

12. ASTM D3017 – Standard Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth).
13. ASTM D4318 – Standard Test Methods for Liquid Limit, Plastic Limit and Plasticity Index of Soils
14. ASTM D6913 – Test Method for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis
15. ASTM D6938 – Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

B. Geotechnical Data Report for the proposed PLU CENTRAL 1 Containment Site.

1.6 QUALITY ASSURANCE

- A. The CONTRACTOR will retain an independent testing laboratory approved by ENGINEER for testing during earthwork operations. The CONTRACTOR shall coordinate and schedule all tests as required by the Drawings and Specifications.

PART 2 - PRODUCTS

2.1 ENGINEERED FILL

- A. Engineered Fill is defined as material obtained from excavations associated with the WORK or designated on-site borrow sources, approved by the ENGINEER, that meet the requirements of the SPECIFICATIONS.
- B. Engineered Fill material shall be free of debris, organics, oversized material (clods or rocks greater than 1 inch in diameter), frozen material, ice, snow, deleterious, or other unsuitable materials.
- C. The aggregate for the fill material should conform to the requirements as shown in Table 1 Grade 1. Each source must meet Table 1 requirements for liquid limit, plasticity index, and wet ball mill for Grade 1. Do not use additives such as, but not limited to lime, cement, or fly ash, to modify aggregate to meet requirement of Table 1. As per the geotechnical study, the on-site material meets these requirements and are suitable as Engineered Fill.
- D. The CONTRACTOR will provide laboratory testing results to the OWNER for all fill material used in construction for verification of material compliance as required for the project.
- E. Based on the results of the geotechnical investigation, native soils at the PLU CENTRAL 1 Containment site are suitable for use as “Engineered Fill” as described in this Section.

2.2 ENGINEERED FILL MATERIAL USED IN SUBGRADE PREPARATION

- A. The upper six (6) inches of the pond bottom, interior embankment slopes, and sump shall be regular, smooth, and compacted; and shall be free of sharp changes in elevation, rocks larger than 1.0 inch, clods, organic debris, and standing water, other unsuitable objects, deleterious materials, or soft unsuitable areas. One hundred percent of the prepared subgrade soil material gradation shall pass a U.S. standard #4 sieve.

- B. Engineered Fill material used for the prepared pond bottom shall meet the liner manufacturer's specifications for material suitable for liner placement.

2.3 DRAINAGE AGGREGATE (DRAIN ROCK)

- A. Drainage Aggregate (Drain Rock) is defined as engineered fill material consisting of selected or processed granular material that meets the requirements of the SPECIFICATIONS and is in accordance with this section. Drain Rock shall be obtained from on-site approved stockpiles or outside sources approved by the ENGINEER or OWNER.
- B. The Drain Rock shall be clean washed sand and gravel with the following gradation:

Gradation	
Sieve Size	Percent by Weight
1 ½ inch	100
1 inch	95-100
½ inch	25-60
No. 4	0-10
No. 8	0-5

Particles shall be rounded and free of sharp, angular edges that may damage the liner.

- C. Drain Rock Aggregate shall be free of organic material, frozen material, ice, snow, or excess moisture.
- D. Drain Rock Aggregate material must be hard, durable, and not subject to grain crushing. Individual rock fragments shall be dense, sound, and resistant to abrasion and shall be free from cracks, seams, and other defects that would tend to increase their destruction from water and frost actions. Drain Rock Aggregate shall be less than 5 percent carbonate.
- E. Material shall be poorly-graded within the SPECIFICATION limits with a uniform grading of coarse to fine particles. No gap-graded material, as determined by the ENGINEER, shall be acceptable.
- F. Verify that all necessary pre-construction submittals such as conformance testing of the Drain Rock Aggregate have been performed prior to placement or importing.

PART 3 - EXECUTION

3.1 PREPARATION, EXAMINATION, AND PROTECTION OF EARTHWORK

- A. Provide construction staking and grade control. Establish and set required lines, levels, grade, contours, and datum by construction staking.
- B. Provide for dust control in accordance with site requirements and OWNER'S direction.

- C. Provide for dewatering as necessary for finish excavation and fill placement.
- D. Locate, identify, and protect all utilities and existing structures from damage (including overhead and suspended utilities).
- E. Protect temporary or permanent bench marks, survey stakes, settlement monuments, existing structures, fences and existing WORK from damage or displacement by construction equipment and vehicular traffic.
- F. Coordinate traffic control, operations, and haul routes with the OWNER and LINER CONTRACTOR.
- G. Note that topography shown on DRAWINGS may differ from topography at time of construction.
- H. Protect the exposed surfaces of compacted lifts from drying and cracking due to excessive heat, or softening due to excessive moisture, until overlying fill material is placed and compacted.
- I. Any earthen surface upon which the liner is installed shall be prepared and compacted in accordance with the project SPECIFICATIONS. The surface shall be smooth, firm, and unyielding. The top six-inches of fill beneath the surface shall be free of:
 - 1. Vegetation/Roots/Sticks
 - 2. Construction debris
 - 3. Sharp, angular rocks
 - 4. Rocks larger than 1 inch in diameter
 - 5. Void spaces
 - 6. Abrupt elevation changes
 - 7. Standing water
 - 8. Cracks larger than six millimeters in width
 - 9. Any other foreign matter that could contact the liner
- J. Immediately prior to liner deployment, LINER CONTRACTOR shall arrange for the subgrade to be final-graded by the EARTHWORK CONTRACTOR to fill in all voids or cracks, then smooth-rolled to provide the best practicable surface for the liner. At completion of this activity, no wheel ruts, footprints or other irregularities in the subgrade are permissible. Furthermore, all protrusions extending more than 0.5-inches from the surface shall be removed, crushed, or pushed into the surface with a smooth-drum roller compactor.
- K. On a continuing basis, the OWNER's REPRESENTATIVE shall examine the subgrade for suitability before liner placement.
- L. It shall be the CONTRACTOR'S responsibility to indicate to the OWNER or ENGINEER any change in the condition of the subgrade that could cause the subgrade to be non-compliance with any SPECIFICATION requirement. If the CONTRACTOR has not notified the OWNER or ENGINEER of changes that cause the subgrade to be non-compliant and installs the liner, then the CONTRACTOR has determined and assumes responsibility that the subgrade is acceptable for liner installation.
- M. At the crest of the embankments, an anchor trench for the liner shall be constructed by the EARTHWORK CONTRACTOR as detailed on the DRAWINGS. Any deviation from the anchor trench details shown on the DRAWINGS requires review and approval by the ENGINEER. No loose soil shall be allowed at the bottom of the trench, and no sharp corners or protrusions shall exist anywhere within the trench.

- N. Verify as applicable that all underlying components such as geomembrane and piping have been installed, tested, and accepted in accordance with the DRAWINGS and SPECIFICATIONS.

3.2 EXCAVATION

- A. Excavate material shown on the DRAWINGS and as necessary to complete the WORK. Excavation carried below the grade lines shown on the drawings shall be repaired as specified by the OWNER unless previously approved by the OWNER. Correction of all over-excavated areas shall be at the CONTRACTOR'S sole expense.
- B. All necessary precautions shall be taken to preserve the material below and beyond the established lines of all excavation in the soundest possible condition. Any damage to the WORK beyond the required excavation lines due to wetting, drying, or the CONTRACTOR'S operations shall be repaired at the CONTRACTOR'S sole expense.
- C. Excavation, shaping, and any other work related to material removal, shall be carried out by the method(s) considered most suitable, provided it meets the design intent as determined by the ENGINEER.
- D. Limits of excavation to accomplish the WORK safely shall be determined by the CONTRACTOR. Any minimum excavation limits shown on the DRAWINGS are for material identification only and do not necessarily represent safe limits. All excavations shall be free of overhangs, and the sidewalls shall be kept free of loose material. As a minimum, the CONTRACTOR shall slope, bench and shore all excavations as necessary to prevent any unsafe conditions as required by OSHA 29 CFR 1926.651 and 1926.652.
- E. Accurate trimming of the slopes of excavations to be filled will not be required, but such excavations shall conform as closely as practical to the established lines and grades.
- F. For pipe trench excavations, grade trench bottom to provide uniform bearing for the entire length of pipe to be installed. Fill in voids, gaps, low points ("dips" or "bellys") and bridging areas within trench bottom and along the entire length of pipe.
- G. Subsoil not to be used in the construction of earth fills or reclamation shall be stockpiled in areas designated by OWNER and in accordance with applicable laws, rules, and regulations.
- H. Permanently stockpiled earth material shall be graded to drain and blended seamlessly into the natural landscape.
- I. Provide and operate equipment adequate to keep all excavations and trenches free of water.
- J. Excavate unsuitable areas of the subgrade and replace with approved fill materials. Compact to density equal to requirements for subsequent fill material.
- K. The subgrade of each pond shall be proof-rolled and compacted in place prior to fill placement or grading.
- L. Grade top perimeter of excavation to prevent surface water from draining into excavation.

3.3 MISCELLANEOUS EXCAVATION

- A. The CONTRACTOR shall perform all excavations necessary for the placing of seeding and plants, for constructing roadways, and any other miscellaneous earth excavation required under this Contract.

3.4 FILL PLACEMENT

A. General

1. Transport, process, place, spread, compact, and complete fill using the appropriate equipment to achieve lift thickness, design lines and grades and compaction specified in the DRAWINGS and SPECIFICATIONS.
2. To the extent practicable, fill shall be placed by routing the hauling and spreading units approximately parallel to the axis of the embankment.
3. Hauling equipment shall be routed in such a manner that they do not follow in the same paths but spread their traveled routes evenly over the surface of the fill.
4. Protect installed measurement instrumentation, structures, and utilities from damage.
5. Care shall be taken at all times to avoid segregation of material being placed, and all pockets of segregated or undesirable material shall be removed and replaced with material matching the surrounding material.
6. Each zone shall be constructed with materials meeting the specified requirements and shall be free from lenses, pockets, and layers of materials that are substantially different in gradation from surrounding material in the same zone.
7. No material shall be placed on material that is too soft, smooth, wet, or dry, or that has been damaged by drying, cracking, frost, runoff, or construction activities. Previously completed portions of the subgrade that are deemed unsuitable for construction shall be repaired until approved by the ENGINEER. **The top 8 inches of the foundation surface shall be scarified, moisture conditioned (as necessary), and compacted so fill material will bond firmly to surfaces of excavation.** Remove standing water prior to placement of all fill material.
8. To the extent practicable, fill materials shall be brought to the placement area at the recommended moisture content.
9. Moisture conditioning is the operation required to increase or decrease the moisture content of material to within the specified limits for proper material placement and compaction. If moisture conditioning is necessary, it may be carried out by whatever method CONTRACTOR deems suitable, provided it produces the moisture content specified in the SPECIFICATIONS.

3.5 TRENCH BACKFILL

- A. Backfilling over pipes, culverts, and pipe boxes shall begin as soon as practicable after the pipe, culvert or box has been laid, jointed and inspected. All backfilling shall be performed expeditiously.

1. Sand bedding material shall be placed around the lower half of the pipe, culvert or box and thoroughly rodded and tamped to fill all voids and provide uniform support. Material shall be thoroughly compacted by machine tamping in 6-inch thick layers as required to provide 95% of the Modified Proctor maximum dry density per ASTM D1557.
2. Common fill shall be placed around the upper half of the pipe, culvert or box and to a minimum depth of 12-inches over the top of the pipe, culvert or box. Common Fill shall be thoroughly compacted by machine tamping in 6-inch thick layers as required to provide 95% of the Modified Proctor maximum dry density per ASTM D1557.
3. The remainder of the trench shall be backfilled with Common Fill in loose layers not to exceed 8-inches in thickness and thoroughly compacted by machine tamping as required to provide 95% of the Modified Proctor maximum dry density per ASTM D1557.
4. Backfilling under haunches shall be performed manually by tamping rods or similar hand equipment to eliminate voids underneath.
5. The minimum frequency of Moisture Content ASTM D3017 and In Place Density ASTM D2922 testing shall be 1 test per lift per 50 linear feet of trench for all material types.

3.6 ROAD SUBGRADE

- A. The final 8-inch lift of road subgrades shall be compacted to 95% of the Modified Proctor maximum dry density per ASTM D1557. The minimum frequency of Moisture Content ASTM D3017 and In Place Density ASTM D2922 testing shall be 1 test per lift per 10,000 square feet or as directed by the ENGINEER.

3.7 MOISTURE CONTROL

- A. Prior to and during all compacting operations, maintain moisture content within the limits recommended herein. Maintain uniform moisture content throughout the lift. To the extent practicable, add water to materials that are too dry at the site of excavation. Supplement, if necessary, by sprinkling and mixing water into the fill material prior to compaction. The moisture content shall be at or no more than 2 percent above the optimum moisture content in accordance with ASTM D2216.
- B. Do not attempt to compact fill material containing excessive moisture. Aerate material by blading, disking, harrowing, or other methods, to dry the material to acceptable moisture content.

3.8 LIFT THICKNESS REQUIREMENTS

- A. Berm Fill:
 1. Placement lift thickness for Engineered Fill shall not exceed 6 inches prior to compaction with hand-operated compaction equipment and should not exceed 8 inches with heavy machine operated compaction equipment. It is the CONTACTOR's responsibility to ensure that the compaction achieved meets the specifications.
 2. Fill placement for anchor trenches shall not exceed 6 inches in loose lift thickness for each lift.
- B. Drain Rock Aggregate:
 1. Drain Rock Aggregate shall be placed and spread in lifts not exceeding 8 inches in thickness.

3.9 COMPACTION AND MOISTURE CONTENT REQUIREMENTS

- A. After material placement, spreading, and leveling to the appropriate lift thickness, all material shall be uniformly compacted in accordance with the requirements for each type of fill as indicated on the following table:

Table 2: Compaction and Moisture Content Requirements

Fill Material	Compaction Specifications	Moisture Content
Engineered Fill	95% of the Modified Proctor maximum dry density	±2% of Optimum
Drain Rock Aggregate	Place uniform thickness and tamp with dozer or loader bucket	No requirements

3.10 COMPACTION EQUIPMENT

- A. Compaction equipment shall be maintained in good working condition at all times to ensure that the amount of compaction obtained is the maximum for the equipment.
- B. Compactor:
1. The fill is required to be compacted with a heavy vibratory-optional roller and a maximum roller speed of approximately 2 mph.
 2. The compactor shall be of self-propelled design to develop 10,000 pounds in weight per linear foot of width at rest on level ground or equivalent as approved by the ENGINEER.
- C. Special Compactors:
1. Special compactors shall be used to compact materials that, in the opinion of the ENGINEER, cannot be compacted properly by the specified roller because of location or accessibility.
 2. Special compaction measures shall be adopted, such as hand-held compactors, smooth drum rollers, or other methods approved by the ENGINEER, to compact fill material in trenches, around structures, around geomembrane, and in other confined areas that are not accessible to the Compactor. The final surface on which the geomembrane will be placed shall be compacted with a smooth drum roller.
 3. Anchor trenches shall be compacted with a hand-operated compaction machine.

3.11 COMPACTION TESTING OF ENGINEERED FILL

Field compaction testing of each lift shall be performed a minimum of one test every 100 to 300 linear feet or 5000 square feet.

3.12 SITE GRADING

- A. Perform all placement of fill to lines and grades as shown in the DRAWINGS and/or established by the ENGINEER, with proper allowance for surface treatments (topsoil placement, etc.) where specified or shown. Neatly blend all new grading into surrounding, existing terrain.

END OF SECTION 02200

SECTION 02776
HIGH DENSITY POLYETHYLENE (HDPE) GEOMEMBRANE

PART 1 - GENERAL

1.1 SUMMARY

- A. Furnish all labor, materials, equipment and incidentals required to install High Density Polyethylene (HDPE) geomembrane as shown on the Drawings and specified herein.

1.2 SUBMITTALS

- A. The CONTRACTOR shall submit a Subgrade Acceptance Letter to the ENGINEER prior to installation of the geomembrane stating the subgrade is acceptable and does not void the warranty.
- B. The CONTRACTOR shall submit the following product data to the ENGINEER:
 - 1. Resin Data:
 - a. Certification stating that the resin meets the SPECIFICATION requirements.
 - 2. Geomembrane Roll:
 - a. Statement certifying no recycled polymer and no more than 10% rework of the same type of material is added to the resin.
- C. Pre-Construction Submittals: Submit the following within 10 days of Notice to Proceed. Pre-Construction materials shall be submitted to the OWNER and ENGINEER.
 - 1. The MANUFACTURER'S Information
 - a. The MANUFACTURER'S name and address and primary contact.
 - b. The manufacturing plant name and address where the geomembrane for this project will be produced.
 - c. The MANUFACTURER'S qualifications including:
 - 1) Evidence of production of at least 10 million square feet of geomembrane that meets the specifications.
 - 2) Certification that the MANUFACTURER has sufficient capacity to provide the required material in the given timeframe.
 - 3) A list of at least 10 projects for which geomembrane has been supplied by the MANUFACTURER, three of which shall have been for projects of similar size.
 - d. Product name and the MANUFACTURER'S description of the proposed geomembrane and five (5) representative samples of the product proposed for use on this project.
 - e. The MANUFACTURER'S material properties sheets (cut sheets) of proposed geosynthetic products meeting the requirements of the specification.
 - f. The MANUFACTURER'S Quality Control (MQC) Plan, including examples of geomembrane certification documents, name and address of the quality control testing laboratory, quality control laboratory certification, examples of retesting notification, and documentation.

- g. The MANUFACTURER'S written instructions for storing, handling, installing, seaming, protecting from hydration, and repairing the proposed geomembrane, including recommendations for handling equipment (model number and load capacity).
 - h. Samples product warranty.
2. CONTRACTOR'S Information:
- a. CONTRACTOR'S name and address and primary contact.
 - b. CONTRACTOR'S qualifications including a list of at least three previous projects of similar size to this project, including project name, location, size and date of installation, and evidence of installing at least 1 million square feet of geomembrane.
 - c. The Construction Quality Control (CQC) Plan, including examples of subgrade certification documents, daily record documents, methods for repairing geomembrane and subgrade and example documents to certify repairs, method for removing rejected materials, proposed staffing, and proposed equipment.
 - d. Description of welding equipment, techniques, and material, including a list of proposed equipment.
 - e. A complete set of forms to be used for record installation CQC data.
 - f. Résumés of key installation personnel. The Installation Supervisor, Master Seamers, and QC Representative must be clearly identified.
 - g. Workmanship warranty.
- D. The CONTRACTOR shall furnish SHOP DRAWINGS to the OWNER and ENGINEER as follows:
- 1. Installation layout SHOP DRAWINGS.
 - a. Must show proposed panel layout including field seams and details.
 - b. Must show panel identification numbers.
 - c. Installed square footage of the geomembrane.
 - d. Must be approved prior to installing the geomembrane.
 - e. Approved SHOP DRAWINGS will be for concept only and actual panel placement will be determined by site conditions.
- E. CONTRACTOR'S geomembrane field installation quality assurance plan.
- F. The CONTRACTOR will submit the following to the OWNER and ENGINEER upon completion of installation:
- 1. Certificate stating the geomembrane have been installed in accordance with the contract documents.
 - 2. Material and installation warranties:
 - a. Material shall be warranted against MANUFACTURER's defects for a period of five (5) years from the date of geomembrane installation.
 - b. Installation shall be warranted against defects in workmanship for a period of one (1) year from the date of geomembrane completion.
 - 3. As-built drawings showing actual geomembrane placement, seams, testing locations and results, and anchor trench details.

1.3 REFERENCES

Note: Where reference is made to one of the standards listed below, the revision in effect at the time of bid opening shall apply.

A. American Society for Testing and Materials (ASTM)

1. ASTM D792 – Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
2. ASTM D1004 – Test Method for Initial Tear Resistance of Plastic Film and Sheeting
3. ASTM D1238 – Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
4. ASTM D1603 - Standard Test Method for Carbon Black Content in Olefin Plastics
5. ASTM D3895 – Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry
6. ASTM D4218 – Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
7. ASTM D4716 - Standard Test Method for Determining the (In-Plane) Flow Rate Per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head
8. ASTM D4873 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples
9. ASTM D4833 – Test Method for Index Puncture Resistance of Geomembranes and Related Products
10. ASTM D5035 - Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method)
11. ASTM D5199 - Standard Test Method for Measuring the Nominal Thickness of Geomembrane
12. ASTM D5596 – Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geomembrane
13. ASTM D5641 – Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber
14. ASTM D5820 – Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes
15. ASTM D5885 - Standard Test Method for Oxidative Induction Time of Polyolefin Geomembrane by High-Pressure Differential Scanning Calorimetry
16. ASTM D5994 – Test Method for Measuring Core Thickness of Textured Geomembrane
17. ASTM D6364 - Standard Test Method for Determining Short-Term Compression Behavior of Geomembrane

18. ASTM D6392 – Test Method for Determining the Integrity of Non-Reinforced Geomembrane Seams Produced Using Thermo-Fusion Methods
19. ASTM D6693 – Test Method for Determining Tensile Properties of Non-Reinforced Polyethylene and Non-Reinforced Flexible Polypropylene Geomembranes
20. ASTM D7179 - Standard Test Method for Determining Geomembrane Breaking Force
21. ASTM D7406 - Standard Test Method for Time-Dependent (Creep) Deformation Under Constant Pressure for Geosynthetic Drainage Products
22. ASTM D7466 – Standard Test Method for Measuring the Asperity Height of Textured Geomembrane

B. Geosynthetic Research Institute (GRI)

1. GRI-GM9 Cold Weather Seaming of Geomembranes.
2. GRI GM10 – Specification for the Stress Crack Resistance of Geomembrane Sheet.
3. GRI GM12 – Measurement of the Asperity Height of Textured Geomembranes Using a Depth Gage.
4. GRI GM13 – Test Properties, Testing Frequency for HDPE Smooth and Textured Geomembranes.
5. GRI GM14 – Test Frequencies for Destructive Seam Testing Selecting, Variable Intervals for Taking Geomembrane Destructive Samples Using the Method of Attributes.
6. GRI GM 19 – Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes.

1.4 DEFINITIONS

- A. Lot – A quantity of resin (usually the capacity of one rail car) used in the manufacture of geomembrane. Finished roll will be identified by a roll number traceable to the resin lot used.
- B. ENGINEER – Party, independent from manufacturer and CONTRACTOR, that is responsible for observing and documenting activities related to quality assurance during the lining system construction.
- C. Geomembrane Manufacturer – The party responsible for manufacturing the geomembrane rolls.
- D. Geosynthetic Quality Assurance Laboratory (testing laboratory) – Party, independent from the OWNER, manufacturer, and CONTRACTOR, responsible for conducting laboratory tests on samples of geomembrane obtained at the site or during manufacturing.
- E. CONTRACTOR – Party responsible for field handling, transporting, storing, deploying, seaming and testing of the geomembrane seams.

- F. Minimum Average Roll Value (MARV): Property value calculated as typical minus two standard deviations. Statistically, it yields a 97.7% degree of confidence that any sample taken during quality assurance testing will exceed value reported.
- G. Panel – Unit area of a geomembrane that will be seamed in the field that is 10 square yards or larger.
- H. Patch – Unit area of a geomembrane that will be seamed in the field that is less than 10 square yards.
- I. Subgrade Surface – Soil layer surface which immediately underlies the geosynthetic material(s).

1.5 QUALIFICATIONS

A. MANUFACTURER

- 1. MANUFACTURER shall have manufactured a minimum of 10 million square feet of HDPE geomembrane material during the last year.
- 2. MANUFACTURER shall have manufactured a minimum of 10,000,000 square feet of polyethylene geomembrane material during the last year.
- 3. MANUFACTURER shall have a GAI-LAP Accredited Laboratory at the manufacturing facility.
- 4. MANUFACTURER shall have ISO 9001; 2008 certification.

B. CONTRACTOR

- 1. CONTRACTOR shall have installed a minimum of 10,000,000 square feet of geomembrane in the last 3 years.
- 2. CONTRACTOR shall have worked in a similar capacity on at least 3 projects similar in complexity to the project described in the contract documents, and within a total of at least 400,000 square feet of geomembrane installation on each project.
- 3. The Installation Supervisor shall have worked in a similar capacity on at least 3 projects similar in size and complexity to the project described in the Contract Documents in the last 5 years.

1.6 MATERIAL LABELING, DELIVERY, STORAGE, AND HANDLING

- A. Geomembrane labeling, shipment, and storage shall follow ASTM D4873. Product labels shall clearly show the manufacturer or supplier name, style name, and roll number.
- B. Each geomembrane roll shall be wrapped with a material that will protect the geomembrane from damage due to shipment, water, sunlight, and contaminants.
- C. The CONTRACTOR shall note any visible damage to roll materials on the Bill of Lading prior to unloading roll materials. Should any visible damage be noted, CONTRACTOR or ENGINEER shall notify the MANUFACTURER in writing immediately.

- D. Labeling – Each roll of geomembrane delivered to the site shall be labeled by the manufacturer. The label will identify:
1. Manufacturer's name
 2. Product identification
 3. Thickness
 4. Length
 5. Width
 6. Roll number
 7. Date and time of production
 8. Resin lot number
- E. Delivery – Rolls of liner will be prepared to ship by appropriate means to prevent damage to the material and to facilitate off-loading.
- F. Storage – The on-site storage location for geomembrane material, provided by the CONTRACTOR to protect the geomembrane from punctures, abrasions and excessive dirt and moisture, should have the following characteristics:
1. Level (no wooden pallets)
 2. Smooth
 3. Dry
 4. Protected from theft and vandalism
 5. Adjacent to the area being lined
 6. Geomembrane shall not be stacked higher than three rolls
- G. Handling – Materials are to be handled to prevent damage. The CONTRACTOR shall take any necessary precautions to prevent damage to underlying layers during placement of the geomembrane.

1.7 WARRANTY

- A. Material shall be warranted, against manufacturer's defects for a period of five (5) years from the date of geomembrane installation.
- B. Installation shall be warranted against defects in workmanship for a period of one year from the date of geomembrane completion.

PART 2 - PRODUCTS

2.1 HIGH DENSITY POLYETHYLENE (HDPE) GEOMEMBRANE

- A. Material shall be **smooth (both sides) 40-mil black LLPDE and 60-mil grey HDPE (textured on one side and smooth on other)** or equivalent HDPE geomembrane meeting the thickness, texture, and color requirements as shown on the DRAWINGS.
- B. Geomembrane Rolls
1. Geomembrane rolls must not exceed a combined maximum total of 1 percent by weight of additives other than carbon black.
 2. Geomembrane shall be free of holes, pinholes, bubbles, blisters, excessive contamination by foreign matter, and nicks and cuts on roll edges.

3. Geomembrane material is to be supplied in roll form. Each roll is to be identified with labels indicating roll number, thickness, length, width, and manufacturer.
4. All liner sheets produced at the factory shall be inspected prior to shipment and be tested by an acceptable method of inspecting for pinholes. If pinholes are located, identified and indicated during manufacturing, these pinholes may be corrected during installation.

2.2 RESIN

1. Resin shall be first quality, compounded polyethylene resin.
2. Resin testing values and testing frequencies requirements are presented in Table 1 below. Natural resin (without carbon black) shall meet the following additional minimum requirements:

TABLE 1: RAW MATERIAL VALUES

Property	Test Method ⁽¹⁾	Testing Frequencies	Value
Density (g/cm ³)	ASTM D 1505	Once Per Resin Lot	>0.94
Melt Flow Index (g/10 min)	ASTM D 1238	Once Per Resin Lot	≤ 1.0

¹Manufacturer may utilize test equipment and procedures that enable effective and economical confirmation that the product will conform to specifications based on the noted procedures. Some test procedures have been modified for application to geomembrane.

2.3 EQUIPMENT

- A. Welding equipment and accessories shall meet the following requirements:
 1. Gauges showing temperatures in apparatus (extrusion welder) or wedge (wedge welder) shall be present.
 2. An adequate number of welding apparatus shall be available to avoid delaying WORK.
 3. Power source must be capable of providing constant voltage under combined line load.
- B. Extrudate Rod or Bead
 1. Extrudate material shall be made from the same type of resin as the geomembrane.
 2. Additives shall be thoroughly dispersed.
 3. Materials shall be free of contamination by moisture or foreign matter.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Preparation of surfaces to be lined shall be completed by the EARTHWORK CONTRACTOR but the LINER CONTRACTOR will be responsible for inspecting the prepared surfaces to verify that the surfaces are acceptable for liner placement and free from any rocks, clods, sticks, surface irregularities or debris which could damage the liner. Acceptance of the subgrade shall be provided in a written submittal.
- B. All geomembrane installation shall meet the manufacturer's recommendations for preparation, storage and placement or installation.

3.2 DEPLOYMENT

- A. Assign each panel a simple and logical identifying code. The coding system shall be subject to approval and shall be determined at the WORK site.
- B. Visually inspect the geomembrane during deployment for imperfections and mark faulty or suspect areas.
- C. The geomembrane installation shall meet the manufacturer's recommendations for preparation, storage and placement or installation.
- D. Deployment of geomembrane panels shall be performed in a manner that will comply with the following guidelines:
 - 1. Unroll geomembrane using methods that will not damage geomembrane and will protect underlying surface from damage (spreader bar, protected equipment bucket).
 - 2. The geomembrane roll shall be installed in the direction of the slope and in the intended direction of flow unless otherwise specified by the ENGINEER.
 - 3. Use full length rolls or those with a significant length remaining at the top of the slope so that no roll end occurs on side slopes.
 - 4. Place ballast (commonly sandbags) on geomembrane, which will not damage geomembrane, to prevent wind uplift.
 - 5. Personnel walking on geomembrane shall not engage in activities or wear shoes that could damage it. Smoking will not be permitted on the geomembrane.
 - 6. Do not allow heavy vehicular traffic directly on geomembrane. Rubber-tired ATVs and trucks are acceptable if wheel contact is less than six (6) pounds per square inch.
- E. Sufficient material (slack) shall be provided to allow for thermal expansion and contraction of the material. This practice will be used to prevent excessive tension (trampolines) from developing. This is particularly important in cold weather conditions.
- F. Anchor trench compacting equipment shall not come into direct contact with the geomembrane.

3.3 FIELD SEAMING

- A. Seams shall meet the following requirements:
 - 1. To the maximum extent possible, orient seams parallel to line of slope, i.e., down and not across slope.
 - 2. Minimize number of field seams in corners, odd-shaped geometric locations and outside corners.
 - 3. Slope seams (panels) shall extend a minimum of five feet beyond the grade break into the flat area.
 - 4. Use a sequential seam numbering system compatible with panel numbering system that is agreeable to the ENGINEER and CONTRACTOR.
 - 5. All seam overlaps shall be aligned consistent with the requirements of the welding equipment being used. Seams shall be made by lapping the uphill material over the downhill material with sufficient overlap. Extrusion seaming shall have a minimum overlap of six (6) inches. Wedge-welded seaming shall have a minimum overlap of six inches.
 - 6. Seaming of the geomembrane at material temperatures below 32 degrees F and above 170 degrees F must be successfully demonstrated to the ENGINEER using prequalification test seams to demonstrate that the seams comply with these SPECIFICATIONS.

B. During Welding Operations

1. Provide at least one master seamer who shall provide direct supervision over other welders as necessary.

C. Extrusion Welding

1. Hot-air tack adjacent pieces together using procedures that do not damage the geomembrane.
2. Clean geomembrane surfaces by disc grinder or equivalent. Number 80-grit sandpaper shall be used.
3. Grinding shall not reduce the thickness of the geomembrane more than one mil.
4. Purge welding apparatus of heat-degraded extrudate before welding.
5. Extrusion welding shall be considered a secondary means of welding and shall be used for repairs unless otherwise approved by ENGINEER.

D. Hot Wedge Welding

1. Welding apparatus shall be a self-propelled device equipped with an electronic controller which displays applicable temperatures.
2. Clean seam area of dust, mud, moisture and debris immediately ahead of hot wedge welder.
3. Protect against moisture build-up between sheets.
4. Hot wedge welding shall be considered the primary method of welding and shall be used for panel seaming unless otherwise approved by ENGINEER.

E. Trial Welds

1. Perform trial welds on geomembrane samples to verify welding equipment is operating properly.
2. Make trial welds under the same surface and environmental conditions as the production welds, i.e., in contact with subgrade and similar ambient temperature.
3. A minimum of two trial welds shall be required per day, per welding apparatus, one made prior to the start of work and one completed at mid-shift. Additional trial welds will be required after repairs are made to the apparatus.
4. Cut six one-inch wide by six-inch long test strips from the trial weld.
5. Quantitatively test three specimens for peel adhesion, and then three specimens for shear strength.
6. Trial weld specimens shall pass when the results shown in Table 2 are achieved in both peel and shear test.

TABLE 2: MINIMUM WELD VALUES FOR HDPE GEOMEMBRANES

Property	Test Method	Minimum Value
Peel Strength (fusion), ppi	ASTM D 6392	98
Peel Strength (extrusion), ppi	ASTM D 6392	78
Shear Strength (fusion & ext.), ppi	ASTM D 6392	121

7. The break, when peel testing, occurs in the liner material itself, not through peel separation (Film Tear Bond (FTB) break).
8. The break is ductile.
9. A test will be considered a failure if one specimen on either peel or shear testing does not meet the requirements on Table 2 or does not achieve an FTB break.

10. Repeat the trial weld, in its entirety, when any of the trial weld samples fail in either peel or shear.
 11. No welding equipment or welder shall be allowed to perform production welds until equipment and welders have successfully completed two additional trial welds.
- F. Seaming shall not proceed when ambient air temperature or adverse weather conditions jeopardize the integrity of the liner installation. The CONTRACTOR shall demonstrate that acceptable seaming can be performed by completing acceptable trial welds.
- G. Defects and Repairs
1. Examine all seams and non-seam areas of the geomembrane for defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter.
 2. Repair and non-destructively test each suspect location in both seam and non-seam areas. Do not cover geomembrane at locations that have been repaired until test results with passing values are available.

3.4 FIELD QUALITY ASSURANCE

- A. The manufacturer and CONTRACTOR shall participate in and conform to all terms and requirements of the OWNER'S quality assurance program. The CONTRACTOR shall be responsible for assuring this participation.
- B. Quality assurance requirements are as specified in this section.
- C. Field Testing
1. Non-destructive testing shall be carried out as the seaming progresses, not at completion of all field seaming. Each seam shall be non-destructive tested with either of the following tests.
 - a. Vacuum Testing
 - 1) Shall be performed in all extrusion welds performed during installation and in accordance with ASTM D 5641.
 - 2) The vacuum box assembly shall consist of the following:
 - a) Rigid housing;
 - b) Transparent viewing window;
 - c) Soft rubber gasket attached to bottom of housing;
 - d) Porthole or valve assembly;
 - e) Vacuum gauge; and
 - f) A vacuum pump capable of delivering a minimum of a 27psi vacuum.
 - 3) When vacuum testing, the installer shall:
 - a) Carefully trim all overlapped material using an approved cutting instrument. The "pull-tear" method of overlap removal shall not be accepted;
 - b) Clean windows, gasket surfaces, and check for leaks;
 - c) Wet a strip of geomembrane approximately 1 foot by 2.5 feet (length of box) with soapy solution;
 - d) Place the vacuum box over the wetted area;
 - e) Ensure that a leak-tight seal is created;