

BCU 12-31-198 Well Pad Earthen Pit Construction Synthetic Lining Plans and Specifications



Prepared for:

***Williams Production RMT
1058 County Road 215
Parachute, Colorado 81635***



Date: November 2010

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Special Provisions

These plans and specifications have been compiled to comply with production, drilling and multi-well earthen pit regulations and policies of the Colorado Oil and Gas Conservation Commission (COGCC), Colorado Department of Natural Resources. Specifically included are the 900 Series Rules adopted in 2009; policy entitled "Notice to Operators Drilling Wells Within $\frac{3}{4}$ Mile of the Rim of the Roan Plateau in Garfield County, Pit Design, Construction and Monitoring Requirements", dated June 12, 2008; and COGCC email correspondence entitled "New Pit Requirements in the Piceance Basin", dated September 8, 2008. The specifications detail pit construction; and liner material, details and installation practices which are to be followed and employed by Williams Production RMT Company and their contractors.

All earthen pits constructed on fill material and/or requiring the construction of embankments above pre-construction grades will require design and certification by a registered professional engineer. Documented inspections, construction observation, compaction testing and hydrostatic monitoring may be performed by the professional engineer or their designee as outlined in the specifications. Within the scope of the work, the contractor(s) shall provide a minimum of 48 hours notice to the engineers for critical construction observations, testing and inspections.

A specific earthen pit location map on a USGS base map, site survey plats, and cross sections are provided in the figures as part of the plans and specifications. Synthetic liner system specification details and drawings are also included in this plan set. If required by the COGCC, a leak detection system shall be installed as specified per the drawings. Changes to the plan set may be made by the professional engineer as warranted to ensure compliance with COGCC regulations and policies. Changes will be conveyed to the contractor in the form of a Notice of Change correspondence.

No work shall commence by the contractor until a Notice to Proceed has been issued by Williams Production RMT Company. The contractor shall be responsible for locating all underground utilities as prescribed by Colorado law. All work shall be conducted within the limits of disturbance, unless approved by the Williams or professional engineer. Earthen pits shall be constructed within the boundary locations shown on the site survey plats and to the depths and side slopes noted, unless otherwise changed by the professional engineer. No changes to the plans and specifications will be permitted by the contractor without the approval of the professional engineer or their designee.

Williams Production RMT Company shall be responsible for providing as-built drawings, if any, including earthen pit plan and cross sections to the professional engineer. The as-built drawings and changes to the specifications shall be noted by the professional engineer as part of their certification and final construction report.

SECTION 1010 - SCOPE OF WORK

The primary work items to be performed under these plans and specifications involves the construction of earthen pits and installation of a synthetic lining systems regulated by the Colorado Oil and Gas Conservation Commission. Portions of well pad construction shall be included within this scope of work for pits influencing well pad cut and/or fill areas. Pits shall not be constructed on known intermittent or perennial springs, seeps, or other surface water features. If groundwater is encountered during pit construction activities, the contract shall immediately cease construction and notify the Owner and the professional engineer. The water source may be mitigated and/or pit relocated at the direction of the Owner and/or professional engineer.

SECTION 1300 - CONSTRUCTION SEQUENCE

The Contractor will follow the general pit construction sequence outlined. Changes to the sequences may be made by the professional engineer as warranted by field or other conditions.

- 1.) Stake pit boundaries and edge of disturbed area including bank above freeboard and anchor trench for liner. Ensure that the edge of all pits maintain a minimum 10 feet setback from the edge well pad boundaries or fill slopes.
- 2.) Excavate the pit bottom and pit slopes per the plan set. Scarify soil in bottom and sides.
- 3.) Excavate pit top perimeter and anchor trench per the plan set.
- 4.) Compact pit bottom and slopes as specified.
- 5.) Compact pit top perimeter and anchor trenches as specified.
- 6.) Install underlayment; leak detection system, if required; and liner system as specified.
- 7.) Backfill and compact anchor trenches as specified.

SECTION 1400 - CONSTRUCTION OBSERVATION NOTIFICATION

The project professional engineer shall provide the Owner with a list of construction observations for each pit that must be witnessed or observed by the professional engineer or their designee. These observations may include, but are not limited to;

1. Construction of fills/embankments.
2. Subgrade completion of pit excavation and liner anchor trench.
3. Placement of underlayment; leak detection system, if required; and liners.
4. Embankment/fill compaction testing by the professional engineer.

The Owner or contractor shall provide the professional engineer with a 48-hour advance notice of the construction events requiring their presence.

The Owner shall provide the professional engineer with a set of surveyed as-built pit plan view and cross sections indicating natural and post construction grades. A copy of the hydrostatic test, if applicable, shall also be provided.

SECTION 2200 - EXCAVATION / EMBANKMENT**PART I - GENERAL****DESCRIPTION OF WORK**

The primary work defined by this Section will be all excavation, embankment, and earthwork associated with the project including but not limited to the production pits, reserve pits, and cuttings pits. Well pad construction shall be included in this Section for pits constructed on or in well pad cut/fill areas.

RELATED WORK SPECIFIED ELSEWHERE

Section 2260 –Synthetic Lining and Underlayment System

SITE INFORMATION

The Contractor will be held to have examined the site(s), and to have detected the conditions under which the work is to be done. The drawings show the physical dimensions and general topography of the site, but do not show the extent of all obstructions and subsurface conditions. The Contractor, at his option and without additional cost to the Owner, may take borings and other exploratory actions to determine conditions of the site and to provide for the construction specified herein.

MEASUREMENTS AND LEVELS

Verify all drawing measurements and levels in relation to existing elevations, grades and adjacent structures, and determine conditions and requirements for excavations, fill, and protection of the premises. Carefully and accurately lay out all lines and grades of the new construction as indicated on the plans before proceeding with any work.

PROTECTION

Shoring - If applicable, provide and maintain all sheeting, shoring and bracing required to retain earth banks properly, protect adjoining grades and structures from caving, sliding, erosion, or other damage, all according to applicable codes and current OSHA requirements. Remove shoring and related items as excavations are backfilled unless approval has been requested in writing and granted by the Owner to leave in place.

Drainage - Maintain excavations and construction site free from water throughout work. Drain surface water or seepage by gravity, sumps, or temporary pumps and discharge lines as necessary for this purpose, complying with the Owner's Storm Water Management Plan. Use drainage methods that will prevent softening of foundation bottoms, undercutting of footings, or other conditions detrimental to proper construction procedures. Contractor shall keep an erosion control plan and best management practices consistent with the Owner's Storm Water Management Plan.

Utilities - Protect from damage existing utility lines and piping shown on drawings or locations of which are made known to the Contractor prior to work, and utility lines constructed during construction operations of the project. Before commencing work, the Contractor shall obtain necessary information concerning location, type, and extent of existing utilities on the site and adjacent properties. The Contractor shall contact the Utility Notification Center of Colorado at phone (800) 922-1987 and have all

utilities located prior to commencing construction activities. Notify the Owner and utility company immediately in the event of damage to utility lines. The Contractor will repair damages to utilities at no additional cost to the Owner.

PART II - PRODUCTS

A. Embankment (Fill) - Embankment, shall consist of approved material acquired from excavations, hauled and placed in embankments in reasonably close conformity with the lines, grades, thicknesses and typical cross sections shown on the drawings or as established in the field by the Owner. All embankment material shall be approved by the geotechnical engineer prior to placement. When the source of the embankment material is not designated on the drawings, approval of the source will be contingent on the material having a resistance value necessary for the construction in which it is used. Only approved materials shall be used in the construction of embankments.

B. Suitable Materials for Structural Fill and Backfill - On-site soil material obtained from excavation and free of debris, roots, organic or frozen materials, and stones or rubble with a maximum dimension smaller than 12 inches and less than 25% courser than 3/4-inches are acceptable. Imported material will be nonexpansive soil, or may be pit-run or bank-run sand and gravel capable of being compacted as specified hereafter. All fill and backfill material must be approved by the geotechnical engineer before fill or backfill work is started.

C. Unsuitable Materials - Expansive materials or materials that contain debris, roots, organic or frozen materials, stone, or concrete having a maximum dimension larger than 12 inches, or materials determined by the geotechnical engineer as unsuitable for providing stable slopes, fill, backfill, foundation or subgrade material for structures or pavements. Material that is unsuitable due to excess moisture content will not be classified as unsuitable if it can be dried by manipulation, aeration, or blending with other materials satisfactorily as determined by the geotechnical engineer.

PART III - EXECUTION

A. Excavation: General - Excavation includes removal and disposition of all materials excavated, despite the nature of materials encountered. Excavations shall be finished to a smooth and uniform surface. Variation from the subgrade plane shall not be more than .25 ft. in soil nor more than .08 ft. above or .50 ft. below in rock. Excavation operations shall be conducted so that material outside the limits of construction shall not be disturbed. Prior to beginning grading operations in any area, all necessary clearing and grubbing in that area shall have been performed. Place suitable excavated materials in fill areas within the limits of work or stockpile as directed by the Owner. Report to the Owner any unsuitable materials or unforeseen obstructions encountered during excavation for proper disposition. Materials shall not be wasted without permission of the Owner.

Unless otherwise specified, rock shall be excavated to a minimum depth of 0.5 ft. below subgrade, within the limits of construction and the excavation backfilled with material designated on the drawings or approved. When rock has been excavated greater than 0.5 ft. below subgrade, within the limits for construction, the excavation shall be backfilled within at least 0.5 ft. below subgrade with material shown on the drawings or as approved. Rock excavation shall not be considered or paid for as extra work.

B. Embankments/Fills - Construct all embankments to the lines and grades shown on the drawings. Immediately before placing fill material, scarify the entire area upon which fill is to be placed to a depth of 12-inches. Remove all frozen material, roots, debris, large stones, or other objectionable materials. Place approved excavated or imported fill material in successive horizontal layers of 8-inch loose depth

for full width of cross section, bring to optimum moisture content for compaction, and compact each layer to the required density. If required compaction cannot be obtained with the existing material, the area will be over-excavated to a depth of 18 inches and filled and compacted with suitable material.

Where fills are placed on natural slopes, within the influence of water pits, as determined by the professional engineer, benches shall be cut into the native material of not less than 42 inches. Material shall be replaced in 10 inch lifts, brought to proper moisture content, (within 1 % below and 3% above) and compacted to not less than 95% of maximum dry density as determined by the professional engineer.

As determined by the professional engineer, a toe drain shall be installed along the toe of the pad slope. Toe key location shall be determined by the professional engineer at the time of construction. Drain shall be encased in free draining aggregate of at least 3 cubic feet per linear foot of drain. Aggregate and pipe shall be wrapped with pipe filter wrap. Drain pipe shall day light as directed by the professional engineer.

Constructed embankments shall be finished to a smooth and uniform surface. Variation from the subgrade plane shall not be more than 0.25 ft. Free running water shall be drained from embankment materials prior to placement. When embankments are to be constructed against existing embankment or hillsides, constructed slopes that are steeper than 4:1 shall be brought up in layers keyed and benched into the existing materials. Where embankments encroach on stream channels or lakes, the largest available rock produced by excavation operations shall be placed at the toes of slopes to protect the embankments against erosion. The professional engineer reserves the right to modify the angle of slope on embankments during the construction process.

C. Pit Bottom Soils – Pit bottom is to be entirely in cut slopes from native and undisturbed material. Pit shall be scarified to a depth of 12" below nominal bottom elevation, and shall be disked or bladed until it is free from large clasts, brought to the proper moisture content (within 1% below to 3% above optimum) and compacted to not less than 95% of maximum dry density as determined in accordance with ASTM D696 standard Proctor. If soft/yielding subgrade conditions are encountered, stabilization may be required as determined by the professional engineer.

Where pit bottoms or portions of pit bottom must be constructed on fill materials, the professional engineer shall examine and approve the fill material; provide over-excavation, benching, compaction and testing requirements; and provide construction observation as necessary.

D. Pit Slope and Bank Soils – Pit slopes and bank or perimeter areas may be constructed from approved fill materials. These materials include, but are not limited to, reworked cuttings, native cut and imported materials. Pit slopes and areas on the top of bank shall be disked or rolled with a sheep's foot or similar equipment until they are free from any protruding sharp clasts larger than 6 inches and with no clasts protruding more than 3 inches above the plane of the slope or bank. If soft/yielding subgrade conditions are encountered, stabilization may be required as determined by the professional engineer.

E. Anchor Trench Soils – An anchor trench shall be excavated as shown and the slopes of the trench shall be disked, raked and/or bladed until it is free from large clods and sharp clasts. Anchor trench backfill material shall be disked, raked, and/or bladed until it is free from clods or clasts over 6 inches diameter, and stockpiled until needed.

F. Anchor Trench Backfill – After installation of synthetic liner system as specified in this plan set, the edge of the liner is to be anchored as shown and covered with anchor trench backfill material as noted. Backfill is to be brought to proper moisture content (within 2% above or below optimum), and compacted to not less than 95% of maximum dry density as determined in accordance with ASTM D698 – standard Proctor or as specified by the professional engineer.

G. Compaction - Perform all compaction with approved equipment well suited to location and material being compacted. Use heavy vibratory rollers for fill work and where heavy equipment is appropriate. In areas where a small amount of fill is necessary, a hand-operated compactor (whacker), will be required. Compact all site fills and embankments to 95% of standard Proctor density for all soil types unless directed otherwise by the professional engineer.

END OF SECTION

SECTION 2260 –SYNTHETIC LINING AND UNDERLAYMENT SYSTEM**PART I - GENERAL**Description of Work

This section covers the synthetic pit lining system and leak detection system, if required, and includes installation; liner and underlayment materials; anchor trench details, leak detection system; per manufacturer's installation guidelines, and warranty.

RELATED WORK SPECIFIED ELSEWHERE

Section 2200 – Excavation / Embankment

PART II - PRODUCTS

A. Polyethylene Liner – The liner material shall be a 36 mil minimum thick reinforced polyethylene liner, black in color, denoted as Dura-Skrim J-Series as manufactured by Raven Industries, Inc., or approved equal. The liner shall be manufactured from virgin resin specifically compounded for use as a hydraulic containment member. Reinforced Polyethylene Geomembrane shall be a Linear Low Density Polyethylene Geomembrane composed of a heavy encapsulated 1300 denier polyester tri-directional reinforcement. Available at Colorado Lining International, Parker, CO Ph: (303) 951-5913.

B. Woven Fabric Underlayment - Underlayment material shall consist of one of the following products as required by the professional engineer. Underlayment materials include a minimum weight 12 oz. per cubic yard nonwoven polypropylene geotextile, denoted as GEO 1208002, as manufactured by GSE Lining Technology or approved equal; and/or a minimum weight 6 oz. per cubic yard geocomposite, denoted as GSE FabriNet F42060060S as manufactured by GSE Lining Technology or approved equal.

C. HyperNet – interstitial water conveyance material shall be 200 mil HyperNet Geonet drain mat as manufactured by GSE Lining Technology, Inc. or approved equal.

D. Perforated Drain and Riser Pipe shall be PVC meeting ASTM D 3034 & D 2729, or approved equal.

E. Leak Detection Collection Rock – shall be washed rounded $\frac{3}{4}$ " to 1 inch diameter rock.

PART III - EXECUTION

A. Layout - The lining system shall be fitted to the as-built constructed pit excavation as detailed in Section 2200 and per the manufacturer's installation guidelines contained in Appendix A of this plan set. Where practical, all liner seams shall be factory welded.

B. Geonet and Woven Fabric Underlayment - The underlayment shall be installed per the configuration shown in Figure 4. The area to be lined shall be graded evenly and be free of loose or

sharp protruding material from the pit floor, slopes or top bank. The geonet or woven fabric underlayment shall be installed per the manufacturer's installation guidelines. The underlayment is to be laid perpendicular to the slope of the pit with no parallel seams in the anchor trench, on top of the bank, or along the pit slope. Woven fabric underlayment shall be overlapped at least 12 inches, heat bonded and stapled to the ground along the overlapped edges.

Underlayment seams are to have 6 inches of overlap with the sandwiched GeoNet attached with 50 lbs. plastic zip ties as per the manufacturer's guidelines included in Appendix A or as specified by the professional engineer. The top nonwoven layers are to be overlapped and heat bonded.

Woven fabric underlayment may be substituted with a layer of fine graded material such as drill cuttings on review and approval by the professional engineer.

C. Liners – The liners shall be installed per the configuration shown in Figure 4 and per the manufacturer's guidelines included in Appendix A. The liners are to be laid perpendicular to the slope of the pit in contact with the underlayment and/or liner. If the liner is not entirely factory-seamed, field seams are to be staggered a minimum of 12 inches from underlayment or other liner seams. The contractor shall implement seaming or welding safeguards to ensure the no tears or burns affect the underlayment or adjacent liner materials. Field seams shall be observed by the professional engineer and tested per the manufacturer's guidelines.

D. Leak Detection System – install per the drawings as required by the COGCC or Williams Production RMT Company. Carefully place drain rock and pipe to prevent damage to liner system.

END OF SECTION

SECTION 2280 –HYDROSTATIC TESTING

PART I - GENERAL

Description of Work

This section covers the hydrostatic integrity testing of the pit lining system and test reporting for pits geographically delineated in the COGCC's policy entitled "Notice to Operators Drilling Wells Within ¼ Mile of the Rim of the Roan Plateau in Garfield County, Pit Design, Construction and Monitoring Requirements", dated June 12, 2008; and COGCC email correspondence entitled "New Pit Requirements in the Piceance Basin", dated September 8, 2008.

PART II - PRODUCTS

- A. Fresh Water – Untreated fresh water obtained from a legal water source and approved by the professional engineer shall be utilized for the hydrostatic integrity test.

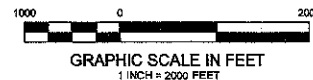
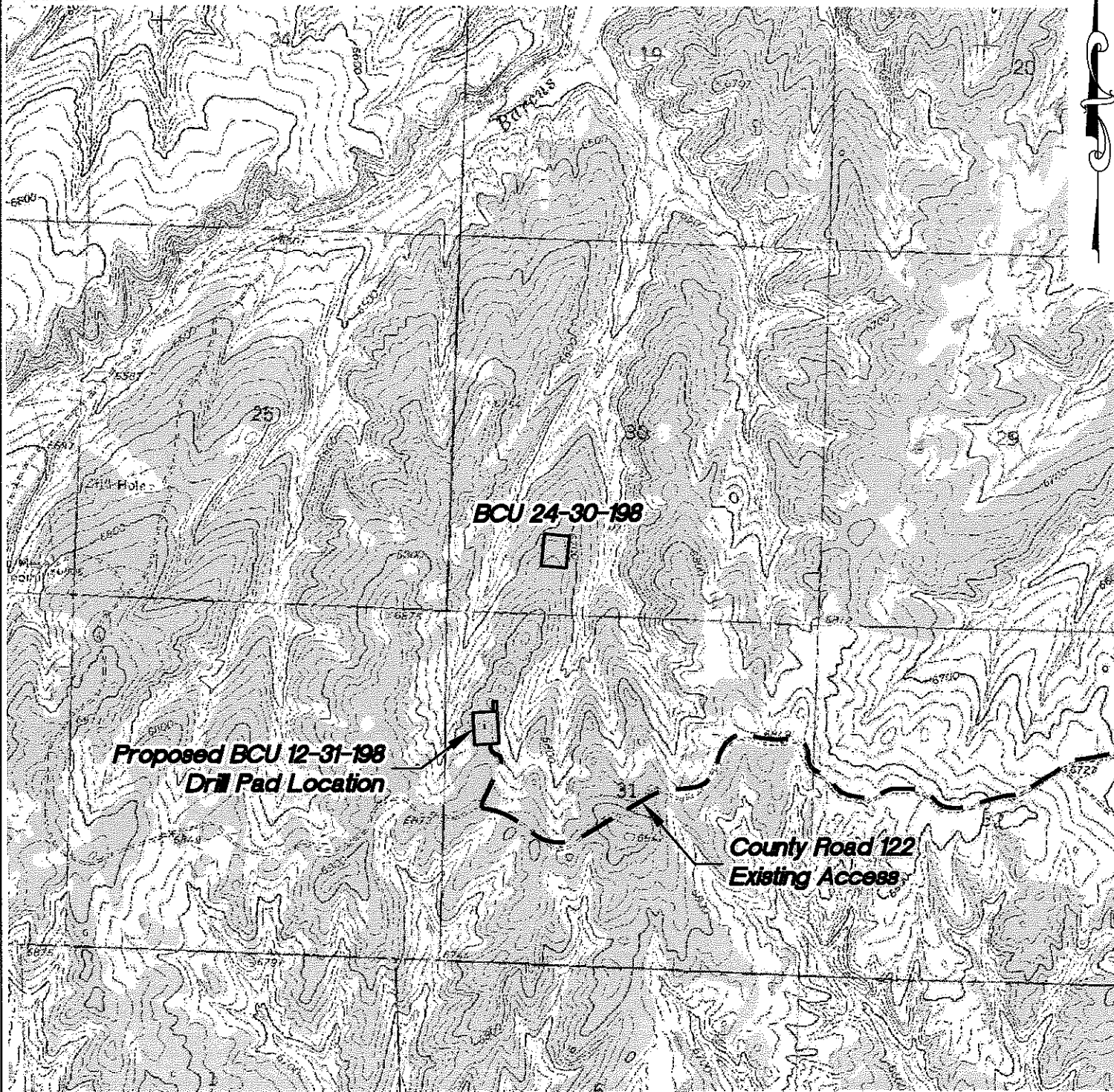
PART III - EXECUTION

- A. Hydrotesting – After complete installation of the liner system and prior to starting pit operations, the pit shall be filled with at least 4 feet of fresh water, measured from the base of the pit and not to encroach into the 2 ft. freeboard. The owner or contractor shall monitor the pit for leaks for a period

of 72 hours prior to draining the pit and commencing operations. Hydrostatic testing results shall be maintained by the Owner for the life of the pit and provide to the Colorado Oil and Gas Conservation Commission upon request.

Figure 1

Section 31
T. 1 N., R 98 W
6th. P.M.



ACCESS DESCRIPTION:

FROM THE INTERSECTION OF STATE HIGHWAY 64 AND RIO BLANCO COUNTY ROAD 5 PROCEED SOUTHERLY ALONG COUNTY ROAD 5 ± 4.6 MILES TO THE INTERSECTION WITH A DIRT/GRAVEL ROAD BEING COUNTY ROAD 20, PROCEED RIGHT IN A WESTERLY DIRECTION ALONG COUNTY ROAD 20 ± 4.9 MILES TO THE INTERSECTION WITH A DIRT/GRAVEL ROAD BEING COUNTY ROAD 122, PROCEED RIGHT IN A WESTERLY TO SOUTHWESTERLY DIRECTION ± 7.1 MILES TO AN INTERSECTION WITH A DIRT/GRAVEL ROAD, PROCEED RIGHT IN A NORTHERLY DIRECTION ± 0.2 MILES TO THE BCU 12-31-198 DRILL PAD LOCATION, AS SHOWN HEREON.

Construction Plan Prepared for:

Williams Williams Production, RMT

BCU 12-31-198 Drill Pad - Sheet 7
Access

136 East Third Street
Rifle, Colorado 81650
Ph. (970) 625-1339
Fax (970) 625-2773

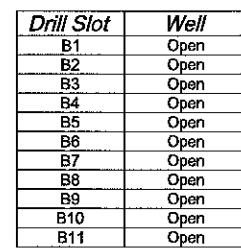


BOOKCLIFF
Survey Services, Inc.

SCALE: 1" = 2000'
DATE: 11/5/10
Drawing: 7 of 10
PROJECT: Williams Highlands
DFT: DPM

Figure 2

GRAPHIC SCALE IN FEET
1 INCH = 100 FEET



ESTIMATED EARTHWORK QUANTITIES (cy)				
ITEM	CUT	FILL	TOPSOIL	EXCESS
PAD	18278	5293	7700	5285
PIT	3300			3300
TOTALS	21578	5293	7700	8585

*NOTE:

- 1.) Volumes Shown are un-adjusted.
- 2.) Topsoil Volume Based on 12" Soil Depth.
- 3.) Total Disturbed Area = 8.72 ac.

Construction Plan Prepared for:
Williams. Williams Production, RMT

BCU 12-31-198 - Sheet 1
CONSTRUCTION LAYOUT

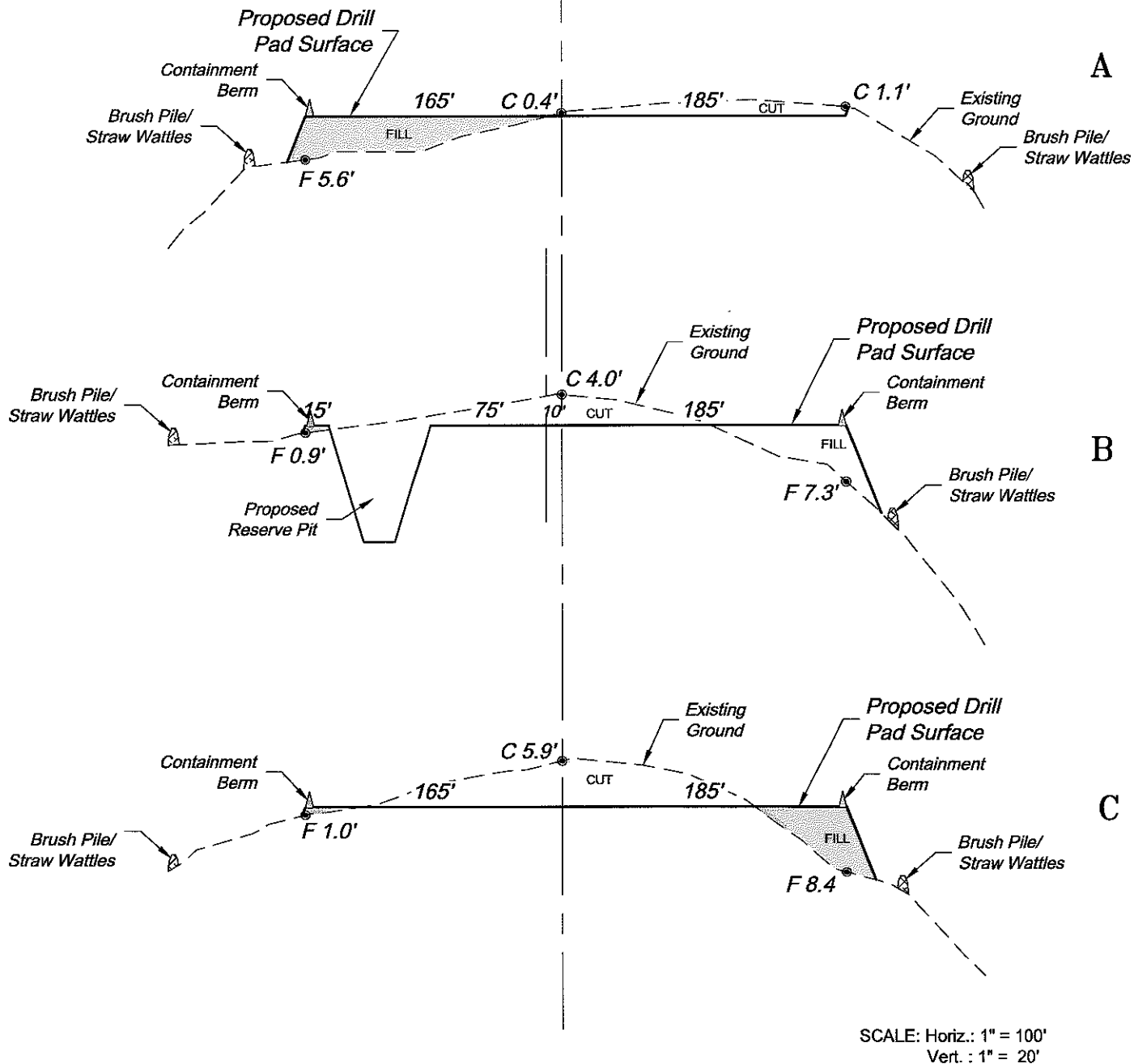
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DATE: 11/16/10
Drawing: 1 of 10
PROJECT: Williams Highlands
DFT: CWS



Figure 3

Section 31
T. 1 N., R 98 W
6th. P.M.

WELLS



SCALE: Horiz.: 1" = 100'
Vert.: 1" = 20'

***NOTE:**
ALL PROPOSED CUT AND FILL
SIDE SLOPES ARE AT 2:1, UNLESS
OTHERWISE NOTED.

136 East Third Street
Rifle, Colorado 81650
Ph. (970) 625-1330
Fax (970) 625-2773



BOOKCLIFF
Survey Services, Inc.

SCALE: As Noted
DATE: 11/2/10
Drawing: 2 of 10
PROJECT: Williams Highlands
DFT: cws

Construction Plan Prepared for:

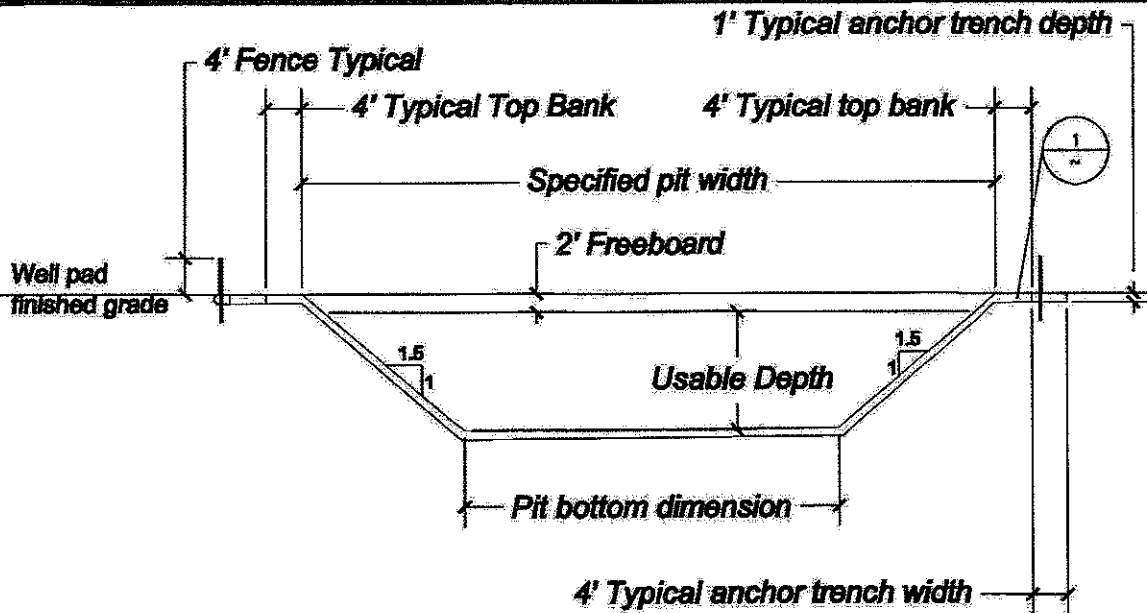


Williams Production, RMT

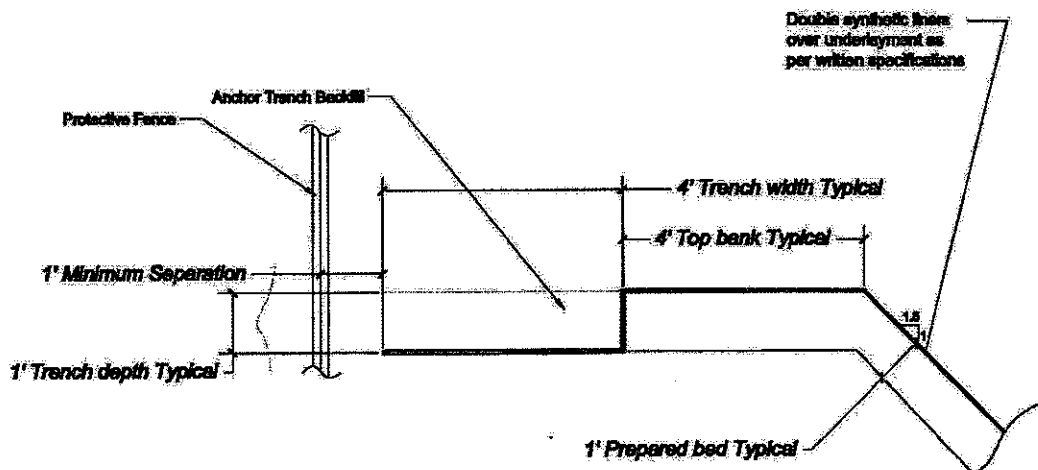
BCU 12-31-198 Drill Pad - Sheet 2
CONSTRUCTION LAYOUT
CROSS SECTIONS

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Figure 4



TYPICAL SECTION THROUGH PIT
 SCALE: N.T.S. Note: See Fig 2 for Pit Dimensions



DETAIL OF ANCHOR TRENCH CONFIGURATION
 SCALE: 1"=3'



Williams RMT
Typical Pit Design
Section Views

DATE:
10/12/09

GEG JOB NO. 3,275

Fig. 4

Figure 5

Figure 5
Liner & Leak Detection System Details
 (if required by COGCC)

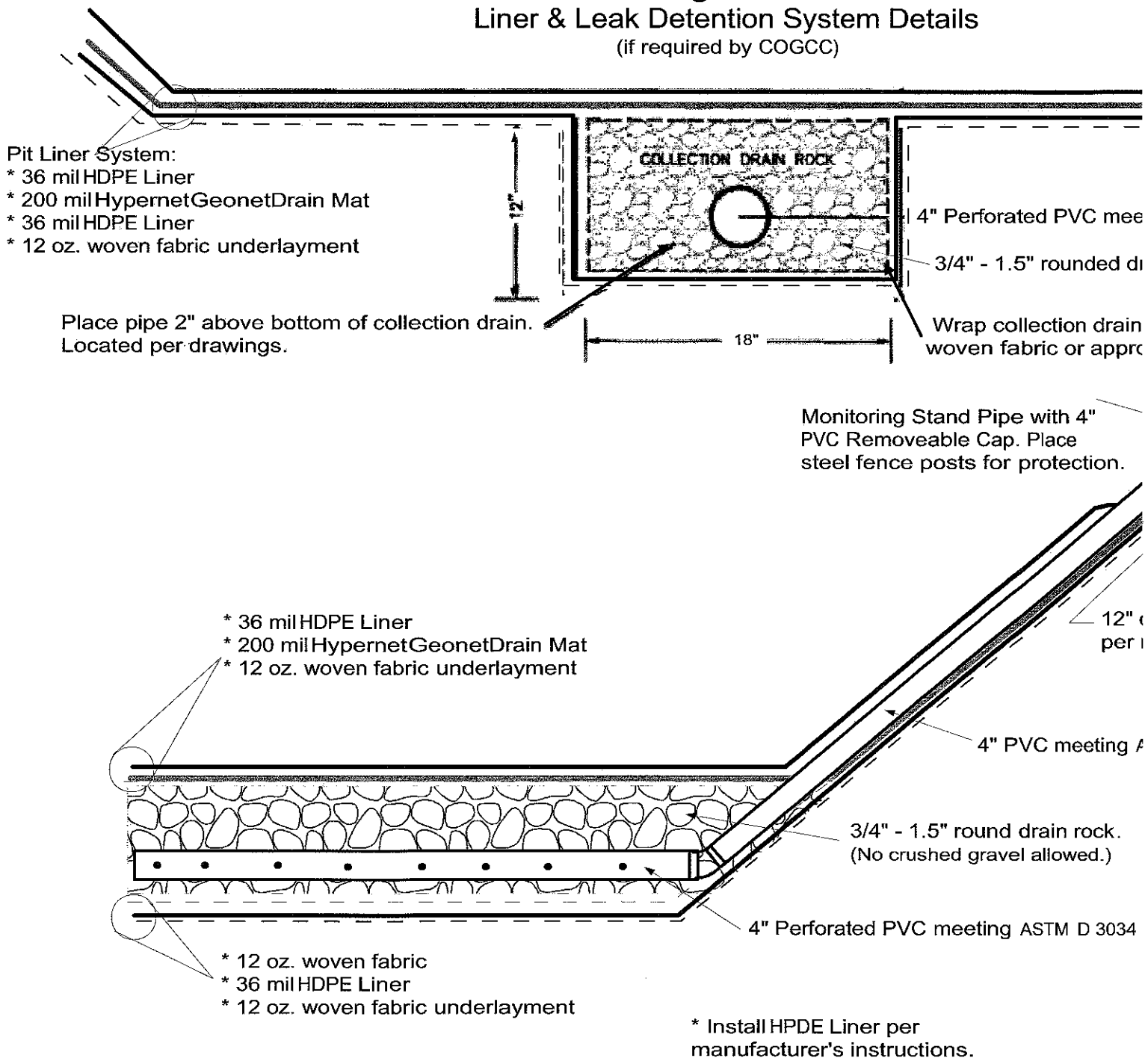
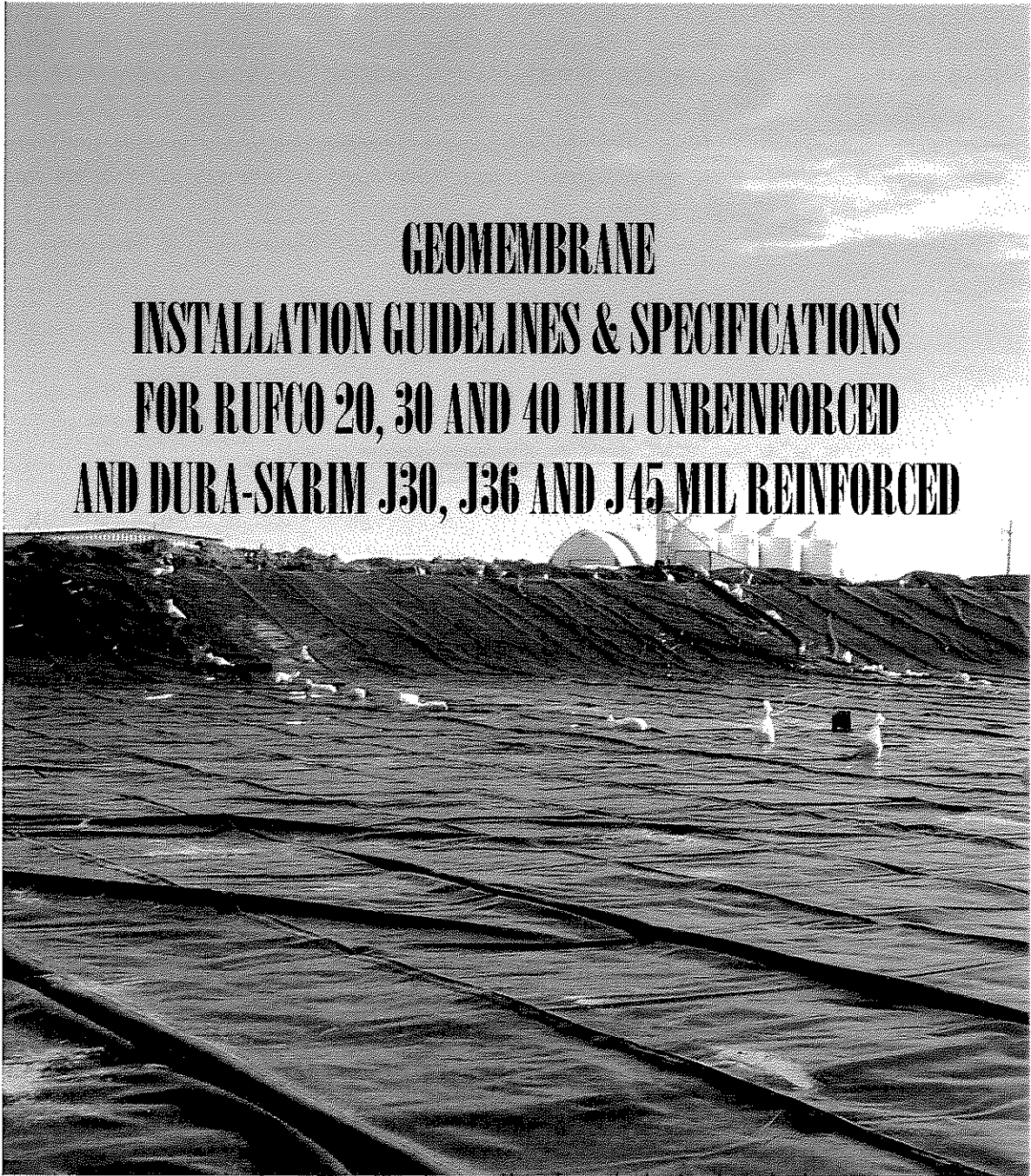


Exhibit A



**GEOMEMBRANE
INSTALLATION GUIDELINES & SPECIFICATIONS
FOR RUFCO 20, 30 AND 40 MIL UNREINFORCED
AND DURA-SKRIM J30, J36 AND J45 MIL REINFORCED**



May 2008

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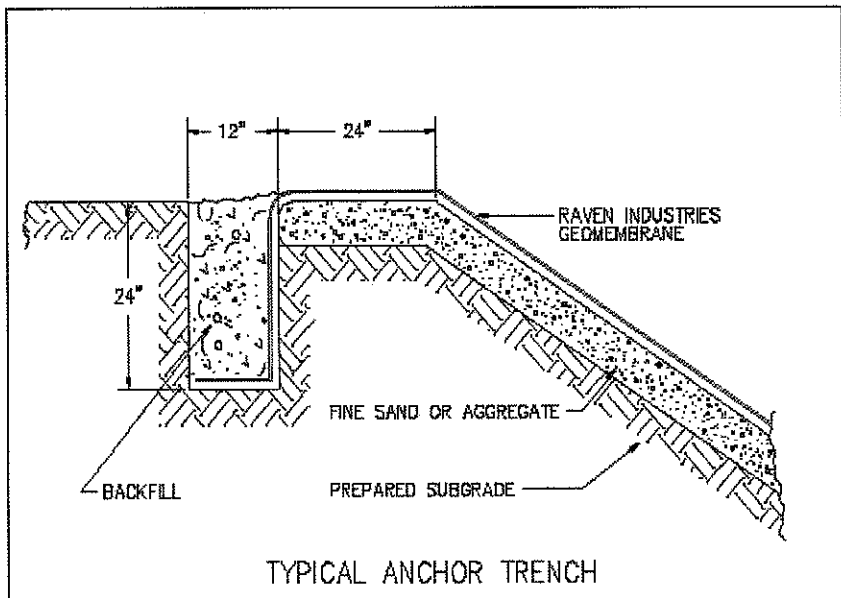
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Membrane Installation

SCOPE: The following instructions are intended as guidelines for the installation of Raven Industries 20, 30 & 40 mil unreinforced geomembranes and Dura-Skrim J30, J36 and J45 mil geomembranes. However, it is vital that individual engineer's detailed specifications and procedures are followed.

1.0 Subgrade Preparation

- 1.1 The foundation area for flexible membrane liners shall be smooth and free of projections that might damage the liner. All stumps and roots shall be removed. Rocks, hard clods, coarse gravel and other such material shall be removed or shall be rolled so as to provide a smooth surface or shall be covered with a cushion of fine soil. Subgrade must be compacted to comply with design specifications and include a stable base to support equipment and necessary vehicle weight and shall be free of standing water.
- 1.2 An effective sterilant shall be applied to the subgrade at the rate recommended by the manufacturer, if installing on soil where seeds and/or plant roots are present.
- 1.3 The foundation area should be sloped if there is a possibility of gas pressure buildup (through organic decay or water table fluctuations). A slope of not less than 1.5% is required. A venting medium, either geotextile or sand, is to be placed over the entire bottom and sides slopes. Venting to the atmosphere will be through vents placed as required for local conditions.
- 1.4 An anchor trench shall be excavated completely around the area to be lined at the planned elevation of the top of the lining. The trench shall be 24 inches deep and about 12 inches wide, or according to the specifications of the design drawing. Care shall be taken when constructing the trench to avoid construction equipment from coming in direct contact with the geomembrane liner.



2.0 Panel Layout

- 2.1 A layout drawing must be produced by the installer that specifies panel configuration and field seam location(s).

3.0 Identification and record keeping

- 3.1 **Record Forms:** Proper documentation must be kept in a record form containing the following information:

3.2 Panel Layout

- (A) Each panel shall be assigned a numeric or alpha-numeric identifier.
- (B) Panel configuration, showing factory seams and field seam location.

3.3 Identification

- (A) Product type
- (B) Panel identification number. (from label with bar code)
- (C) Manufacturing date. (from label with bar code)

3.4 Field Seaming

- (A) Welding equipment model and identification number
- (B) Welding Technician Name
- (C) Temperature control settings
- (D) Date
- (E) Time
- (F) Location
- (G) Ambient temperature

3.5 Seam Test Results

- (A) Vacuum test settings (typically used for extrusions welds and repairs)
- (B) Air pressure test settings (typically used for double track welds)
- (C) Seam Strength results

4.0 Location

- 4.1 Panels are to be placed in their respective locations as specified by the layout drawings. An as-built drawing must be completed indicating actual panel placement, seams and patches.

5.0 Weather Conditions

- 5.1 Unacceptable conditions for panel installation include: precipitation or the presence of any standing water, high winds, or extreme temperatures. Ideal installation air temperatures should range between 40°F and 90°F. During extremely warm or cold temperatures it is recommended that frequent trial seams are made and evaluated to ensure that the welders are properly set up for the conditions.

6.0 Method of Installation

- 6.1 The method, personnel, and equipment used for panel installation must not damage the membrane or the supporting subgrade surface. All installers must wear non-damaging footwear. Smoking or any action that may result in damage to the geomembranes in any way will not be allowed. Proper repair procedures must be followed should any damage occur.
- 6.2 Panels should be positioned to minimize handling and to allow enough slack to compensate for shrinkage.

7.0 General Field Seaming Requirements

- 7.1 There are several different types of field welding equipment available. The most common are fusion welding and extrusion fillet welding. Sewing, taping, gluing and solvent welding are not acceptable for field seaming Raven unreinforced geomembranes. Extrusion welding is preferred for repairs, patching and installing pipe boots.

7.2 Welding Equipment

(A) Fusion welding consists of placing a self-propelled hot wedge or hot air welder between two overlapped panel edges. The welders heat and melt the surface of the geomembrane and then compress the material between two rollers where the combination of heat and pressure creates a fusion weld.



(B) Extrusion fillet welding consists of extruding a bead of molten resin along the edge of a panel lapped on top of another panel. The molten resin causes the melting of each sheet, which results in a homogeneous bonding of the panels. The polyethylene rod used for welding must be compatible with the liner material.

7.3 Seaming Personnel

- 7.4 All personnel performing seaming operations must be trained on the specific equipment to be used, and the seaming techniques recommended by the equipment manufacturer. A project foreman must supervise all personnel to insure proper seaming procedures are followed.

7.5 Seaming Procedures

- 7.6 Welders must be set up and adjusted per welder manufacturer requirements. Welders must be allowed to heat up as specified by the welder manufacturer. Extrusion fillet welders must be purged of degraded material before use. Monitor and maintain proper edge overlap and operating temperature of the sealing apparatus during the seaming process.

(A) Seam Preparation

- 1 Overlap panel edges a minimum of four (4) inches, or as specified by the welder manufacturer. Extrusion fillet welding requires six (6) inch overlap.
- 2 Seal defects must be repaired; "fish mouths" must be trimmed, laid flat and patched.
- 3 Clean the welding surfaces prior to welding to assure the seam is free of moisture, dust, dirt, or any debris.
- 4 For extrusion fillet welding the surfaces do not need to be abraded (roughened). If surfaces are cleaned by abrading be careful not to abrade too much and damage the material. If damage occurs the proper repair technique must be followed.

8.0 Destructive Seam Test

- 8.1 Make test runs of the seams before beginning actual production seaming in order to make sure equipment is setup correctly. These tests should be run at least every five (5) hours. Note: These are clock hours, not operating hours.

8.2 Test Seam Description

- 8.3 Test seams shall be performed using pieces of liner long enough for the welder temperatures to stabilize. Follow the welder manufacturer's recommendations. At a minimum, fusion welded seam samples will be 10 feet long and extrusion welded seams 3 feet long. Cut test specimens from the end of the test seams. Test seams must be made under the same conditions as the actual sealing process.

8.4 Peel Test Procedure

- (A) Unless otherwise required, only seam peel tests need to be done in the field. For unreinforced geomembrane seam peel should be tested in accordance with ASTM D 6392 using the 90° T-peel method. Test five samples one inch wide, pulled at a rate of 20 inches/minute using a field tensiometer. The failure must be a film tear bond (FTB). A FTB is failure of one of the parts of a ply by tearing, instead of separating from the other part of the specimen in a peel type failure. Samples that do not fail within the stroke of the field tensiometer and elongate more than 50% may be considered passing.

Unless otherwise required, 4 passing samples out of 5 will be acceptable. If more specimens fail in a peel type mode, the procedure shall be repeated using another set of samples. If the second set of specimens fails, the welding procedure shall not be accepted until the deficiencies are corrected and a passing seam is achieved. See the procedure for removal of bad seams in Section 10.6. Documentation of test seams must list: peel failure mode, welding machine number, welder's name, time, date and temperature control setting.

For reinforced geomembranes seal test should be performed per ASTM D4437-99.

9.0 NON-DESTRUCTIVE SEAM TEST

- 9.1 100 Percent of the field seams will be tested for leaks. The preferred test methods are vacuum box and air pressure testing

- 9.2 **Vacuum Test Equipment:** The vacuum box consists of a rigid housing with a clear viewing window, soft neoprene gasket, valve assembly, vacuum gauge, pressure controlled vacuum pump, and container of soapy solution. Vacuum box and procedures should be in accordance with ASTM D-5641.

9.3 Vacuum Testing Procedure

- (A) Trim excess overlap from seal, if any, and apply a generous amount of soapy solution to test area.
- (B) Place the box over the area and press downward to "seat" the gasket strip against the liner to ensure a leak tight seal.
- (C) Close the bleed valve and open the vacuum valve. Apply a minimum of eight inches of Hg. (4 PSI.) vacuum.
- (D) Monitor, at least 10 seconds, for air bubbles forming on the inside of the gasket.

- (E) If no bubbles appear after 10 seconds, close the vacuum valve and open bleed valve. Continue along the seam maintaining at least a three (3) inch overlap between test areas. All field seams and repairs must be inspected in this manner except for seams that can be tested using the air pressure method.
- (F) If bubbles appear, mark all areas and follow proper repair procedures before rechecking.
- (G) Record test data including: date of seam fabrication, date of test, ambient temperature, typical vacuum pressure, hold duration, foaming solution, and location and size of all defects

NOTE: 1 inch of Hg. (mercury) = .5 P.S.I.
1 Bar = 14.5 P.S.I.
1 P.S.I = 6.8 kPa

9.4 Air Pressure Testing

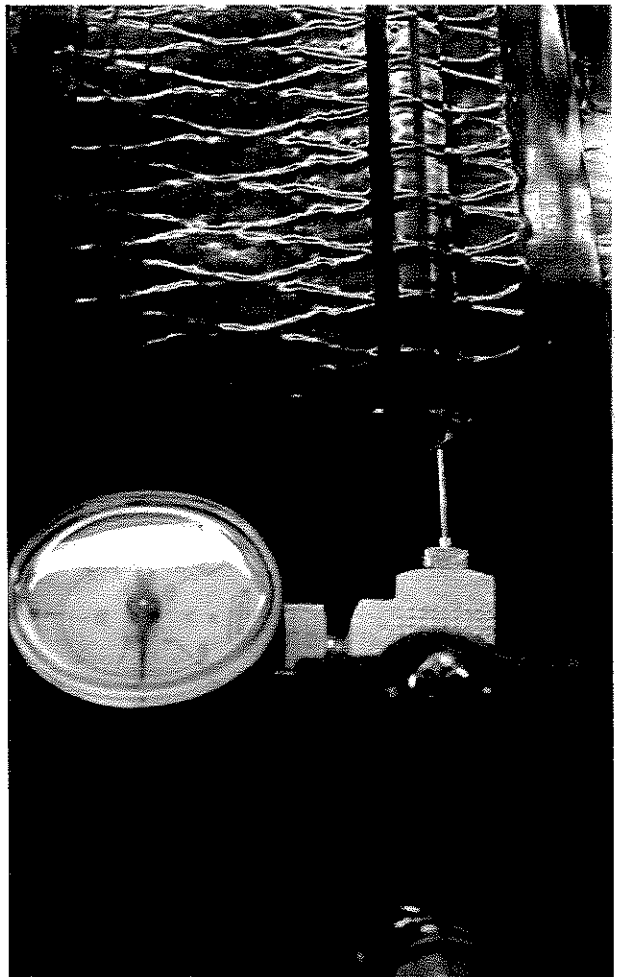
The wedge welded seam process creates a hollow channel approximately 3/8 of an inch between the two weld seal. The sealed channel is inflated to a predetermined air pressure and is observed over a period of time for stability. This test should be performed in accordance with ASTM D-5820

9.5 Air Pressure Testing Equipment

- (A) An air pump capable of generating and sustaining pressures up to 30 P.S.I. is required.

9.6 Air Pressure Testing Procedure

- (A) Seal both ends of the seam to be tested and insert a pressure feed device into sealed channel. Unless other requirements are given the following pressures and times may be used. Inflate to a pressure in accordance with the following chart, close valve, and observe the initial pressure after 2 minutes



(B) **Initial Pressure**

<u>Material (Mil)</u>	<u>Min. PSI</u>	<u>Max. PSI</u>	<u>PSI Diff.</u>
20-45	20	25	4

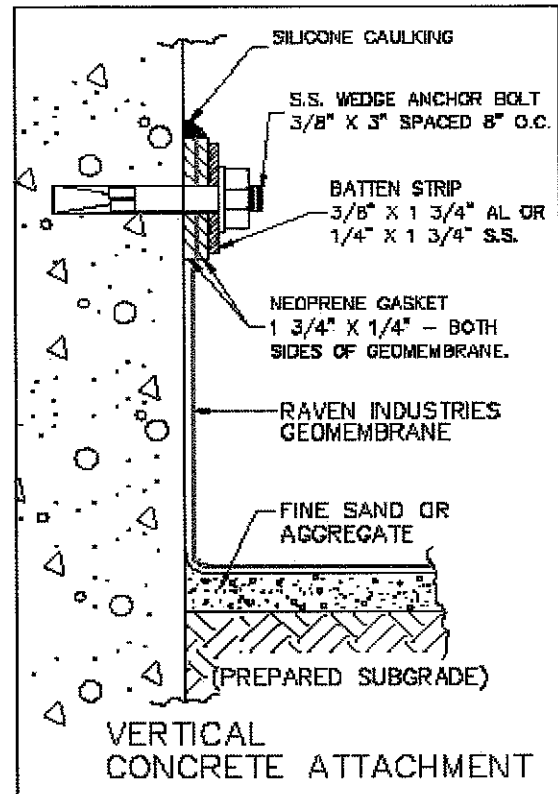
NOTE: If gauges are in bars use 1 Bar = 14.5 P.S.I.

- (C) Initial pressure settings are read after a two minute relaxing period. The air is given time to stabilize during the period.
- (D) Observe and record the air pressure 5 minutes after the relaxation period ends. Subtract this pressure from the initial pressure and compare it to the allowable maximum pressure difference listed in the initial Pressure Chart. (See 9.6 B). If pressure does not stabilize, locate and repair the faulty area. At the conclusion of the pressure test the end of the seam opposite the pressure gauge is cut. A decrease in the gauge pressure must be observed or the channel will be considered blocked and the test will have to be repeated after the blockage is removed.
- (E) Remove the pressure feed device and seal the resulting hole by extrusion welding.
- (F) Record test data including: date of seam fabrication, date of test, ambient temperature, inflation pressure, hold duration, pressure after hold, and location and size of all defects

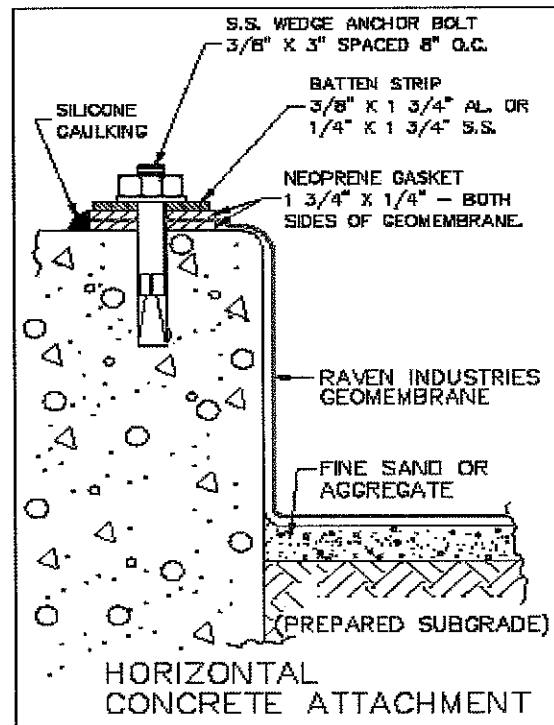
10.0 **Defects and Repairs**

- 10.1 All defects and repairs must be marked, repaired, and documented. A complete search must be conducted throughout the entire surface of the geomembrane. Defects may consist of holes, snags, or any penetrations.
- 10.2 Small holes or snags 1/4" in diameter or less, may be repaired using the extrusion welding process.
- 10.3 Large holes or tears larger than 1/4" in diameter must be repaired by "overlaying" a patch consisting of the geomembrane itself. This patch must extend beyond the damaged area by at least 6" in every direction. The patch shall have all corners rounded with at least a 1 1/2 inch radius for ease of extrusion welding.

- 10.4 The patch shall be "spot welded" in place and extrusion welded around the entire perimeter.
- 10.5 All extrusion weld repairs must be vacuum tested to assure a proper repair (See 9.3).
- 10.6 Removal of bad seams shall be repaired in the same manner as large holes. The defective seam shall be removed and patched with an overlay patch and extrusion welded.
- 11.0 **Suggested Attachment to Concrete**
- 11.1 ASTM D 6497 also provides valuable attachment information. Concrete attachment areas shall be designed with rounded edges and prepared with as smooth of a surface as possible.



- 11.2 Horizontal attachments to concrete are preferred over vertical attachments if possible.
- 11.3 At the attachment point the geomembrane shall be sandwiched between two neoprene gaskets 1/4" thick x 1 1/2" wide and capped with a 1 3/8" wide x 1/4" thick stainless steel batten strip, or a 1 3/8" wide x 3/8" thick aluminum batten strip.
- 11.4 Gaskets, geomembrane, and batten strip may be attached with 3/8" Dia. x 3" long wedge type stainless steel anchor bolts 8" on center. The top edge of the gaskets and geomembrane should be caulked with a General Electric Sealer, RTV 103, or equivalent to prevent seepage behind liner. If for strictly fastening purposes only, a pressure treated wooden batten strip (2" x 4") attached to concrete by stainless steel power nails 12" on center is acceptable.



12.0 Pipe Boot Attachment

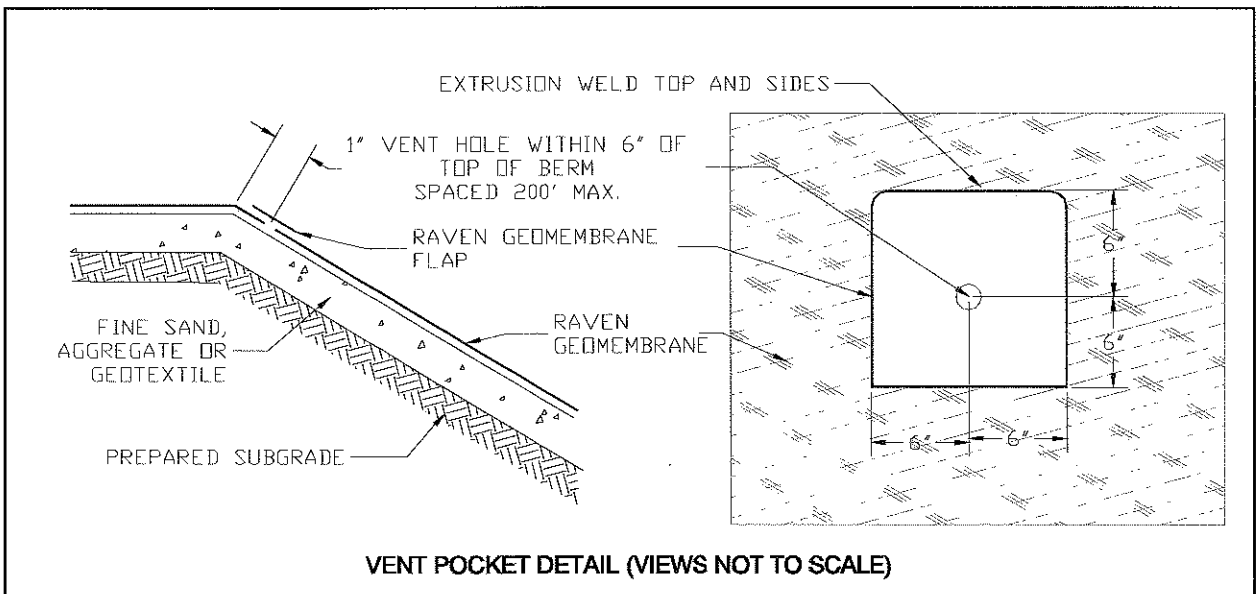
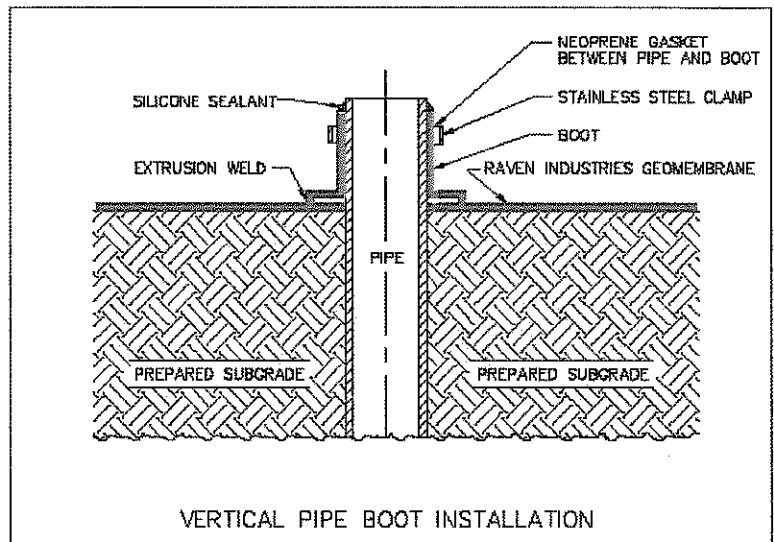
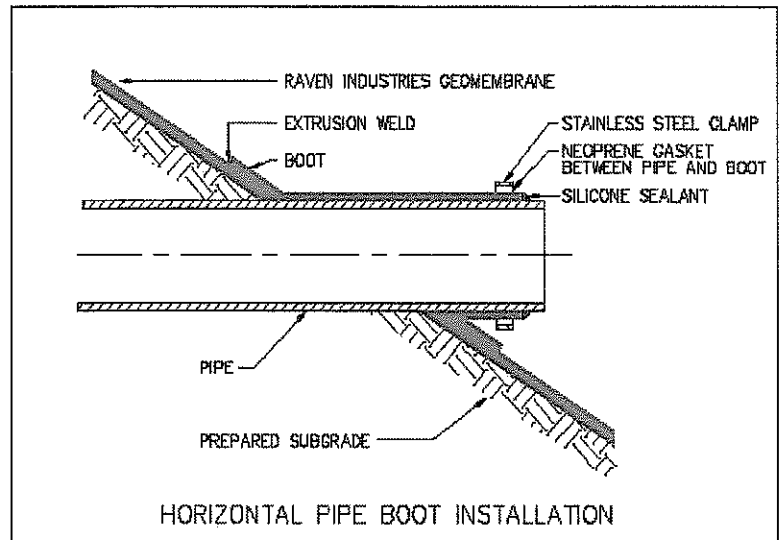
12.1 ASTM D 6497 also provides valuable attachment information. Pipe boots can be fabricated from the geomembrane. Fabrication and attachment of the boot to the geomembrane should be done with the extrusion welding process.

12.2 The geomembrane should be sealed to the pipe with a neoprene gasket and a stainless steel clamp sealed on the edge of the geomembrane with a General Electric Sealer, RTV 103, or equivalent.

NOTE:

The types of mechanical fastening will vary with the application and project. The attached drawings only demonstrate a general standard method. Strict compliance with the design engineer's specifications and recommendations is vital.

13.0 Pocket vents may be installed to allow air trapped under the geomembrane during installation or gasses given off by certain soil types to escape.





Panel Layout Log

INDUSTRIES

Project Name: _____
Location: _____
Job Number: _____
Deployment Date: _____

Site Manager: _____
Material: _____
Thickness _____

Panel Number	Roll Number(s)	Manufacturing Date	Width (feet)	Length (feet)

As built Drawing



Seam Test Log

Project Name: _____
 Location: _____
 Job Number: _____

Site Manager: _____
 Material: _____
 Thickness: _____

Destructive test log							
Date of Weld	Time Started	Ambient Temperature	Type of Weld	Temperature Settings		Machine Number	Technician ID Number

Non-destructive test log								
Seal Number	Test Date	Ambient Temperature	Vacuum pressure	Or	Air Pressure Test PSI Start Psi End		Pass/Fail	Rep

Appendix A

REINFORCED POLYETHYLENE GEOMEMBRANE SPECIFICATION

Reinforced Polyethylene Geomembranes serve as liners and covers to contain water, leachate or other liquids. As a liner they can contain the liquid to prevent leakage or environmental impact and as a cover to minimize evaporation or contamination. It is of great importance that the Reinforced Polyethylene Geomembrane be free from defects and installed without damage.

A. DESCRIPTION

1. General:

The purpose of this specification is to provide details of Manufacturing Quality Control (MQC), Manufacturing Quality Assurance (MQA), Construction Quality Control (CQC), and Construction Quality Assurance (CQA) for the manufacture and pre-assembly of geomembrane products. The Contractor shall furnish all labor, material, and equipment to install the Reinforced Polyethylene Geomembrane including all necessary and incidental items as detailed or required to complete the installation in accordance with the Contract Drawing and these Specifications

2. Related Work:

Related Contract Work is described in the following section of the specification as approved by the CQA Engineer.

3. Reference Standards:

ASTM D5199 *Standard Test Method for Measuring the Nominal Thickness of Geosynthetics.*

ASTM D5261 *Standard Test Method for Measuring Mass per Unit Area of Geotextiles.*

ASTM D6636 *Standard Test Method for Determination of Ply Adhesion Strength of Reinforced Geomembranes.*

ASTM D7003 *Standard Test Method for Strip Tensile Properties of Reinforced Geomembranes.*

ASTM D5884 *Standard Test Method for Determining Tearing Strength of Internally Reinforced Geomembranes.*

ASTM D7004 Standard Test Method for Grab Tensile Properties of Reinforced Geomembranes.

ASTM D4533 Standard Test Method for Trapezoid Tearing Strength of Geotextiles.

ASTM D4833 Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products.

4. Quality Assurance:

Quality Assurance during installation of Reinforced Polyethylene Geomembrane will be provided by the Owner as described in the accompanying Project CQA Manual.

5. Manufacturers Qualifications:

- a. The Manufacturer shall have previously demonstrated his ability to produce the required Reinforced Polyethylene Geomembrane by having successfully manufactured a minimum of 10,000,000 ft² of scrim reinforced Polyethylene Geomembrane.
- b. Manufacturer must be ISO 9001 certified

6. Installer Qualifications:

The Reinforced Polyethylene Geomembrane Installer shall have installed a minimum of 500,000 ft² of Reinforced Polyethylene Geomembrane (or similar material).

7. Warranties:

The manufacturer of the Reinforced Polyethylene Geomembrane will warrant the material to the installer on a pro rata basis for up to 20 years after the final acceptance of the work, based on thickness of product, the application and location of the installation. This warranty shall include but not be limited to defects related to workmanship and manufacturing.

B. MATERIALS

1. General:

The materials supplied under these Specifications shall consist of first-quality 100% virgin products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes.

2. Reinforced Polyethylene Geomembrane Materials:

a. Reinforced Polyethylene Geomembrane shall be manufactured to meet the following requirements:

- (1) Provide finished product free from holes, pin holes, bubbles, blisters, excessive gels, undispersed resins and/or carbon black, or contamination by foreign matter.
- (2) Reinforced Polyethylene Geomembrane shall be a Linear Low Density Polyethylene Geomembrane composed of a heavy encapsulated 1300 denier polyester tri-directional reinforcement.

b. Approved Reinforced Polyethylene Geomembrane:

- (1) Dura-Skrim J30BB
Dura-Skrim J36BB
Dura-Skrim J45BB

NSF 61 Certified Geomembranes

Dura-Skrim J30WB6
Dura-Skrim J36WB6
Dura-Skrim J45WB6

As manufactured by Raven Industries of Sioux Falls, SD.

- (2) Equal material, as approved by the Engineer.

C. FACTORY FABRICATION

1. The Reinforced Polyethylene Geomembrane shall be supplied in panels which shall be of maximum size to provide the largest manageable sheet for the fewest seams.
2. Factory seams are produced by thermal sealing methods and shall have a minimum seam width of 1 ½ inch scrim to scrim.
3. Factory seams are 100% visually inspected and destructive testing is done to verify quality compliance.
4. Labels on the panels shall identify the thickness, length, width, lot and panel numbers, and name of Manufacturer.
5. Factory pre-assembled panels are accordion folded and rolled on a cardboard core. Rolled panels are wrapped in a protective layer for shipment.

D. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Pre-Installation Requirements:

Prior to Reinforced Polyethylene Geomembrane installation the Contractor shall submit the following:

- a. Certificate of Conformance and Sample: Prior to shipping to the site, the Contractor shall submit a certificate or affidavit signed by a legally authorized official of the Manufacturer for the Reinforced Polyethylene Geomembrane attesting that the Reinforced Polyethylene Geomembrane meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample of the Reinforced Polyethylene Geomembrane to be used (sample may be of different color). The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.
- b. Shipping, Handling, and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.
- c. Installation Procedures:

Submit installation procedures for carrying out the work. Installation procedures to be addressed shall include but not be limited to material installation, repair, and protection to be provided in the event of rain or strong winds. With regard to protection, the Contractor shall provide a plan of anchoring the Reinforced Polyethylene Geomembrane sufficient to satisfy the Contractor's Performance Warranty. This plan shall be approved by the Engineer prior to construction.

- d. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

2. Post-Installation Requirements:

Upon completion of the Reinforced Polyethylene Geomembrane installation, the Contractor shall submit the following:

- a. Completed material performance warranty.

E. SITE PREPERATION AND INSTALLATION

- 1. Installation shall be in done in accordance with the manufactures Geomembrane Installation Guidelines.

**TABLE 1:
REQUIRED REINFORCED POLYETHYLENE GEOMEMBRANE PROPERTIES
30 MIL.**

PROPERTY	TEST METHOD	UNITS	MIMUM ROLL AVERAGES	TYPICAL ROLL AVERAGES
Thickness	ASTM D5199	Mils	27	30
Weight	ASTM D5261	Lbs.	126	140
Ply Adhesion	ASTM D6636	Lbs.	16	20
1" strip tensile	ASTM D7003	Lbf.	88 MD 63 DD	110 MD 79 DD

Tongue Tear	ASTM D5884	Lbf.	75 MD 75 DD	97 MD 90 DD
Grab Tensile Strength	ASTM D7004	Lbf.	180 MD 180 DD	218 MD 210 DD
Trap Tear	ASTM D4533	Lbf.	120 MD 120 DD	146 MD 141 DD
Puncture Resistance	ASTM D4833	Lbf.	50	64

MD Machine Direction DD Diagonal Direction

TABLE 2:
REQUIRED REINFORCED POLYETHYLENE GEOMEMBRANE PROPERTIES
36 MIL.

PROPERTY	TEST METHOD	UNITS	MINIMUM ROLL AVERAGES	TYPICAL ROLL AVERAGES
Thickness	ASTM D5199	Mils	32	36
Weight	ASTM D5261	Lbs.	151	168
Ply Adhesion	ASTM D6636	Lbs.	19	224
1" strip tensile	ASTM D7003	Lbf.	90 MD 70 DD	113 MD 87 DD
Tongue Tear	ASTM D5884	Lbf.	75 MD 75 DD	104 MD 92 DD
Grab Tensile Strength	ASTM D7004	Lbf.	180 MD 180 DD	222 MD 223 DD
Trap Tear	ASTM D4533	Lbf.	130 MD 130 DD	189 MD 172 DD
Puncture Resistance	ASTM D4833	Lbf.	65	83

MD Machine Direction DD Diagonal Direction

TABLE 3:

**REQUIRED REINFORCED POLYETHYLENE GEOMEMBRANE
PROPERTIES 45 MIL.**

PROPERTY	TEST METHOD	UNITS	MINIMUM ROLL AVERAGES	TYPICAL ROLL AVERAGES
Thickness	ASTM D5199	Mils	40	45
Weight	ASTM D5261	Lbs.	189	210
Ply Adhesion	ASTM D6636	Lbs.	25	31
1" strip tensile	ASTM D7003	Lbf.	110 MD 84 DD	138 MD 105 DD
Tongue Tear	ASTM D5884	Lbf.	100 MD 100 DD	117 MD 118 DD
Grab Tensile Strength	ASTM D7004	Lbf.	220 MD 220 DD	257 MD 258 DD
Trap Tear	ASTM D4533	Lbf.	160 MD 160 DD	193 MD 191 DD
Puncture Resistance	ASTM D4833	Lbf.	80	99

MD Machine Direction DD Diagonal Direction

Notes:

1. The Engineer may allow alternates to these requirements.

Appendix B

ENHANCED GRIP UN-REINFORCED POLYETHYLENE GEOMEMBRANE SPECIFICATION

Enhanced Grip Un-reinforced Polyethylene Geomembranes serve as liners to contain water, leachate or other liquids. As a liner they can contain the liquid to prevent leakage or environmental impact. It is of great importance that the Enhanced Grip Un-reinforced Polyethylene Geomembrane be free from defects and installed without damage.

A. DESCRIPTION

1. General:

The purpose of this specification is to provide details of Manufacturing Quality Control (MQC), Manufacturing Quality Assurance (MQA), Construction Quality Control (CQC), and Construction Quality Assurance (CQA) for the manufacture and pre-assembly of geomembrane products. The Contractor shall furnish all labor, material, and equipment to install the Enhanced Grip Un-reinforced Polyethylene Geomembrane including all necessary and incidental items as detailed or required to complete the installation in accordance with the Contract Drawing and these Specifications

2. Related Work:

Related Contract Work is described in the following section of the specification as approved by the CQA Engineer.

3. Reference Standards:

ASTM D5199 *Standard Test Method for Measuring the Nominal Thickness of Geosynthetics.*

ASTM D5261 *Standard Test Method for Measuring Mass per Unit Area of Geotextiles.*

ASTM D4882 *Standard Test Method for Tensile Properties of Thin Plastic Sheeting.*

ASTM D4833 *Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products.*

ASTM D1709 Standard Test Methods for Impact Resistance of Plastic Film by the Free-Falling Dart Method.

4. Quality Assurance:

Quality Assurance during installation of Enhanced Grip Un-reinforced Polyethylene Geomembrane will be provided by the Owner as described in the accompanying Project CQA Manual.

5. Manufacturers Qualifications:

- a. The Manufacturer shall have previously demonstrated his ability to produce the required Enhanced Grip Un-reinforced Polyethylene Geomembrane by having successfully manufactured a minimum of 10,000,000 ft² of Enhanced Grip Un-reinforced Polyethylene Geomembrane.
- b. Manufacturer must be ISO 9001 certified

6. Installer Qualifications:

The Enhanced Grip Un-reinforced Polyethylene Geomembrane Installer shall have installed a minimum of 500,000 ft² of Enhanced Grip Un-reinforced Polyethylene Geomembrane (or similar material).

7. Warranties:

The manufacturer of the Enhanced Grip Un-reinforced Polyethylene Geomembrane will warrant the material to the installer on a pro rata basis for up to 15 years after the final acceptance of the work, based on the application and location of the installation. This warranty shall include but not be limited to defects related to workmanship and manufacturing.

B. MATERIALS

1. General:

The materials supplied under these Specifications shall consist of first-quality 100% virgin products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes.

2. Enhanced Grip Un-reinforced Polyethylene Geomembrane Materials:

- a. Enhanced Grip Un-reinforced Polyethylene Geomembrane shall be manufactured to meet the following requirements:

- (1) Provide finished product free from holes, pin holes, bubbles, blisters, excessive gels, undispersed resins and/or carbon black, or contamination by foreign matter.
 - (2) Enhanced Grip Un-reinforced Polyethylene Geomembrane shall be a multi-layer Premium Linear Low Density Polyethylene Geomembrane
- b. Approved Enhanced Grip Un-reinforced Polyethylene Geomembrane:
- (1) Rufco E30BS

As manufactured by Raven Industries of Sioux Falls, SD.
 - (2) Equal material, as approved by the Engineer.

C. FACTORY FABRICATION

1. The Enhanced Grip Un-reinforced Polyethylene Geomembrane shall be supplied in panels which shall be of maximum size to provide the largest manageable sheet for the fewest seams.
2. Factory seams are produced by thermal sealing methods and shall have a minimum seam width of 1 ½ inch.
3. Factory seams are 100% visually inspected and destructive testing is done to verify quality compliance.
4. Labels on the panels shall identify the thickness, length, width, lot and panel numbers, and name of Manufacturer.
5. Factory pre-assembled panels are accordion folded and rolled on a cardboard core. Rolled panels are wrapped in a protective layer for shipment.

D. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Pre-Installation Requirements:

Prior to Enhanced Grip Un-reinforced Polyethylene Geomembrane installation the Contractor shall submit the following:

- a. Certificate of Conformance and Sample: Prior to shipping to the site, the Contractor shall submit a certificate or affidavit signed by a legally authorized official of the Manufacturer for the Enhanced Grip Un-reinforced Polyethylene Geomembrane attesting that the Enhanced Grip Un-reinforced Polyethylene Geomembrane meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample of the Enhanced Grip Un-reinforced Polyethylene Geomembrane to be used (sample may be of different color). The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.
- b. Shipping, Handling, and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.
- c. Installation Procedures:

Submit installation procedures for carrying out the work. Installation procedures to be addressed shall include but not be limited to material installation, repair, and protection to be provided in the event of rain or strong winds. With regard to protection, the Contractor shall provide a plan of anchoring the Enhanced Grip Un-reinforced Polyethylene Geomembrane sufficient to satisfy the Contractor's Performance Warranty. This plan shall be approved by the Engineer prior to construction.
- d. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

2. Post-Installation Requirements:

Upon completion of the Enhanced Grip Un-reinforced Polyethylene Geomembrane installation, the Contractor shall submit the following:

- a. Completed material performance warranty.

E. SITE PREPERATION AND INSTALLATION

1. Installation shall be in done in accordance with the manufactures Geomembrane Installation Guidelines.

**TABLE 1:
REQUIRED ENHANCED GRIP UN-REINFORCED POLYETHYLENE
GEOMEMBRANE PROPERTIES 30 MIL.**

PROPERTY	TEST METHOD	UNITS	TYPICAL ROLL AVERAGES
Thickness	ASTM D5199	Mils	30
Weight	ASTM D751	Lbs.	150
1" strip tensile	ASTM D882	Lbf.	127
Tensile Elongation	ASTM D882	%	850
Impact Resistance	ASTM D1709	g.	3440
Puncture Resistance	ASTM D4833	Lbf.	54

Tests are average of machine and transverse directions

Appendix C
LINEAR LOW DENSITY POLYETHYLENE GEOMEMBRANE
SPECIFICATION

Linear Low Density Polyethylene (LLDPE) Geomembranes serve as liners and covers to contain water, leachate or other liquids. As a liner they can contain the liquid to prevent leakage or environmental impact and as a cover to minimize evaporation or contamination. It is of great importance that the LLDPE Geomembrane be free from defects and installed without damage.

A. DESCRIPTION

1. General:

The purpose of this specification is to provide details of Manufacturing Quality Control (MQC), Manufacturing Quality Assurance (MQA), Construction Quality Control (CQC), and Construction Quality Assurance (CQA) for the manufacture and pre-assembly of geomembrane products. The Contractor shall furnish all labor, material, and equipment to install the LLDPE Geomembrane including all necessary and incidental items as detailed or required to complete the installation in accordance with the Contract Drawing and these Specifications

2. Related Work:

Related Contract Work is described in the following section of the specification as approved by the CQA Engineer.

3. Reference Standards:

Geosynthetic Research Institute Test Method GM17 *Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes.*

ASTM D5199 *Standard Test Method for Measuring the Nominal Thickness of Geosynthetics.*

ASTM D1505 *Standard Test Method for Density of Plastics by the Density-Gradient Technique.*

ASTM 638 *Standard Test Method for Tensile Properties of Plastics.*

ASTM D751 *Standard Test Methods for Coated Fabrics.*

ASTM D1004 *Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting.*

ASTM D1603 *Standard Test Method for Carbon Black Content in Olefin Plastics.*

ASTM D4833 *Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products.*

4. Quality Assurance:

Quality Assurance during installation of LLDPE Geomembrane will be provided by the Owner as described in the accompanying Project CQA Manual.

5. Manufacturers Qualifications:

- a. The Manufacturer shall have previously demonstrated his ability to produce the required LLDPE Geomembrane by having successfully manufactured a minimum of 10,000,000 ft² of LLDPE Geomembrane.
- b. Manufacturer must be ISO 9001 certified

6. Installer Qualifications:

The LLDPE Geomembrane Installer shall have installed a minimum of 500,000 ft² of LLDPE Geomembrane (or similar material).

7. Warranties:

The manufacturer of the LLDPE Geomembrane will warrant the material to the installer on a pro rata basis for up to 20 years after the final acceptance of the work, based on thickness, the application and location of the installation. This warranty shall include but not be limited to defects related to workmanship and manufacturing.

B. MATERIALS

1. General:

The materials supplied under these Specifications shall consist of first-quality 100% virgin products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes.

2. LLDPE Geomembrane Materials:

a. LLDPE Geomembrane shall be manufactured to meet the following requirements:

- (1) Provide finished product free from holes, pin holes, bubbles, blisters, excessive gels, undispersed resins and/or carbon black, or contamination by foreign matter.
- (2) LLDPE Geomembrane shall be a very flexible Linear Low Density Polyethylene Geomembrane containing carbon black for UV stability and contain no plasticizers.

b. Approved LLDPE Geomembrane:

- (1) Rufco 2000B
Rufco 3000B
Rufco 4000B

As manufactured by Raven Industries of Sioux Falls, SD.

- (2) Equal material, as approved by the Engineer.

C. FACTORY FABRICATION

1. The LLDPE Geomembrane shall be supplied in panels which shall be of maximum size to provide the largest manageable sheet for the fewest seams.
2. Factory seams are produced by thermal sealing methods and shall have a minimum seam width of 1 ½ inch.
3. Factory seams are 100% visually inspected and destructive testing is done to verify quality compliance.
4. Labels on the panels shall identify the thickness, length, width, lot and panel numbers, and name of Manufacturer.

5. Factory pre-assembled panels are accordion folded and rolled on a cardboard core. Rolled panels are wrapped in a protective layer for shipment.

D. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Pre-Installation Requirements:

Prior to LLDPE Geomembrane installation the Contractor shall submit the following:

- a. Certificate of Conformance and Sample: Prior to shipping to the site, the Contractor shall submit a certificate or affidavit signed by a legally authorized official of the Manufacturer for the LLDPE Geomembrane attesting that the LLDPE Geomembrane meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample of the LLDPE Geomembrane to be used (sample may be of different color). The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.
- b. Shipping, Handling, and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.
- c. Installation Procedures:

Submit installation procedures for carrying out the work. Installation procedures to be addressed shall include but not be limited to material installation, repair, and protection to be provided in the event of rain or strong winds. With regard to protection, the Contractor shall provide a plan of anchoring the LLDPE Geomembrane sufficient to satisfy the Contractor's Performance Warranty. This plan shall be approved by the Engineer prior to construction.
- d. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

2. Post-Installation Requirements:

Upon completion of the LLDPE Geomembrane installation, the Contractor shall submit the following:

- a. Completed material performance warranty.

E. SITE PREPERATION AND INSTALLATION

1. Installation shall be in done in accordance with the manufactures Geomembrane Installation Guidelines.

**TABLE 1:
REQUIRED LLDPE GEOMEMBRANE PROPERTIES 20 MIL.**

PROPERTY	TEST METHOD	UNITS	MIMUM ROLL AVERAGES	TYPICAL ROLL AVERAGES
Thickness	ASTM D5199	Mils	20	21
Density	ASTM D1505	g/cm ³	.939 max	.939 max
1" strip tensile	ASTM D638	Lbf.	76	104
Tensile elongation	ASTM D638	%	800	875
Hydrostatic Resistance	ASTM D751	psi.	118	122
Puncture Resistance	ASTM D4833	Lbf.	30	44
Tear Resistance	ASTM D1004	Lbf.	11	14
Carbon Black	ASTM D1603	%	2.0	2.5
Bonded Seam Strength	ASTM D4545*	Lbf/inch	40	45
Seam Peel Adhesion	ASTM D4545*	Lbf/inch	30	36

Seam testing performed at 12" per minute

**TABLE 2:
REQUIRED LLDPE GEOMEMBRANE PROPERTIES 30 MIL.**

PROPERTY	TEST METHOD	UNITS	MINIMUM ROLL AVERAGES	TYPICAL ROLL AVERAGES
Thickness	ASTM D5199	Mils	30	31.2
Density	ASTM D1505	g/cm ³	.939 max	.939 max
1" strip tensile	ASTM D638	Lbf.	114	144
Tensile elongation	ASTM D638	%	800	875
Hydrostatic Resistance	ASTM D751	psi.	175	180
Puncture Resistance	ASTM D4833	Lbf.	45	60
Tear Resistance	ASTM D1004	Lbf.	16	20
Carbon Black	ASTM D1603	%	2.0	2.5
Bonded Seam Strength	ASTM D4545*	Lbf/inch	60	68
Seam Peel Adhesion	ASTM D4545*	Lbf/inch	45	53

Seam testing performed at 12" per minute

**TABLE 3:
REQUIRED LLDPE GEOMEMBRANE PROPERTIES 40 MIL.**

PROPERTY	TEST METHOD	UNITS	MINIMUM ROLL AVERAGES	TYPICAL ROLL AVERAGES
Thickness	ASTM D5199	Mils	40	41.5
Density	ASTM D1505	g/cm ³	.939 max	.939 max
1" strip tensile	ASTM D638	Lbf.	152	185
Tensile elongation	ASTM D638	%	800	875
Hydrostatic Resistance	ASTM D751	psi.	230	250

Puncture Resistance	ASTM D4833	Lbf.	60	75
Tear Resistance	ASTM D1004	Lbf.	22	27
Carbon Black	ASTM D1603	%	2.0	2.5
Bonded Seam Strength	ASTM D4545*	Lbf/inch	75	80
Seam Peel Adhesion	ASTM D4545*	Lbf/inch	60	69

Seam testing performed at 12" per minute

Notes:

1. The Engineer may allow alternates to these requirements.