Density-Gradient Technique
G. Carbon Black in Olefin Plastics
H. Copper-Induced Oxidative Induction Time of Polyolefins
I. Index Puncture of Geotextiles, Geomembranes, and Related Products
J. Nominal Thickness of Geotextiles and Geomembranes
K. Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction
L. Evaluation of Stress Crack of Polyolefin Geomembranes
M. Microscopic Evaluation of Dispersion of Carbon Black
N. Multi-Axial Tension Test for Geosynthetics
O. Using Notched Constant Tensile Load Test
P. Oxidation Induction Time of Polyolefin Geosynthetics
Q. Integrity of Non-reinforced Geomembrane Seams

References and methods/standard numbers included in these specifications will be modified/updated as necessary to be consistent with standards current at the time construction documents are issued.

1.3 DEFINITIONS

Batch: A quantity of resin, usually the capacity of one rail car, used in the manufacture of high density polyethylene (HDPE) geomembrane sheet. The finished sheet will be identified by a roll number corresponding to the particular lot of resin used.

Bridging: The condition when geomembrane becomes suspended over its subgrade due to contraction of the material or poor installation.

Construction Quality Assurance Consultant (CQAC): The party, independent from Manufacturer or Installer, that is responsible for observing and documenting activities related to the quality assurance of production and installation of the geosynthetic components of the lining system.

Construction Quality Assurance (CQA) Laboratory: The party, independent from the OWNER, Manufacturer, Fabricator, and Installer, responsible for conducting tests on samples of geosynthetics obtained at the site.

Construction Quality Assurance (CQA) Monitor: The site representative of the CQAC. Also referred to as the CQA Engineer or CQA Officer.

Extrudate: The molten polymer, which is emitted from an extruder during seaming using either extrusion fillet or extrusion flat methods. The polymer is initially in the form of a ribbon rod, bead or pellets.

Fabricator: The party responsible for the fabrication of geomembrane panels constructed from rolls received from the manufacturer.

Geomembrane Manufacturer: The party responsible for the production of the geomembrane rolls from resin and for the quality of the resin.

Geomembrane: An essentially impermeable membrane used as a solid or liquid barrier. Synonymous term for flexible membrane liner (FML).

Geomembrane Subsurface: The soil or geosynthetic surface on which the geomembrane lies.

Installer: The party responsible for field handling, transporting, storing, deploying, seaming, temporary restraining (against wind), and installation of the geomembrane.
Panel: The unit area of geomembrane that will be seamed in the field. If the geomembrane is not fabricated into panels in a factory, a panel is identified as a roll or portion of a roll without any seams.

1.4 SUBMITTALS (MANUFACTURER AND INSTALLER)

A. Submit the following to the OWNER, 7 days prior to receiving material at site.

B. Resin Data (Manufacturer)
   1. Statement of production date or dates.
   2. Certification stating that the resin meets the product requirements (see Article 2.2 of this Section).
   3. Certification stating that all resin is from the same manufacturer.
   4. Copy of quality control certificates issued by manufacturer.
   5. Test reports from manufacturer.

C. Geomembrane Roll (Manufacturer)
   1. Statement of production date or dates.
   2. Laboratory test results and certification stating that the geomembrane meets the product requirements (see Article 2.3 of this Section).
   3. Certification stating that all geomembrane rolls are furnished by one supplier, and that all rolls are manufactured from one resin type obtained from one resin supplier.
   4. Copy of quality control certificates issued by manufacturer.
   5. Test reports from the manufacturer.
   6. Typical test results of complete notched constant tensile load test (ASTM D 5397) for specified resin and sheet thickness.
   7. Statement certifying that no reclaimed polymer is added to the resin.
   8. Statement listing percentages of processing aids, antioxidants, and other additives other than carbon black added to or in the resin.
   9. Geomembrane delivery, storage, and handling instructions.

11. Sample warranties for review.

D. Extrudate Beads and/or Rod (Manufacturer)

1. Statement of production date or dates.

2. Laboratory certification stating that the extrudate meets the product requirements (see Article 2.4 of this Section).

3. Certification stating that all extrudate is manufactured by one manufacturer and resin is supplied from one supplier.

4. Copy of quality control certificates issued by manufacturer.

5. Test reports from the manufacturer.

6. Certification stating that the extrudate bead or rod resin is the same type, from the same manufacturer and compatible with the resin used to manufacture the geomembrane supplied for this project.

E. Schedules and Drawings (Installer)

1. Submit installation schedule one week prior to installation. Include hours worked per day, week and per shift. Indicate all weather delays built into schedule.

2. Installation layout drawings: Two weeks prior to installation of geomembrane, submit drawings showing the panel layout indicating both fabricated (if applicable) and field seams, and details not conforming to the Contract Drawings. Upon acceptance, use these drawings for installation of geomembrane.

F. Qualifications (Installer)

1. Submit, two weeks prior to installation, name of installer, and resume of installation supervisor/field engineer to be assigned to the project.

2. Submit, two weeks prior to installation, resume of master seamer.

G. Equipment and Personnel: Submit the following two weeks prior to installation: (Installer)

1. Equipment List Stating Quantity and Types.
2. List of personnel to perform field-seaming operations.

1.5 SUBMITTALS DURING CONSTRUCTION (INSTALLER)

A. Submit quality control documentation prepared during installation.

B. Submit daily prior to the start of installation, subgrade acceptance certificate signed by the installation supervisor for each area to be covered by the geomembrane.

1.6 SUBMIT UPON COMPLETION OF THE INSTALLATION (INSTALLER)

A. Certificate stating the liner has been installed in accordance with the plans and specifications.

B. The warranty obtained from the manufacturer/fabricator and the installation warranty.

C. As-built drawings showing location of panels, seams, repairs, patches, and destructive samples, including measurements.

D. Copies of seam test results and statistical analysis of each welder’s performance.

1.7 QUALIFICATIONS

A. Installer: Must have successfully installed a minimum of 10,000,000 square feet of welded polyethylene geomembrane with documented references.

B. Master Welder Qualifications: Must have completed a minimum of 5,000,000 square feet of polyethylene geomembrane seaming work using the same type of seaming apparatus proposed for use on this project.

C. Other Seamers Qualifications: Must have seamed a minimum of 1,000,000 square feet of HDPE geomembrane.

1.8 QUALITY ASSURANCE

A. All work shall be constructed, monitored, and tested in accordance with the requirements of the CQA Plan.

B. The OWNER will engage and pay for the services of (1) Construction Quality Assurance Consultant (CQAC), and (2) Construction Quality Assurance (CQA) Laboratory for monitoring the quality and installation of geomembrane material being installed unless otherwise specified.
C. The Geosynthetics Installer shall be aware of all activities outlined in the CQA Plan, and the CONTRACTOR shall account for these activities in the construction schedule.

D. The Geosynthetics Installer shall assure that the geomembrane is delivered to the site at least 14 calendar days prior to installation to allow sufficient time for conformance testing.

E. Upon delivery of the geomembrane to the site, samples of geomembrane will be removed by the CQA Monitor for laboratory testing to ensure conformance with this Specification. Conformance sampling and testing will be performed in accordance with the CQA Plan.

F. Any geomembrane rolls that do not meet the requirements of this Specification will be rejected. The Geosynthetics Installation CONTRACTOR shall replace the rejected material with new material that conforms to the Specification requirements, at no additional cost to the OWNER.

G. Personnel Qualifications
   1. Ensure that all personnel performing geomembrane seaming operations are qualified by experience or by successfully passing seaming tests (see Article 3.4B of this Section).
   2. Personnel qualifications in accordance with Article 1.4 of this Section.

H. Field Samples
   1. Geomembrane sampling shall be conducted in accordance with those specifications and the CQA Plan for the following:
      a) Conformance Testing (Article 3.1 A of this Section)
      b) Destructive Seam Testing (Article 3.4 D of this Section)

I. In order to prevent wind-damaged geomembranes from being placed, the following Quality Assurance procedures shall be followed:
   1. The Geosynthetics Installation CONTRACTOR shall perform his work to prevent wind damage to the geomembrane.
   2. Wind damage shall be determined by the CQA Monitor during deployment of the geomembrane. Wind damage to the geomembrane will include wrinkles, creases, and tears, as determined by the CQA ENGINEER.
3. Repair of the wind-damaged geomembrane shall be completed by the Geosynthetics Installation CONTRACTOR at no additional cost to the OWNER.

4. As determined by the CQA Monitor, the geomembrane panel may be rejected at no cost to the OWNER.

1.9 DELIVERY, STORAGE, AND HANDLING

A. Packing and Shipping

1. Labels on each roll delivered to site shall identify the following.
   a) Manufacturer’s name
   b) Product Identification
   c) Thickness
   d) Roll number
   e) Batch or lot number
   f) Panel number (when applicable)
   g) Roll dimensions

2. Ensure that geomembrane rolls are properly loaded and secured to prevent damage during transit.

3. Protect geomembrane from excessive heat, cold, puncture, cutting, or other damaging or deleterious conditions.

4. Ensure personnel responsible for loading, transport, and unloading of geomembrane are fully aware of the consequences of damage to geomembrane, and are familiar with handling and transport constraints imposed by manufacturer.

B. Delivery

1. Deliver materials to the site only after the OWNER accepts required submittals.

2. Separate damaged rolls from undamaged rolls and store in locations designated by the OWNER until proper disposition of material is determined by OWNER.

3. OWNER will determine the extent of damage to geomembrane.
4. Delivery in rolls, do not fold.

C. Acceptance at Site

1. Perform inventory and surface inspection for defects and damage of all geomembrane rolls upon delivery.

2. Unroll and inspect any geomembrane roll that shows signs of internal damage.

3. Damage resulting from handling and transport of geomembranes shall be repaired at no cost to OWNER. If irreparable, in the opinion of the CQA ENGINEER, damaged materials shall be replaced at no cost to OWNER.

D. Storage and Protection

1. OWNER will provide on-site storage area for geomembrane rolls from time of delivery until installation.

2. The storage of the materials is the responsibility of the Geosynthetic Installer from the time the materials are off-loaded until the time the completed installation is accepted by the OWNER.

3. After Geosynthetic Installer has removed material from storage area, protect geomembrane from puncture, dirt, grease, water, moisture, mud, mechanical, abrasion, excessive heat and other sources of damage.

4. Preserve integrity and readability of geomembrane roll labels.

5. Store geomembrane rolls on prepared surface (not on wooden pallets).

6. Stack no more than three rolls high.

1.10 SITE CONDITIONS

A. Geomembrane Deployment

1. Do not proceed with deployment at an ambient temperature below 40 degrees F or above 110 degrees F unless otherwise authorized, in writing, by OWNER. If surface temperatures exceed 140 degrees F, regardless of ambient temperature, deployment shall continue only if CQA Monitor allows after testing trial welds.

2. Do not deploy during precipitation, in the presence of excessive moisture (e.g., fog, dew), in an area of ponded water, or in the presence of excessive winds.
3. Do not undertake deployment if weather conditions will preclude material seaming on same day as deployment.

B. Seaming

1. Normal seaming procedures may take place if the following weather conditions exist:
   a) Ambient temperature, measured 6 inches above the liner surface, shall be between 40 degrees F and 105 degrees F. Do not seam if ambient temperature is below or above 40 degrees F and 105 degrees F, respectively, unless approved by the CQA Monitor.
   b) Dry conditions (i.e., no precipitation or other excessive moisture, such as fog or dew).
   c) No excessive winds.

PART 2: PRODUCTS

2.1 MATERIALS

A. Geomembrane Liner

1. Geomembrane shall be 60-mil high-density polyethylene (HDPE), textured as indicated on the Drawings.

2. Only geomembranes and resins that meet these specifications.

3. Geomembrane shall be manufactured from new polyethylene resin.

4. Geomembrane manufactured from non-complying resin shall be rejected.

5. Resin shall be designed and manufactured specifically for use in geomembranes.

6. The geomembrane shall have the following characteristics:
   a) Contain a maximum of 2 percent by weight of additives, fillers, or extenders (not including carbon black).
   b) Contain between 2 percent and 3 percent carbon black for ultra-violet light resistance. This shall be added to the otherwise pure polyethylene resin as part of resin manufacturing or roll manufacturing processes.
c) No thin spots, striations, pinholes, or bubbles on surface. Free of blisters, undispersed raw materials, or other signs of contamination by foreign matter.

d) The geomembrane is to be roughened or textured during the manufacturing process.

2.2 SEAMING AND TESTING EQUIPMENT

A. Welding

1. Maintain on-site a minimum of two spare operable seaming apparatus, unless otherwise agreed upon at pre-construction meeting.

2. Seaming equipment shall not damage geomembrane.

3. No solvent or adhesive is used unless the product is approved in writing by the OWNER prior to use.

4. Use extrusion welding apparatus equipped with gauges giving temperature of extrudate at nozzle of apparatus.

5. Use fusion welding apparatus which are self-propelled devices equipped with the following:
   a) A gauge indicating temperature of heating element.
   b) A method of monitoring relative pressure applied to geomembrane.

6. Use power source capable of providing constant voltage under combined line load.

7. Provide protective lining and splash pad large enough to catch spilled fuel under electric generator, if located on liner.

8. Provide tensiometers capable of measuring seam strength, calibrated and accurate within 2 pounds.

9. Provide dies for cutting seam samples.

B. Vacuum Testing

The equipment shall consist of the following:
1. Vacuum box assembly consisting of: rigid housing, transparent viewing window, soft neoprene gasket attached to bottom of housing, port hole or valve assembly, and vacuum gauge.

2. Pump assembly equipped with pressure controller and pipe connections.

3. Rubber pressure/vacuum hose with fittings and connections.


5. Wide paint brush, or other means of applying soap solution.

C. Air Pressure Testing (for double fusion seam only)

The equipment shall consist of the following:

1. Air pump (manual or motor driven), equipped with a pressure gauge, capable of generating, sustaining, and measuring pressure between 24 and 35 psi and mounted on a cushion to protect geomembrane.

2. Rubber hose with fittings and connections.

3. Sharp hollow needle, or other approved pressure feed device.

4. An air pressure-monitoring device.

2.3 SOURCE QUALITY CONTROL TESTING

All of the specified tests are the CONTRACTOR’S responsibility. Testing during manufacturing shall be accomplished by the manufacturer’s laboratory.

A. Tests and Inspection

1. Geomembranes shall be tested by geomembrane manufacturer for quality control to demonstrate that resin meets specifications in Table 02778-1.

2. Geomembrane manufacturer shall continuously monitor during manufacturing process for inclusions, bubbles, or other defects. Geomembranes which exhibit defects shall not be acceptable for installation.

3. Geomembrane manufacturer shall monitor thickness continuously during manufacturing process. No geomembrane which fails to meet specified values shall be acceptable for installation.

4. At a minimum, the following tests shall be performed in accordance with test methods specified in Table 02778-2:
a) Density
b) Carbon black content
c) Carbon black dispersion
d) Thickness
e) Tensile properties

Geomembrane manufacturer shall perform these tests on geomembrane, at a minimum of once every 50,000 ft². Samples not satisfying specifications shall result in rejection of the rolls represented by the tests. At the geomembrane manufacturer’s discretion and expense, additional testing of individual rolls may be performed to more closely identify the non-complying rolls and to qualify individual rolls.

5. The Environmental stress crack resistance test need not be run at 1 per 50,000 ft² frequency. Geomembrane manufacturer shall certify that these tests have been performed for each resin in accordance with test methods specified in Table 02774-2.

Table 02778-1
Properties for High Density Polyethylene Resin

<table>
<thead>
<tr>
<th>Test</th>
<th>Test Method</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity (Density)</td>
<td>ASTM D-1501</td>
<td>&gt;0.93</td>
</tr>
<tr>
<td>Melt Index</td>
<td>ASTM D-1238</td>
<td>&lt;1.0 g/10 min</td>
</tr>
</tbody>
</table>
### Table 02778-2
**Properties for High Density Polyethylene Liner (60 mil)**

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness, Mil (min.)</td>
<td>ASTM D5994</td>
<td>60 mils (See Note 1)</td>
</tr>
<tr>
<td>Asperity Height (mil)</td>
<td>GRI-GM-12(a)</td>
<td>See note 2</td>
</tr>
<tr>
<td>Sheet Density, g/cm (min.)</td>
<td>ASTM D1505</td>
<td>0.940-0.950</td>
</tr>
<tr>
<td>Carbon Black Content (%)</td>
<td>ASTM D1603</td>
<td>2.0-3.0</td>
</tr>
<tr>
<td>Carbon Black Dispersion</td>
<td>ASTM D5596</td>
<td>See note 3</td>
</tr>
<tr>
<td><strong>Min. Tensile Properties</strong>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength at Yield (lb/in)</td>
<td>ASTM D638 (Type IV @ 2 i/m)</td>
<td>126</td>
</tr>
<tr>
<td>Elongation at Yield (%)</td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>Strength at Break (lb/in)</td>
<td></td>
<td>228</td>
</tr>
<tr>
<td>Elongation at Break (%)</td>
<td></td>
<td>700</td>
</tr>
<tr>
<td>Tear Resistance, lbs</td>
<td>ASTM D1004</td>
<td>42</td>
</tr>
<tr>
<td>Notched Constant Tensile Load Test5</td>
<td>ASTM D5397</td>
<td>&gt; 200 hrs @ 30% of yield stress</td>
</tr>
<tr>
<td>Puncture Resistance (min. lbs.)</td>
<td>ASTM D4833</td>
<td>90</td>
</tr>
<tr>
<td><strong>Min. Seam Strengths</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shear, ppi</td>
<td>ASTM D6392</td>
<td>120</td>
</tr>
<tr>
<td>Peel, ppi</td>
<td></td>
<td>88 for wedge seams</td>
</tr>
<tr>
<td></td>
<td></td>
<td>78 for extrusion seams</td>
</tr>
</tbody>
</table>

1. Tolerance for thickness shall be specified for each cell constructed based on manufacturing process used for selected geomembrane and current industry standards.
2. Or as required to meet interface shear requirements from Section 02779, Table 02779-1 (whichever is greater).
3. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
4. Reduced strength tensile properties may be specified for textured geomembranes based on manufacturing process used for selected geomembrane and current industry standards.
5. The single point NCTL test is not appropriate for testing geomembranes with irregular rough surfaces. The test should be conducted on smooth edge of textured rolls or on smooth sheets made from the same formulation as the textured material being evaluated.
2.4 EXTRUDATE ROD OR BEAD

A. Meeting the geomembrane manufacturer requirements.

B. Made from same resin as the geomembrane.

C. Throughly disperse additives throughout rod or bead.

D. Containing 2 to 3 percent carbon black.

E. Free of contamination by moisture or foreign matter.

2.5 MANUFACTURER SOURCE QUALITY CONTROL

A. Perform the following quality control tests at the manufacturing plant on geomembrane products.

<table>
<thead>
<tr>
<th>Test</th>
<th>Test Designation</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet Thickness</td>
<td>ASTM D5994</td>
<td>25 per roll</td>
</tr>
<tr>
<td>Sheet Density</td>
<td>ASTM D792, Method A, or ASTM D1505</td>
<td>(a)</td>
</tr>
<tr>
<td>Oxidation Induction Time of Polyolefins</td>
<td>ASTM D3895 or D5885</td>
<td>(e)</td>
</tr>
<tr>
<td>Tensile Strength Yield</td>
<td>ASTM D638</td>
<td>(c)</td>
</tr>
<tr>
<td>Elongation at Yield</td>
<td>ASTM D638</td>
<td>(c)</td>
</tr>
<tr>
<td>Elongation at Break</td>
<td>ASTM D638</td>
<td>(c)</td>
</tr>
<tr>
<td>Strain at Break</td>
<td>ASTM D5617</td>
<td>(b)</td>
</tr>
<tr>
<td>Tear Resistance</td>
<td>ASTM D1004, Die C</td>
<td>(c)</td>
</tr>
<tr>
<td>Puncture Resistance</td>
<td>ASTM D4833</td>
<td>(c)</td>
</tr>
<tr>
<td>Notched Constant Tensile Load Test (single point)</td>
<td>ASTM D5397</td>
<td>(f)</td>
</tr>
<tr>
<td>Low Temperature Britleness</td>
<td>ASTM D746</td>
<td>(d)</td>
</tr>
<tr>
<td>Carbon Black Content</td>
<td>ASTM D1603</td>
<td>(g)</td>
</tr>
<tr>
<td>Carbon Black Dispersion</td>
<td>ASTM D5596</td>
<td>(h)</td>
</tr>
</tbody>
</table>

(a) One per 100,000 square feet of sheet produced or one per resin batch, whichever results in the greatest number of tests.
(b) One test per formulations.
(c) One per 50,000 square feet or one per resin batch, whichever results in the greater number of tests.
(d) Certification only required.
(e) One test per resin lots (~ 180,000 lbs of natural resin)
(f) Two samples per each resin lot at 30 percent of yield stress. Minimum time to failure of 200 hours. Provide certification that material from the same formulation has been tested and exceeds 400 hours under the same conditions.
(g) One test per every 20,000 lbs.
(h) One test per every 45,000 lbs.
PART 3   EXECUTION

3.1   EXAMINATION

A.   Conformance Testing

1. The CQA ENGINEER shall collect samples of geomembrane for conformance testing, as outlined in the CQA Plan and as described herein.

2. The following tests shall be performed by the CQA Consultant using the test methods listed in Table 02778-2 at the frequency specified in the CQA Plan:

   a) Thickness (minimum)
   b) Density
   c) Tensile properties (all)
   d) Carbon black content

3. Geomembrane shall be rejected if conformance test results do not meet or exceed the values presented in Table 02778-2.

3.2   PREPARATION

A.   Surface Preparation

1. The Earthwork CONTRACTOR shall be responsible for preparing the supporting subgrade for placement of the geosynthetics. The OWNER shall coordinate the Work of the earthwork CONTRACTOR and the Geosynthetic Installation CONTRACTOR so that the requirements of the specifications and the project CQA Plan are met.

2. Before the geomembrane installation begins, the CQA ENGINEER shall verify that:

   a) A qualified land surveyor has verified all lines and grades.
   b) A qualified engineer has verified that the supporting subgrade meets all requirements in the project specifications.
   c) The surface to be lined has been rolled, compacted, or handworked so as to be free of irregularities, protrusions, loose soil, and abrupt changes in grade.
   d) Round edges of Anchor Trenches or cushion with geotextiles.
   e) The surface to be lined does not contain stones which may be damaging to the geosynthetics.
f) There is no area excessively softened by high water content.

g) The Geosynthetic Installer, on a daily basis, shall certify in writing that the surface on which the geosynthetics will be installed is acceptable. A certificate of acceptance shall be given to the Geosynthetic Installer and to the CQA ENGINEER prior to commencement of liner deployment in the area under consideration. The OWNER shall be given a copy of this certificate by the CQA ENGINEER.

h) After the supporting subgrade has been accepted by the Geosynthetic Installer, it is the Geosynthetic Installer’s responsibility to indicate to the OWNER any change in the support subgrade condition that may require repair Work. The surface to be lined must exhibit adequate strength, as required by the OWNER, prior to liner deployment. Any damage to the subgrade caused by installation activities shall be repaired at the Geosynthetic Installer’s expense. The OWNER may consult the CQA ENGINEER regarding the need for repairs. If the CQA ENGINEER concurs with the Geosynthetic Installer, the OWNER shall ensure that the supporting subgrade is repaired.

i) At any time before or during the liner installation, the CQA ENGINEER shall indicate to the OWNER any locations, which may not be adequately prepared for the liner.

3.3 INSTALLATION

A. Panel Layout

Any anticipated modification to the geomembrane panel layout, particularly at penetrations, sumps, or other critical locations should be presented to the OWNER in writing or by drawing by the Geosynthetic Installer a minimum of three (3) working days in advance of the Work requiring the modification.

B. Panel Nomenclature

1. A field panel is defined as a unit of geomembrane that is to be seamed in the field (i.e., a field panel is a roll or a portion of roll cut in the field).

2. Identify each field panel with an identification code (number or letter-number) consistent with Geosynthetics Installer’s layout plan. This identification code shall be agreed upon by the OWNER, Geosynthetic Installer, and CQA ENGINEER.

3. The Geosynthetics Installer shall be responsible for labeling each panel as it is installed in bold print which is easily visible. The labels shall include, as a minimum: identification code, which indicates the sequence of deployment, the roll number from which the panel was obtained and the date the panel was
placed. The OWNER may refuse to accept any panel, portion of panel, or roll which is not correctly labeled.

C. Protection

1. Do not use equipment or tools that damage geomembrane or GCL by handling, trafficking, excessive tear, leakage of hydrocarbons, or other means.

2. Ensure prepared surface underlying geomembrane and GCL has not deteriorated since previous acceptance, and remains acceptable immediately prior to geomembrane and GCL deployment.

3. Keep geosynthetic elements immediately underlying the geomembrane clean and free of debris.

4. Do not permit personnel to smoke or wear damaging shoes while working on geomembrane.

5. Unroll panels in a manner which does not cause excessive scratches or crimps in geomembrane and does not damage the underlying GCL or subgrade.

6. Place panels in a manner which minimizes wrinkles (especially differential wrinkles between adjacent panels.).

7. Prevent wind uplift by providing adequate temporary loading and/or anchoring (e.g., sandbags, tires) that will not damage geomembrane. In case of high winds, continuous loading along panel edges is recommended. It is the responsibility of the Geosynthetic Installer to prevent wind damage to liner components.

8. Minimize direct contact with geomembrane.

9. Protect geomembrane in areas where excessive traffic is expected with geotextiles, extra geomembrane, or other suitable materials, as approved by the CQA ENGINEER.

10. Install material to account for shrinkage and contraction while avoiding wrinkles. Install material stress-free with no bridging before it is covered. Add material as needed to avoid bridging.

D. Field Panel Deployment

1. Install field panels at locations indicated on the Geosynthetics Installer’s layout plan, as approved by OWNER.
2. Replace damaged (torn, twisted, or crimped) field panels, or portions thereof, at no cost to OWNER. Repair lesser damage according to Article 3.03 I of this Section. CQA ENGINEER shall determine if material is to be repaired or replaced.

3. Remove damaged panels or portions of damaged panels which have been rejected from Work area.

4. Do not deploy more geomembrane field panels in one day than can be seamed during that day.

E. Seam Layout

1. When possible, orient seams parallel to line of maximum slope (i.e., oriented along, not across or at an angle to the slope).

2. No horizontal seam shall be on a slope or less than 5 feet (1.5m) from the toe of a slope, without prior acceptance by the CQA ENGINEER.

3. Do not locate seams in areas of potential stress concentrations, unless otherwise authorized by OWNER.

4. In general, maximize lengths of field panels and minimize number of field seams.

5. Use seam numbering system compatible with panel numbering system.

F. Temporary Bonding

1. Hot air device ("Lister") may be used to temporarily bond geomembrane panels that are to be extrusion welded.

2. Do not damage geomembrane when temporarily bonding adjacent panels. Apply minimal amount of heat to lightly tack geomembrane panels together. Control temperature of hot air at nozzle of any temporary welding apparatus to prevent damage to geomembrane.

3. Do not use solvent or adhesive unless product is approved for use, in writing, by the OWNER.

G. Seaming Methods

Approved processes for field seaming are extrusion welding and dual-track fusion welding. Proposed alternate processes shall be documented and submitted to OWNER for approval.
1. Align geomembrane panels to have a nominal overlap of 3 inches for extrusion welding and 4 inches for fusion welding. The Geosynthetics Installation CONTRACTOR shall indicate the lap by making reference marks prior to seaming at an interval of not more than fifty (50) feet. The location and type of reference mark shall be agreed upon by all parties at the pre-construction meeting.

2. After seaming operations have occurred, the remaining overlap(s) shall be enough to destructively test. If insufficient overlap for destructive testing is determined to exist on a portion of a seam, that portion of the seam shall be reconstructed by the procedures described in Article 3.03 I.

3. Use double-fusion welding as primary method of seaming adjacent field panels.
   
   a) For cross seam tees associated with fusion welding, extrusion weld to a minimum distance of 4 inches on each side of tee. The edge of the cross seam is ground to an incline prior to welding.

   b) Place electric generator on a smooth base such that no damage occurs to geomembrane.

   c) Place a protective layer (e.g., insulating plate or fabric) beneath hot welding apparatus after usage.

   d) When subgrade conditions dictate, use a movable protective layer directly below each overlap of geomembrane that is to be seamed to prevent buildup of moisture between sheets and prevent debris from collecting around pressure rollers.

4. Use conventional extrusion welding as a secondary method for seaming between adjacent panels and as a primary method of welding for detail and repair Work.

   a) Purge heat-degraded extrudate from barrel of extruder under the following conditions:

      1) Prior to beginning a seam.

      2) Whenever extruder has been inactive.

   b) Place electric generator on a smooth base such that no damage occurs to geomembrane.

   c) Place a smooth insulating plate or fabric beneath hot welding apparatus after usage.
d) Use clean and dry welding rods or extrudate pellets.

e) Complete grinding process without damaging geomembrane according to manufacturer’s instructions within 1 hour of seaming operation.

f) Minimize exposed grinding marks adjacent to an extrusion weld. Do not extend exposed grinding marks more than 1/4 inch from seam area. The OWNER may request that all abraded areas be covered with extrudate.

g) Extrusion weld all cross seam tees to a minimize distance of 4 inches on each side of the tee.

H. Seaming Procedures

1. General Seaming Procedures; Ensure That:

   a) Spare operable seaming equipment is on-site at all times.

   b) Equipment used for seaming will not damage the geomembrane.

   c) The electric generator is placed on a smooth base such that no damage occurs to the geomembrane.

   d) A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage.

   e) The geomembrane is protected from damage in heavily trafficked areas, using a method approved by the CQA ENGINEER.

   f) No solvent or adhesive is used unless the product is approved in writing by the OWNER prior to use.

   g) Areas to be seamed shall be cleaned and free of moisture, debris, or any marking on the geomembrane.

   h) Use a flat board, a conveyor belt, or similar hard surface directly under the seam overlap to achieve proper support, if required.

   i) Cut fishmouths or wrinkles at the seam overlap along the ridge of the wrinkle in order to achieve a flat overlap. The cut fishmouths or wrinkles shall be seamed and any portion where the overlap is inadequate shall then be patched with an oval or round patch of the same geomembrane extending a minimum of six (6) inches beyond the cut in all directions.
j) Provide adequate illumination if seaming operations are carried out at night.

k) Extend seaming to the outside edge of panels placed in the anchor trench.

l) No field seaming shall be performed without the Seaming Supervisor being present.

m) The welding process (Restart/Reseaming procedures) shall start with grinding the existing seam and rewelding a new seam. Welding shall commence where the grinding started and must overlap the previous seam by at least two (2) inches. Reseaming over an existing seam without regrinding shall not be permitted.

I. Repair Procedures

All seams and non-seam areas of the geomembrane shall be inspected by the CQA Officer for defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane shall be clean at the time of inspection. The geomembrane surface shall be brushed, blown, or washed by the Installer if the amount of dust or mud inhibits inspection. The CQA Officer shall decide if cleaning of the geomembrane is needed to facilitate inspection.

1. Repair portions of geomembrane exhibiting a flaw, or failing a destructive or nondestructive test.

2. Final decision as to appropriate repair procedure shall be agreed upon between OWNER, Geosynthetics Installation CONTRACTOR, and CQA ENGINEER.

3. Available repair procedures include the following:

   a) Patching: A piece of geomembrane extrusion welded into place. Use to repair large holes, tears, undispersed raw materials, and contamination by foreign matter.

   b) Spot welding or seaming: A bead of molten extrudate placed on flaw. Use to repair small tears, pinholes, or other minor, localized flaws.

   c) Capping: A strip of geomembrane extrusion welded into place over an inadequate seam. Use to repair large lengths of failed seams.

   d) Extrusion welding the flap: A bead of molten extrudate placed on exposed flap of fusion weld. Use to repair areas of inadequate fusion seams which have an exposed edge. Repairs of this type shall be reviewed by CQA ENGINEER and shall not exceed 50 feet in length.
e) Removal and replacement: Remove defective seams and replace with a strip of new material welded into place. Use to repair large lengths of failed seams.

f) Acceptable wrinkle size and extent shall be determined and agreed upon by all parties during the pre-construction meeting. Wrinkles larger than that specified shall be cut and seamed, if the overlap is sufficient, or cut and patched or capped.

4. For any repair method, satisfy the following:

a) Surfaces of the geomembrane that are to be repaired using extrusion methods shall be abraded no more than one (1) hour prior to the repair. No more than 10 percent of the thickness shall be removed.

b) Ensure surfaces are clean and dry at time of repair.

c) Ensure seaming equipment used in repairing procedures meets requirements of this section.

d) Extend patches or caps at least 6 inches beyond edge of defect. Round corners of patches with a radius of approximately 3 inches.

5. Do not place overlying layers over locations which have been repaired until appropriately passing nondestructive and laboratory test results are obtained.

J. Anchor Trench

1. Earthwork CONTRACTOR shall excavate anchor trenches, unless otherwise specified, to lines and grades shown on design Drawings, prior to geomembrane placement.

2. Provide slightly rounded corners in anchor trench to avoid sharp bends in geomembrane.

3. If anchor trench is excavated in clay material susceptible to desiccation, the amount of trench open at any time shall be minimized, subject to the approval of the CQA ENGINEER.

4. Earthwork CONTRACTOR shall backfill and compact anchor trench as described in Section 02222. Care shall be taken when backfilling trenches to prevent any damage to geosynthetics.
5. Earthwork CONTRACTOR will ensure that the anchor trench will be adequately drained to prevent ponding or softening of adjacent soils while trench is open.

3.4 FIELD QUALITY CONTROL

A. Visual Inspection

1. CQA ENGINEER shall examine seam and non-seam areas of geomembrane for identification of defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter.

2. Clean and wash geomembrane surface if CQA ENGINEER determines that the amount of dust or mud inhibits examination.

3. Do not seam any geomembrane panels that have not been examined for flaws by CQA ENGINEER.

4. Nondestructively test each suspect location of seam and non-seam areas using methods described in Article 3.4C of this Section, as appropriate.

B. Trial Seams

1. Make trial seams on fragment pieces of geomembrane liner to verify that conditions are adequate for production seaming.

2. Make trial seams at beginning of each seaming period, at the CQA ENGINEER’s direction and at least once each four (4) hours, for each production seaming apparatus used that day. Each seamer shall make at least one trial seam each day. The CQA ENGINEER, may at his sole discretion, require addition trial seams if surface temperatures exceed 140 degrees Fahrenheit.

3. Make trial seams under same conditions as actual seams.

4. Make trial seams only under observation by CQA ENGINEER.

5. Overlap seam of geomembrane pieces as indicated in Article 3.3 G of the Section.

6. Make trial seam sample at least 5 feet long by 1 foot wide (after seaming) with seam centered lengthwise.

7. Cut two specimens from sample with a 1-inch wide die. These specimen locations shall be selected randomly along the trial seam sample by the CQA ENGINEER. Test specimens in peel using a field tensiometer. The
tensiometer shall be capable of maintaining a constant jaw separation rate of 2 inches per minute. These tests shall not fail according to criteria in Table 02778-2.

8. If a specimen fails, repeat the entire operation. If the additional specimen fails, do not use seaming apparatus and seamer until the deficiencies are corrected and two consecutive successful trial seams are achieved.

9. Cut remainder of successful trial seam into three pieces; one to be retained in OWNER’s archives, one to be retained by Geosynthetics Installation CONTRACTOR, and one to be retained by CQA ENGINEER for possible laboratory testing. Alternatively, if required by OWNER, remaining portion of trial seam sample may be subjected to destructive testing as discussed in Article 3.4 D of this Section.

C. Nondestructive Seam Testing

1. General

   The purpose of nondestructive tests is to check the continuity of the seams. It does not provide quantitative information on seam strength. Nondestructively test field seams over their full length using a vacuum test unit, air pressure (for double fusion seams only), or other method approved by the CQA ENGINEER. Perform nondestructive testing as seaming Work progresses, not at the completion of all field seaming.

2. Vacuum Testing

   a) Energize vacuum pump and reduce tank pressure to approximately 5 psi (10 inches of Hg) gauge pressure.

   b) Wet strip of seam area approximately 12 inches by 48 inches with soapy solution.

   c) Place box over wetted area.

   d) Close bleed valve and open vacuum valve.

   e) Ensure that a leak tight seal is created.

   f) For a period of not less than 10 seconds, apply vacuum and examine seam area through viewing window for presence of soap bubbles.

   g) If no bubbles appear within 10 seconds, close vacuum valve and open bleed valve, move box over to next adjoining area with a minimize 3-inch overlap and repeat process.
h) Mark and repair areas where soap bubbles appear in accordance with Article 3.3 I of this Section.

3. Air Pressure Testing (for double fusion seam only)

a) Temporarily seal both ends of seam to be tested using locking pliers or other similar devices.

b) Insert needle or other approved pressure feed device into air channel created by fusion weld.

c) Place a protective layer between air pump and geomembrane.

d) Pressurize air channel to a pressure of approximately 30 psi. Close valve and allow pressure to stabilize for approximately 2 minutes. Ensure after 2-minute stabilization period that the pressure is between 27 and 33 psi.

e) Observe the air pressure 5 minutes after the initial 2-minute stabilization period ends. If pressure loss exceeds 3 psi or the pressure does not stabilize, locate the faulty area and repair in accordance with Article 3.3 I.

f) Once pressure testing is completed, cut end of tested seam area opposite to needle insertion end to verify continuity of the air channel. If air does not escape, locate blockage and retest unpressurized area. Repair cut end of air channel in accordance with Article 3.3 I of this Section.

g) Remove needle or other approved pressure feed device and seal hole in geomembrane with extrusion weld.

4. Inaccessible Seams

a) Install cap strip over any seam that cannot be nondestructively tested. Cap strip material shall be composed of the same type and thickness geomembrane as the geomembrane to be capped.

b) CQA ENGINEER shall observe cap stripping operations for uniformity and completeness.

D. Destructive Seam Testing

1. General

The purpose of destructive seam testing is to evaluate seam strength. Perform destructive seam tests as seaming progresses, not at the completion of all field
2. Frequency

a) A minimum frequency of one test location per 1,000 feet of seam length performed by each welder. This minimum frequency is to be determined as an average taken throughout the entire facility.

b) OWNER reserves the right to increase the frequency of testing in accordance with performance results of samples previously tested.

3. Sampling Procedures

a) Cut samples at locations as directed by CQA ENGINEER. CQA ENGINEER shall number each sample and record sample number and location on the panel layout Drawing.

b) Repair holes in geomembrane resulting from destructive seam sampling immediately in accordance with repair procedures described in Article 3.3 I of this Section.

c) Nondestructively test continuity of new seams in the repaired area according to Article 3.4 C of this Section.

4. Sample Dimensions

Take the following two types of samples at each sampling location:

a) Take two samples for field testing. Cut each of these samples with a 1-inch-wide die, with seam centered parallel to width. The distance between these two samples shall be 42 inches. If both samples pass the field test described in Article 3.4, D-5 of this Section, take a sample for laboratory testing as described in paragraph b below.

b) The sample for laboratory testing shall be located between the samples cut for field testing. Cut sample for laboratory testing 12 inches wide by 42 inches long with seam centered lengthwise. Cut this sample into three parts. CQA ENGINEER shall distribute the parts as follows:

1) One portion to Geosynthetics Installation CONTRACTOR for optional laboratory testing, 12 inches by 12 inches.

2) One portion to Geosynthetic Quality Assurance Laboratory for testing, 12 inches by 18 inches.
3) One portion to OWNER for archive storage, 12 inches by 12 inches.

4) Final determination of sample sizes shall be agreed upon at the pre-construction meeting.

5. Field Testing

a) Test the two 1-inch-wide strips described in Article 3.4, D4a for peel strength. Use a tensiometer as described in paragraph (b) below to conduct these tests. These tests shall exceed the strength criteria in Table 02278-2.

b) Use a tensiometer capable of maintaining a constant jaw separation rate of two inches per minute.

c) Test field samples only under CQA ENGINEER’s observation.

d) If test sample passes in accordance with the Section, the seam qualifies for laboratory testing. If any field test sample fails to pass, the follow procedures outlined in Article 3.4 D-6 of this Section.

e) Final judgment regarding seam acceptability, based on failure criteria in these specifications, rests with CQA ENGINEER.

6. Destructive Test Failure Procedures

Apply following procedures when a sample fails destructive testing, when conducted by CQA Laboratory or by the Geosynthetics CONTRACTOR using a field tensiometer.

a) Geosynthetics CONTRACTOR has the following options:

1) Repair seam between any two passing destructive test locations, or

2) Trace welding path to an intermediate point (10 feet) minimum from point of failed test in each direction) and take a small sample at each location with a 1-inch-wide die for an additional field test. If these additional samples pass the test, take full laboratory samples. If these laboratory samples pass the tests, repair seam between these locations. If either sample fails, repeat process to establish zone in which seam should be repaired.

b) Acceptable repaired seams shall be bound by two locations from which samples passing laboratory destructive tests have been taken. Passing laboratory destructive tests of trial seam samples, taken as indicated in Article 3.4 D-4, may be used as a boundary for the failing seam. In cases
exceeding 150 feet of repaired seam, a sample taken from the zone in which seam has been repaired shall pass destructive testing. Make repairs in accordance with Article 3.3 I.

c) When a sample fails, OWNER may require additional testing of seams that were welded by the same welder and/or welding apparatus during the same time shift.

E. Repair Verification

1. Nondestructively test each repair using methods described in Article 3.4 C, as appropriate. CQA ENGINEER shall number and log each repair.

2. Passing nondestructive test results indicate an adequate repair.

3. Repairs more than 150 feet long require destructive test sampling, in accordance with Article 3.4 D of this Section.

4. Failed destructive or nondestructive tests indicate that the repair shall be redone and retested until a passing test results.

F. Large Wrinkles

Wrinkles are considered to be large when a geomembrane can be folded over onto itself.

1. Cut and reseam all wrinkles identified by CQA ENGINEER. Test repair seams in accordance with Article 3.4 E.

3.5 PROTECTION OF WORK

A. The Geosynthetics Installation CONTRACTOR shall use all means necessary to protect all materials and all partially completed and completed Work of these Specifications.

B. In the event of damage, the Geosynthetics Installation CONTRACTOR shall make all repairs and replacements necessary to the approval of the CQA ENGINEER and at no additional cost to the OWNER.

C. The CQA ENGINEER will issue an approval of the geomembrane liner installation and inspection to the OWNER prior to placement of any material over the geomembrane.
3.6 RECORD DRAWINGS

A. After the completion of installation of geomembrane liner, the installer shall complete an “as-built” record drawing. The plan shall be prepared by the installer and reviewed/approved by the CQA ENGINEER and shall be at a scale of no less than 1 inch = 100 feet. It shall indicate the limits of geomembrane installed, panel layout with panel identification per paragraph 3.3.B.2 of this Section, location of destructive seam testing samples, and location of repairs. Additionally, the limits of geomembrane will be surveyed by OWNER.

END OF SECTION
SECTION 02779
GEOSYNTHETIC CLAY LINER

PART 1: GENERAL

1.1 SUMMARY

A. The Geosynthetics Installation CONTRACTOR shall furnish all labor, materials, tools, equipment supervision, transportation, and installation services necessary for the installation of the geosynthetic clay liners of the cell. The Work shall be carried out in accordance with these Specifications, the CQA Plan, and the Construction Drawings.

1.2 RELATED SECTIONS

A. Section 02221 - Excavating.
B. Section 02222 – Engineered Fill, Drainage Layer, Stockpiling.
C. Section 02778 – HDPE Geomembrane.

1.3 REFERENCES

Latest ASTM Standards or other recognized agency standards at the time construction documents are issued for the following items:

A. Sieve Analysis of Fine and Course Aggregates
B. Particle Size Analysis of Soil
C. Tensile Properties of Plastics
D. Compaction Characteristics of Soil
E. Initial Tear Resistance of Plastic Film or Sheeting
F. Water (Moisture) Content of Soil, Rock, and Soil-aggregate Mixtures
G. Mass Per Unit Area (Weight) of Fabric
H. Sampling of Geosynthetics for Testing
I. Grab Breaking Load and Elongation of Geotextiles
J. Water (Moisture) Content of Soil by the Microwave
K. Specification Conformance of Geosynthetics

L. Identification, Storage, and Handling of Geosynthetic Rolls

M. Hydraulic Conductivity of Saturated Porous Materials

N. Measuring Nominal Thickness of Geotextiles and Geomembranes

O. Mass per Unit Area of Geotextiles

P. Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction

Q. Index Flux through Saturated Geosynthetic Clay Liner

R. Guide for Storage and Handling of Geosynthetic Clay Liners

S. Quality Control of Geosynthetic Clay Liners

T. Fluid Loss of Clay Component of Geosynthetic Clay Liners

U. Mass Per Unit of Geosynthetic Clay Liners

V. Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method

References and methods/standard numbers included in these specifications will be modified/updated as necessary to be consistent with standards current at the time construction documents are issued.

1.4 DEFINITIONS

Bentonite: Clay soil, comprised primarily of sodium montmorillonite, characterized by high-swelling potential and low-hydraulic conductivity.

Construction Quality Assurance (CQA) Consultant: The owner or the monitoring firm responsible for implementation of the CQA plan.

Construction Quality Assurance (CQA) Laboratory: The party, independent from the Owner, Manufacturer, Fabricator, and Installer, responsible for conducting tests on samples of geosynthetics obtained at the site. Also referred to as the Geosynthetics Laboratory.

Construction Quality Assurance (CQA) Officer: The professional representative of the CQA monitoring firm who shall be responsible for implementation of the CQA plan.
Construction Quality Assurance (CQA) Monitor: Site representative of the CQA Monitor responsible for documenting field observations and tests.

Engineer: The individual or firm responsible for the design and preparation of the project Construction Drawings and Specifications.

Geomembrane: An essentially impermeable synthetic membrane used as a solid or liquid barrier. Synonymous term for flexible membrane layer (FML).

Geosynthetic Clay Liner: Relatively thin factory-manufactured liner material consisting of bentonite supported by textile backing or geomembrane held together by needling, stitching, or chemical adhesives.

Installer: The party responsible for field handling, transporting, storing, deploying, and temporary restraining (against wind) of the GCL.

Lot: Group of consecutively numbered rolls from the same manufacturing line.

GCL Manufacturer (Manufacturer): The party responsible for the production and quality of GCL.

Minimum Average Roll Value (MARV): Minimum value of a limited series of tests that represents a value two standard deviations lower than the overall average value. Ninety-five percent of any individual samples will have greater than the MARV for any given property.

Textile Backing (textile or geotextile): Geosynthetic support material consisting of woven slit film, needle-punched nonwoven, or spunlaced polymer fabric, used for supporting bentonite in a GCL.

1.5 SUBMITTALS

A. Product Data (Manufacturer): Submit the following 7 days prior to shipping material to the site.

1. Textile Backing
   a) Certification stating that the textiles meet the product requirements and are needle-free.
   b) Copy of quality control tests performed by textile supplier (if different from GCL manufacturer).
   c) Copy of quality control tests performed by GCL manufacturer.

2. Bentonite
a) Certification stating that the bentonite meets the product requirements (Table 02779-1).

b) Copy of quality control tests performed by bentonite supplier.

c) Copy of quality control tests performed by GCL manufacturer (if different than supplier).

3. GCL

a) Certification stating that the GCL meets the product requirements (Table 02779-1).

b) Copy of quality control tests performed by GCL manufacturer.

c) Permeability testing on typical product by independent laboratory (not necessarily for product delivered to site).

d) Laboratory test data on typical product for:
   1) Swell
   2) Permeability of overlapped GCL
   3) Freeze-thaw behavior of GCL

e) Supply 3-foot by 12-foot sample to CQA organization for testing.

B. Qualifications (Installer)

1. Submit, three (3) weeks prior to installation, name of installer, résumé of installation supervisor/field engineer to be assigned to the project, and list of projects completed by installer that involved GCLs. Installer shall have experience in similar capacity involving GCLs on at least 3 landfill projects and have installed a minimum of 500,000 square feet of GCL.

C. Quality Control Plan and Installation Procedures (Manufacturer)

1. Submit, three weeks prior to installation, copy of manufacturer’s quality control plan including list of quality control tests performed and typical testing frequencies.

2. Submit, three weeks prior to installation, recommended installation procedures, and proposed panel layout.

D. Submit, upon completion of the installation, manufacturer’s 10-year product warranty against manufacturer defects (material not in compliance with this Specification). The warranty shall cover the full material replacement cost not including installation.
1.6 QUALITY ASSURANCE

A. The OWNER will engage and pay for the services of (1) Construction Quality Assurance Monitor, and (2) Construction Quality Assurance (CQA) Laboratory to monitor the quality and installation of the GCL unless otherwise specified.

B. The manufacturer shall not charge any time or material expenses to the OWNER, related to a plant visit by the OWNER/ENGINEER representations, the CQA Monitor, or designated representative to visit the plant during manufacturing.

C. The GCL Installer shall aid the CQA Monitor in product sampling by providing personnel and equipment necessary to move, cut, and protect GCL rolls.

1.7 DELIVERY, STORAGE, AND HANDLING

A. General: Conform to the manufacturer’s requirements unless otherwise specified.

1. Deliver materials to the site only after the CQA Monitor accepts required submittals.

2. Material shall be covered with a waterproof, tightly-fitting, plastic covering resistant to ultraviolet degradation.

3. Ship less than one month prior to scheduled installation.

4. Ship in closed trailer or securely tarped flat bed.

5. Each roll shall be marked with the following information:

   a) Manufacturer’s name
   b) Product identification
   c) Lot and roll numbers
   d) Roll dimensions and weight

B. Storage

1. Store rolls in space allocated by the OWNER. Space should be at high ground level or elevated above ground surface.

2. Stack no more than two (2) rolls high, and provide continuous support under each roll.
3. Protect rolls from precipitation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions.

4. Preserve integrity and readability of roll labels.

C. Handling

1. Use appropriate handling equipment to load, move, or deploy GCL rolls. A 3-inch Schedule 120 steel support pipe, long enough to go through the entire roll core, mounted on a fork lift or lifted with a wide spreader bar, shall be used. If a spreader bar is used, it shall be wide enough to prevent damage to the edges of the rolls from the lifting strap or chain.

2. Handling of rolls shall be done in a competent manner such that damage does not occur to the product or to its protective wrapping. Follow handling procedures outlined in ASTM D-4873.

3. Damage to protective covering due to mishandling or sampling must be repaired immediately. Repairs shall be such that the GCL roll is protected from moisture or other deleterious conditions.

4. Installer is responsible for off-loading, storage, and transporting material from storage area to installation site.

PART 2: PRODUCTS

2.1 GEOSYNTHETIC CLAY LINER (GCL)

A. The GCL shall consist of a layer of bentonite encapsulated between two geotextiles, meeting characteristics as indicated on the Drawings. The bentonite shall be a high quality, natural sodium bentonite composed of a minimum of 80 percent montmorillonite, by dry weight, when tested by X-ray diffraction methods.

B. The GCL shall be internally reinforced through a process such as needle punching through the top and bottom layers of geotextile and the bentonite. The reinforcing fibers shall be a polypropylene thread.

C. Continuous waterproof laplines and matchlines shall be printed directly on the geotextile-type GCL at 6 and 9 inches from the edges of the rolls, respectively.

D. Wrapped around structurally-sound core that can support weight of GCL without excessive bending or buckling. The core shall be accessible to stingers or rods placed full-length within the core.
E. Meet the requirements of Table 02779-1.

2.2 MANUFACTURER SOURCE QUALITY CONTROL

A. Perform the quality control tests at the frequencies meeting, at a minimum, the requirements of Geosynthetic Research Institute (GRI) Test Method GRI-GCL3. Provide a certification letter that states all quality control tests were performed in accordance with this Specification and all properties met or exceeded the requirements listed in Table 02779-1.

B. Supply copies of testing data, results, and certification letter to CQA Monitor.

Table 02779-1
Properties for Geosynthetic Clay Liner

<table>
<thead>
<tr>
<th>Test</th>
<th>Test Designation(^{(1)})</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentonite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture Content</td>
<td>ASTM D-2216</td>
<td>&lt;40% when installed for geotextile-type GCL</td>
</tr>
<tr>
<td>Particle Size</td>
<td>ASTM D-422</td>
<td>&lt;20% passing #200 U.S. sieve</td>
</tr>
<tr>
<td>Swell Index</td>
<td>ASTM D5890</td>
<td>&gt;24 ml/2 g</td>
</tr>
<tr>
<td>Geotextile(^{(2)})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass per Unit Area</td>
<td>ASTM D-5261</td>
<td>&gt;5.0 oz/yd(^2)</td>
</tr>
<tr>
<td>GCL(^{(2)})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass per Unit Area</td>
<td>ASTM D-5993</td>
<td>&gt;0.75 pounds(^{(3)})</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>ASTM D-6768</td>
<td>&gt;23 pounds/in</td>
</tr>
<tr>
<td>Peel Strength</td>
<td>ASTM D-6496</td>
<td>2.1 pounds/in</td>
</tr>
<tr>
<td>Hydraulic Conductivity</td>
<td>ASTM D-5887</td>
<td>&lt;5.0 x 10^-9 cm/sec(^{(4)})</td>
</tr>
</tbody>
</table>
| Residual Shear Strength\(^{(5)}\) | ASTM D-6243 | Confining Stress  Shear Stress
|                       |                             | psf          psf                                       |
|                       |                             | 5,000        1,100                                   |
|                       |                             | 10,000       2,150                                  |
|                       |                             | 15,000       3,200                                  |

Notes:
(1) Alternate tests are allowed only with prior written approval of Engineer.
(2) Required values for geotextile and GCL are MARV.
(3) Weight of GCL minus weight of geotextiles or geomembrane and corrected to 0 percent bentonite moisture content.
(4) Measured under 10 psi confining pressure and 30 psi head pressure.
(5) Determine residual shear strength (at each confining stress level) of the liner system with shear failure possible via the following mechanisms: (1) internal GCL strength, (2) HDPE geomembrane/GCL interface strength, (3) GCL/soil subgrade interface strength and (4) geomembrane/geocomposite interface strength. Failure should occur first within the geomembrane/geocomposite interface. As an alternative, and upon approval by the Engineer, each interface may be tested separately at each confining stress level. The interface with the lowest peak shear strength at each confining stress level shall be deemed to control and the residual strength of the interface shall be compared to the values listed to identify conformance with this Section.

PART 3: EXECUTION

3.1 PREPARATION OF SUBGRADE

A. Subgrade shall be compacted as specified in Section 02223.

B. Subgrade shall be rolled to a smooth and level surface.

C. Surface shall be free of stones greater than 0.5-inch diameter, protrusions or sharp objects that may damage the GCL, and organics or other deleterious material.

D. Fill voids and cracks.

E. Ruts shall be limited to 1-inch maximum depth.

3.2 DEPLOYMENT

A. General

1. Deploy only after subgrade is accepted by CQA Monitor.

2. Place nonwoven side up, or in accordance with Manufacturer’s recommendation.

3. Deploy manually or by use of spreader bar attached to loader or backhoe with support rod through entire roll width.

4. Take care not to entrap objects or moisture beneath GCL.

5. Beginning deployment implies acceptance of subgrade by installer.

3.3 JOINING

A. Overlaps

1. Using the lapline and matchline as guides, overlap a minimum of 6 inches along length and 18 inches along width (butt seams).
2. Overlap a minimum of 12 inches along width and in sump areas.

3. Overlaps or seams are not allowed perpendicular (horizontal seams) to slopes greater than 10 percent. In these areas, GCLs must be placed in one piece along the entire slope.

4. If length of slope is greater than manufactured length, horizontal seams will be allowed at the direction of the OWNER.

**B. Seams**

1. Spread granular bentonite at the rate of 4 ounces per lineal foot of overlap. Bentonite along overlaps is not required if manufacturer can document (through GRI GCL-3 or similar testing) that the permeability at the overlaps is no greater than the permeability of the GCL material. Approval to forego the use of additional bentonite along seams must be received in writing from the design ENGINEER before installation begins.

2. Bentonite shall be same material used in the GCL.

3. Use lime spreader for powder bentonite to reduce wind-blown particles.

4. Do not sew or use mechanical connections (except for repairs).

**3.4 RESTRAINING AND PROTECTING**

A. Restrain GCL against wind using sandbags filled with fine-grained material, or other approved methods. Protect GCL from water intrusion in the event of precipitation.

B. Sandbags must remain until GCL is covered.

C. GCL must be fully covered with geomembrane the day it is installed. If overlying geomembrane is not seamed the same day, the Monitor may request geomembrane edges to be pulled back to inspect GCL at no additional cost to OWNER. Torn, punctured, or hydrated material shall be removed and replaced in accordance with Section 3.5 at no additional cost to OWNER.

D. GCL bentonite material that becomes hydrated to a moisture content greater than 40 percent before being covered by a seamed geomembrane may be rejected. Rejected material shall be removed and replaced at no additional cost to the OWNER.

**3.5 REPAIR PROCEDURES**

A. Remove punctured, torn, or hydrated material, and as instructed by the CQA Monitor.
B. Repair subgrade, if necessary.
C. Cover area with same type of GCL material with same side up.
D. Overlap defective area by a minimum of 12 inches in all directions.
E. Adhesion tape or wood glue may be used to keep patch in place.
F. Apply granular bentonite as with normal overlaps at 4 ounces per linear foot.

3.6 FIELD QUALITY CONTROL AND QUALITY ASSURANCE

A. General

1. Field quality control is the responsibility of the GCL Installer who must document that the installation proceeds in accordance with this specification.

2. Field quality assurance is the responsibility of the CQA Monitor.

B. The GCL Installer and CQA Monitor shall inspect:

1. The underlying surface for entrapped particles that may impact the GCL.

2. The surface of the GCL for needles, punctures, tears, thinning, or other evidence that the material may not meet specification requirements.

3. The GCL for evidence of premature hydration such as wet areas or swelling. Hydrated areas (moisture content >40%) shall be removed and replaced with dry material.

4. Overlaps using the laplines and matchlines as a guide. The Monitor shall periodically measure the distance of the laplines and matchlines from the edge of the GCL.

5. The bentonite seam (if necessary) to check the location of the seams over the overlap and the amount of bentonite being used.

6. The Monitor must approve each section of the GCL before the GCL is covered.

C. The GCL Installer shall aid the CQA Monitor in collecting samples for testing. The collection of samples shall be conducted in accordance with the CQA Plan, this specification, and the manufacturer’s requirements.

1. Any roll that cannot be identified shall be rejected.
2. Samples shall be tested at a minimum frequency as specified in the CQA Plan for mass per unit area, grab strength, and permeability. Only one sample per GCL type is required for interface shear and internal shear testing.

3. A minimum of one sample shall be taken from each lot.

4. Sample shall be a minimum of two (2) feet long and run the entire width of the roll.

5. Mark the roll number and machine direction on each sample.

D. Quality Assurance Laboratory Testing (by CQA Monitor)

1. The following laboratory tests shall be conducted by the CQA Monitor at the frequencies identified in the CQA Plan:
   
   a) Mass per unit area (ASTM D 5993)
   b) GCL Grab strength (ASTM D 4632)
   c) Permeability (ASTM D5887)
   d) Moisture Content (ASTM D 2216)
   e) Internal Shear Strength (ASTM D-6243), see note 2 below.

2. Test specimens shall be hydrated under 200 psf normal load for 24 hours, and subsequently tested for shear strength at normal loads of 5,000, 10,000 and 15,000 pounds per square foot.

3. The test results shall be evaluated according to ASTM D-4759 and must the minimum requirements stated in Table 02779-1.

3.7 ACCEPTANCE

A. CONTRACTOR shall retain ownership and responsibility of GCL until acceptance by the OWNER.

B. OWNER will accept GCL installation when:

1. All required documentation from the manufacturer and installer has been received and accepted.

2. Test reports verifying material properties have been received and accepted.
3. The CQA Monitor has completed final inspection and any noted defects have been repaired.

4. The material is in place and covered with seamed and anchored geomembrane.

END OF SECTION