01630584

FORM 15 Rev 6/99

State of Colorado
Oil and Gas Conservation Commission

1120 Lincoln Street, Suite 801, Denver, Colorado 80203 (303)894-2100 Fax:(303)894-2109

FOR OGCC USE ONLY

S

EARTHEN PIT REPORT/PERMIT

This form is to be used for both reporting and permitting pits. Rule 903 describes when a Permit with prior approval, or a Report within 30 days, is required for pits. Submit required attachments and forms.

Complete the Attachment Checklist

	Oper	OGCC
Detailed Site Plan	✓	
Topo Map w/ Pit Location	✓	
Water Analysis (Form 25)		
Source Wells (Form 26)		
Pit Design/Plan & Cross Sect	✓	
Design Calculations	✓	
Sensitive Area Determ.	✓	
Mud Program		
Form 2A		

FORM SUBMITTED FOR:

☐ Pit Report ☑ Pit Permit

OGCC Operator Number: 19160

Name of Operator: ConocoPhillips Company

Address: 743 Horizon Court, Suite 201

City: Grand Junction State: CO Zip: 81506

Contact Name and Telephone: Justin B. Lovato

No: 970.263.3123

Fax: 970.263.3124

API Number (of associated well): 05-045-14297 OGCC Facility ID (of other associated facility): N. Parachute CP14B-21 G21 59

Pit Location (QtrQtr, Sec, Twp, Rng, Meridian): SWNE 21 5S 96W

Latitude: N 39.602503 Longitude: W -108.172519 County: Garfield

Pit Use: ☑ Production ☐ Drilling (Attach mud program) ☐ Special Purpose (Describe Use):

Pit Type: ☑ Lined ☐ Unlined Surface Discharge Permit: ☐ Yes ☑ No

Offsite disposal of pit contents: ☐ Injection ☐ Commercial Pit/Facility Name: G21 Pit/Facility No: G21

Attach Form 26 to identify Source Wells and Form 25 to provide Produced Water Analysis results.

Existing Site Conditions

Is the location in a "Sensitive Area?" ☐ Yes ☑ No **Attach data used for determination.**

Distance (in feet) to nearest surface water: 1,441 ground water: > 6.67 ft water wells: 1.78 miles

LAND USE (or attach copy of Form 2A if previously submitted for associated well) Select one which best describes land use:

Crop Land: ☐ Irrigated ☐ Dry Land ☐ Improved Pasture ☐ Hay Meadow ☐ CRP

Non-Crop Land: ☑ Rangeland ☐ Timber ☐ Recreational ☐ Other (describe):

Subdivided: ☐ Industrial ☐ Commercial ☐ Residential

SOILS (or attach copy of Form 2A if previously submitted for associated well)

Soil map units form USNRCS survey: Sheet No: N/A Soil Complex/Series No: 56 and 46

Soils Series Name: Parachute-Irigul-Rhone association Horizon thickness (in inches): A: 0-10 ; B: 10-55 ; C: 55-59

Soils Series Name: Happle-Rock outcrop association Horizon thickness (in inches): A: 0-7 ; B: 7-60 ; C: 60+

Attach detailed site plan and topo map with pit location.

Pit Design and Construction

Size of pit (feet): Length: 200 Width: 96.09 Depth: 15.94

Calculated pit volume (bbls): 36,280 Daily inflow rate (bbls/day): variable

Daily disposal rates (attach calculations): Evaporation: Minimal bbls/day Percolation: N/A bbls/day

Type of liner material: Reinfornced Polyethylene Thickness: 36 mil top layer/ 24 mil bottom layer

Attach description of proposed design and construction (include sketches and calculations).

Method of treatment of produced water prior to discharge into pit (separator, heater treater, other): Separtor

Is pit fenced? ☑ Yes ☐ No Is pit netted? ☑ Yes ☐ No

I hereby certify that the statements made in this form are, to the best of my knowledge, true, correct, and complete.

Print Name: Justin B. Lovato Signed: [signature]

Title: Project Lead Date:

OGCC Approved: Chris Canfield Title: EPS - NW Area Date: 4/13/09

CONDITIONS OF APPROVAL, IF ANY:

FACILITY NUMBER: 414390

JAK

ConocoPhillips

January 6, 2008

Chris Canfield
Environmental Protection Specialist
Oil and Gas Conservation Commission
707 Wapiti Ct. Suite 204
Rifle, CO 81650

ConocoPhillips Company
744 Horizon Ct. Suite 201
Grand Junction, CO 81506
970/263.3123 phone
970/263.3124 fax

Re: Form 15 Application – G21

Dear Mr. Canfield,

Enclosed is the COGCC application Form 15 with attachments for the produced water pit referenced as the G21, owned by ConocoPhillips Company (COP). This location is found in the SWNE of Section 21, T5S, R96W, 6th P.M. The enclosures include:

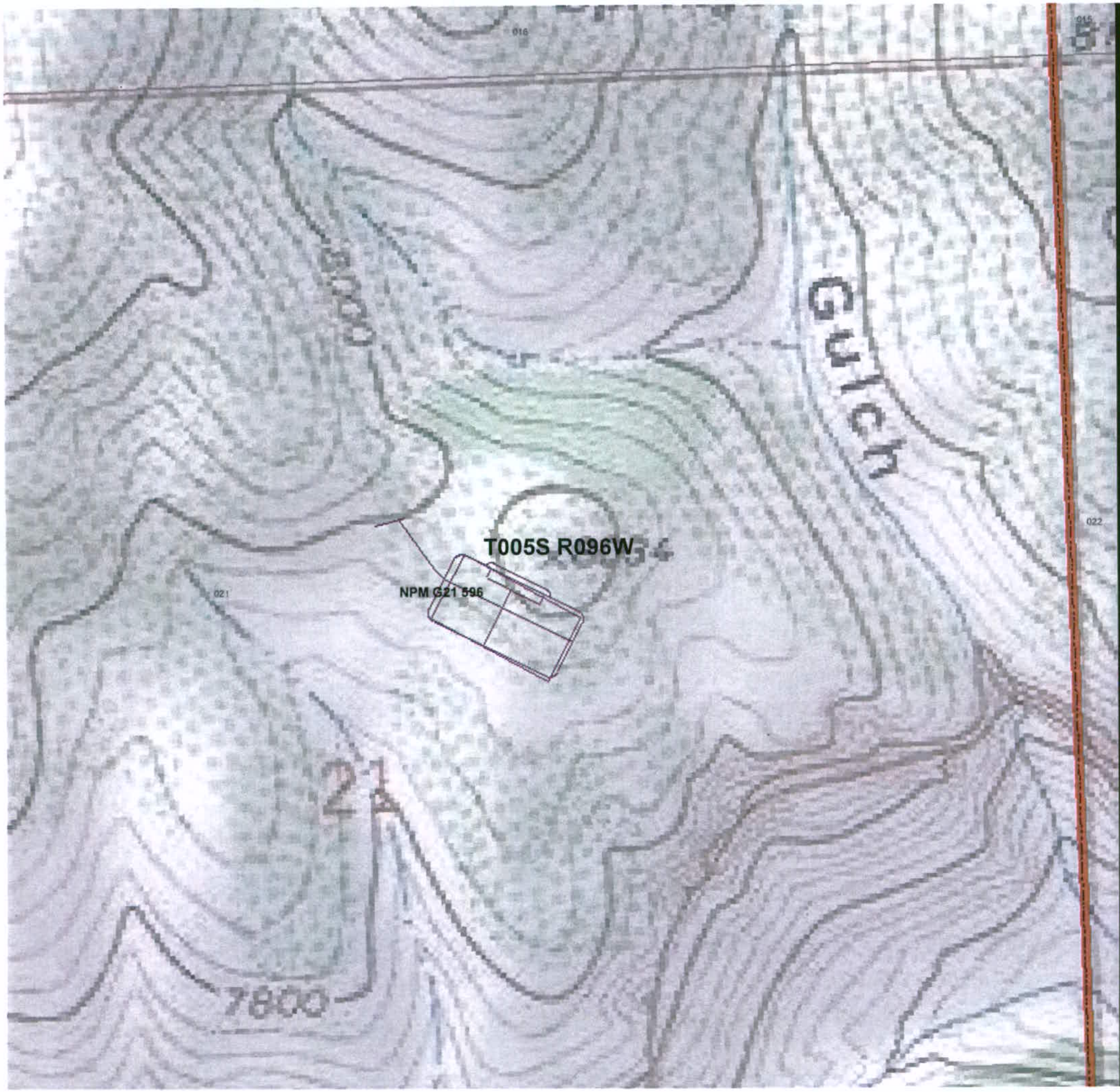
1. COGCC Form 15
2. Topographic Site Map
3. Geosynthetics Intsallation and Testing Specifications
4. Earthwork and Leak Detection Well Specifications
5. Pit Design Calculations
6. Surface Plan and Profile Details
7. Sensitive Area Determination

A surface impoundment is the preferred choice for storage of produced water (completion fluid) instead of "frac tanks" as less surface space is taken. This pit will have the capacity to hold 36,280 bbls with 2 feet of freeboard. Frac tanks also require trucking to and from the site. Please note that the G21 will be lined with a synthetic liner, fenced and netted.

We appreciate your consideration in this matter. If you have any questions or need additional information, please don't hesitate to call me at (970) 263-3123.

Best Regards,

Justin B. Lovato
Project Lead



Topographic Facility Map
G 21

ConocoPhillips

Revision Date: 11/18/08

Surface Landowner

- Bureau of Land Management
- State
- Private
- Other Federal

Other Structural and Non-structural

- Guardshack
- County Line
- Streams

Comments:

01630585

N W E S

HRL COMPLIANCE SOLUTIONS, INC.

0 135 270 540 810 1,080 Feet

01630586

Samuel Engineering, Inc.
We Provide Solutions

8450 E. Crescent Parkway, Suite 200
Greenwood Village, Colorado 80111-2855

Tel: 303-714-4840
Fax: 303-714-4800

PERFORMANCE SPECIFICATION

SPECIFICATION 02530

GEOSYNTHETICS INSTALLATION AND TESTING

FOR

ConocoPhillips

G-21 Produced Water Pit Geosynthetic Lining System
SE Project 8053-14

Orig./Lead Eng.: Melissa C Lambert Date 1/6/09

Project Engineer Approval: Melissa C Lambert Date 1/6/09

Project Manager Approval: [signature] Date 1/6/09

Client Approval: ____________ Date ____________

Rev. No.	By	Revisions	Approval	Date
0	JM	ISSUED FOR CONSTRUCTION		

1.0 GENERAL

A. This specification establishes the quality of materials and workmanship and defines how quality is measured for geosynthetic materials to be manufactured and installed for the N-07 Drill Pad as part of the Piceance Basin Project on the Roan Plateau, Garfield County CO.

B. The word "Owner", as used here, shall mean Conoco Phillips.

C. Measurement shall be made of the total surface area in square feet covered by the geosynthetic. Final quantities will be based on as-built conditions. Allowance will be made for geosynthetic in anchor and drainage trenches; however, no allowance will be made for waste, overlap, repairs, or materials used for the convenience of the Contractor.

2.0 ABBREVIATIONS

ASTM .... American Society for Testing Materials

HDPE................. High Density Polyethylene

LLDPE................ Linear Low Density Polyethylene

RPE.................... Reinforced Polyethylene

LDS.................... Leak Detection System

3.0 CODES AND STANDARDS

ASTM D751 (2006)	Standard Test Methods for Coated Fabrics
ASTM D413 98(2007)	Standard Test Methods for Rubber Property—Adhesion to Flexible Substrate
ASTM D 1004 (2007)	Initial Tear Resistance of Plastic Film and Sheeting
ASTM D 1203 (1994; R 2003)	Volatile Loss from Plastics Using Activated Carbon Methods
ASTM D 1204 (2007)	Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature
ASTM D 1505 (2003)	Density of Plastics by the Density-Gradient Technique
ASTM D 1603 (2006)	Carbon Black Content in Olefin Plastics

ASTM D 1790 (2002)	Brittleness Temperature of Plastic Sheeting by Impact
ASTM D 3895 (2007)	Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry
ASTM D 4218 (1996; R 2001)	Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
ASTM D 4354 (1999; R 2004)	Sampling of Geosynthetics for Testing
ASTM D 4355 (2007)	Deterioration of Geotextiles from Exposure to Light, Moisture and Heat in a Xenon-Arc Type Apparatus
ASTM D 4491 (1999a; R 2004e1)	Water Permeability of Geotextiles by Permittivity
ASTM D 4533 (2004)	Trapezoid Tearing Strength of Geotextiles
ASTM D 4595 (2005)	Tensile Properties of Geotextiles by the Wide-Width Strip Method
ASTM D 4632 (1991; R 2003)	Grab Breaking Load and Elongation of Geotextiles
ASTM D 4716 (2004)	Determining the (In-Plane) Flow Rate Per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head
ASTM D 4751 (2004)	Determining Apparent Opening Size of a Geotextile
ASTM D 4759 (2002)	Determining the Specification Conformance of Geosynthetics
ASTM D 4833 (2000e1)	Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products
ASTM D 4873 (2002)	Identification, Storage, and Handling of Geosynthetic Rolls and Samples
ASTM D 5035 (2006)	Breaking Force and Elongation of Textile Fabrics (Strip Method)
ASTM D 5199 (2001; R 2006)	Measuring Nominal Thickness of Geosynthetics
ASTM D 5261 (1992; R 2003)	Measuring Mass Per Unit Area of Geotextiles
ASTM D 5262 (2007)	Evaluating the Unconfined Tension Creep Behavior of Geosynthetics

ASTM D 5321 (2002)	Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method
ASTM D 5397 (2007)	Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test
ASTM D 5596 (2003)	Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
ASTM D 5721 (1995; R 2002)	Air-Oven Aging of Polyolefin Geomembranes
ASTM D 5885 (2006)	Oxidative Induction Time of Polyolefin Geosynthetics by High-Pressure Differential Scanning Calorimetry
ASTM D 5994 (1998; R 2003)	Measuring Core Thickness of Textured Geomembrane
ASTM D 6497 (2002)	Mechanical Attachment of Geomembrane to Penetrations or Structures
ASTM D 792 (2000)	Density and Specific Gravity (Relative Density) of Plastics by Displacement
GSI GRI GC7 (1997)	Determination of Adhesion and Bond Strength of Geocomposites
GSI GRI GM7 (1995)	Accelerated Curing of Geomembrane Test Strip Seams Made by Chemical Fusion Methods
GSI GRI GM9 (1995)	Cold Weather Seaming of Geomembranes
GSI GRI GM11 (1997)	Accelerated Weathering of Geomembranes Using a Fluorescent UVA Device

4.0 SUBMITTALS

A. Shop Drawings

1. Geomembrane panel layout and penetration detail drawings.

B. As-Built Drawings

1. Final as-built drawings of geomembrane installation.

C. Product Data

1. Tests, Inspections, and Verifications – Manufacturer's and fabricator's QC manuals.

2. Fiėld Seaming – Installer's QC manual.

3. Qualifications

   a. Manufacturer's, and fabricator's qualification statements, including resumes of key personnel involved in the project.

   b. Installer's, QC inspector's, and QC laboratory's qualification statements including resumes of key personnel involved in the project.

   c. The submittal from the QC laboratory shall include verification that the laboratory is accredited via the Geosynthetic Accreditation Institute's Laboratory Accreditation Program (GAI-LAP) for the tests the QC laboratory will be required to perform.

4. Samples – Geomembrane QA and QC samples.

5. Test Reports

   a. Materials – Manufacturer's certified raw and sheet material test reports and a copy of the QC certificates.

   b. Surface Preparation – Certification from the QC inspector and installer of the acceptability of the surface on which the geomembrane is to be placed, immediately prior to geomembrane placement.

   c. Non-Destructive Field Seam Continuity Testing – QC inspector certified test results on all field seams.

   d. Destructive Field Seam Testing – Installer and certified QC laboratory test results on all destructively tested field seams.

   e. Destructive Seam Test Repairs – QC inspector certified test results on all repaired seams.

   f. Interface Friction Testing - Certified laboratory interface friction test results including description of equipment and test method.

   g. Tests – Certified QC test results.

5.0 QUALIFICATIONS

A. Manufacturer – Manufacturer shall have produced the proposed geomembrane sheets for at least 5 completed projects and a minimum total area of 10 million square feet.

B. Fabricator – The fabricator is responsible for seaming geomembrane sheets into panels. Fabricator shall have fabricated the proposed geomembrane panels for at least 5 completed projects and a total area of 2 million square feet.

C. Installer – The installer is responsible for field handling, deploying, seaming, anchoring, and field Quality Control (QC) testing of the geomembrane. The installer shall have installed the proposed geomembrane material for at least 5 completed projects, for a minimum total area of 2 million square feet. At least one seamer shall have experience seaming a minimum of 500,000 square feet of the proposed geomembrane using the same type of seaming equipment and geomembrane thickness specified for this project.

D. QC Technician – The QC inspector is the person or corporation hired by the Owner, who is responsible for monitoring and documenting activities related to the QC of the geomembrane from manufacturing through installation. The QC inspector shall have provided QC inspection during installation of the proposed geomembrane material for at least 5 completed projects having a total minimum area of 2 million square feet.

E. QC Laboratory – The QC laboratory shall have provided QC and/or Quality Assurance (QA) testing of the proposed geomembrane and geomembrane seams for at least five completed projects having a total minimum area of 2 million square feet. The QC laboratory shall be accredited via the Geosynthetic Accreditation Institute's Laboratory Accreditation Program (GAI-LAP) for the tests the QC laboratory will be required to perform.

6.0 MATERIALS

A. Geocomposite

1. Geocomposite Manufacturer's Quality Control

a. The geocomposite material to be used for lining the pond shall be a double sided geotextile-geonet geocomposite. The bottom geocomposite layer is to act as cushion and gas vent and the top one as a leak detection layer.

b. The polymer used to manufacture the geonet core of the geocomposite shall be polyethylene which is clean and free of any foreign contaminants.

c. Regrind material, which consists of edge trimmings and other scraps, may be used to manufacture the geonet; however, post consumer recycled material shall not be used.

d. The drainage core of the geocomposite shall be manufactured by extruding three sets of polyethylene strands to form a triaxial void maintaining structure consisting of a thick vertical rib with diagonally placed top and bottom ribs. The geonet shall meet the property requirements listed in Table 1.

e. The geotextile of the geocomposite shall be high UV resistant, continuous filament which is a needle punched, nonwoven polypropylene geotextile. The strength retained after 500 hours of UV exposure shall be at least 95% per ASTM G154. The filter and cushioning properties of the geotextile shall meet the property requirements listed in Tables 2 and 3.

2. Geocomposite Material Properties.

The Geocomposite Layer shall conform to the following material properties:

Table 1: Required Geocomposite Material Properties

Tested Property	Test method	Frequency	Minimum Average Roll Value		
Geocomposite			**6 oz/yd^2**	**8 oz/yd^2**	**10 oz/yd^2**
Product Code			**F42060060S**	**F42080080S**	**F42100100S**
Transmissivity[a], gal/min/ft (m^2/sec)	ASTM D 4716-00	1/540,000 ft^2	0.48 (1 x 10^{-4})	0.48 (1 x 10^{-4})	0.43 (9 x 10^{-5})
Ply Adhesion, lb/in (g/cm)	GRI GC-7	1/50,000 ft^2	1.0 (178)	1.0 (178)	1.0 (178)
Roll Width, ft (m)			14.5 (4.4)	14.5 (4.4)	14.5 (4.4)
Roll Length, ft (m)			230 (70.1)	200 (60.9)	190 (58.0)
Roll Area, ft^2 (m^2)			3,335 (310)	2,900 (269)	2,755 (256)
Geonet core[b]					
Transmissivity[a], gal/min/ft (m^2/sec)	ASTM D 4716-00		9.66 (2 x 10^{-3})	9.66 (2 x 10^{-3})	9.66 (2 x 10^{-3})
Thickness, mil (mm)	ASTM D 5199	1/50,000 ft^2	200 (5)	200 (5)	200 (5)
Density, g/cm^3	ASTM D 1505	1/50,000 ft^2	0.94	0.94	0.94
Tensile Strength (MD), lb/in (N/mm)	ASTM D 5035	1/50,000 ft^2	45 (7.9)	45 (7.9)	45 (7.9)
Carbon Black Content, %	ASTM D 1603	1/50,000 ft^2	2.0	2.0	2.0
Geonet core[b,c]					
Mass per Unit Area, oz/yd^2 (g/m^2)	ASTM D 5261	1/90,000 ft^2	6 (200)	8 (270)	10 (335)
Grab Tensile, lb (N)	ASTM D 4632	1/90,000 ft^2	170 (755)	220 (975)	260 (1,155)
Puncture Strength, lb (N)	ASTM D 4833	1/90,000 ft^2	90 (395)	120 (525)	165 (725)
AOS, US sieve (mm)	ASTM D 4751	1/540,000 ft^2	70 (0.212)	80 (0.180)	100 (0.150)
Permittivity, (sec^{-1})	ASTM D 4491	1/540,000 ft^2	1.5	1.5	1.2
Flow Rate, gpm/ft^2 (lpm/m^2)	ASTM D 4491	1/540,000 ft^2	110 (4,480)	110 (4,480)	85 (3,460)
UV Resistance, % retained	ASTM D 4355 (after 500 hours)	Once per formulation	70	70	70

NOTES:

[a] Gradient of 0.1, normal load of 10,000 psf, water at 70 degrees F between steel plates for 15 minutes..

[b] Component properties prior to lamination.

[c] Several geotextiles are available and and may be supplied bu GSE or other approved equivalent.

[d] These are MARV values that are based on the cumulative results of specimens tested and determined by GSE. AOS in mm is maximum average roll value.

B. Geomembranes (24 mil Primary and 36 mil Secondary RPE)

1. Geosynthetics Manufacturer's Quality Control

a. The geomembrane liner shall be a four layer reinforced laminate containing no adhesives.

b. The outer layers of the RPE shall consist of a high strength polyethylene film and shall be resistant to ultraviolet rays in exposed applications.

c. The manufacturer of the liner shall take random samples of the liner material from each fabricated roll during manufacturing. Samples shall be tested by methods specified within this Section, or applicable ASTM standards, for thickness, strength, tear resistance, low temperature impact density and dimensional stability. Each roll of material shall be clearly identified and correlated to the test results provided.

d. The geomembrane manufacturer shall confirm in writing, that the geosynthetics to be furnished will be free of defects in materials and workmanship at the time of sale, and against deterioration due to the effects of ozone, ultraviolet or other normal weathering on a pro-rata basis. The geomembrane manufacturer shall furnish a sample warranty during the submittal process for review and approval prior to shipment. In addition, the manufacturer shall provide a minimum warranty against material failure of 15 years in case of the 24 mil RPE and for a minimum of 20 years for the 36 mil RPE.

2. RPE Material Properties

The material provided as Reinforced Polyethylene (RPE) liner shall conform to the following standards or approved equivalent:

Table 2: Required Primary Geomembrane Properties

Properties	Test Method	30 mil		36 mil		45 mil	
		Min. Roll Avg.	Typical Roll Avg.	Min. Roll Avg.	Typical Roll Avg.	Min. Roll Avg.	Typical Roll Avg.
Appearance		Black/Black		Black/Black		Black/Black	
Thickness	ASTM D 5199	27 mil	30 mil	32 mil	36 mil	40 mil	45 mil
Weight Lbs Per MSF (oz/yd^2)	ASTM D 5261	126 lbs (18.14)	140 lbs (20.16)	151 lbs (21.74)	168 lbs (24.19)	189 lbs (27.21)	210 lbs (30.24)
Construction		**Extrusion laminated with encapsulated tri-directional scrim reinforcement					
Ply Adhesions	ASTM D 413	16 lbs	20 lbs	19 lbs	24 lbs	25 lbs	31 lbs
1" Tensile Strength	ASTM D 7003	88 lbf MD 63 lbf DD	110 lbf MD 79 lbf DD	90 lbf MD 70 lbf DD	113 lbf MD 87 lbf DD	110 lbf MD 84 lbf DD	138 lbf MD 105 lbf DD
1" Tensile Elongation @ Break % (Film	ASTM D 7003	550 lbf MD	750 lbf MD	550 lbf MD	750 lbf MD	550 lbf MD	750 lbf MD

Break)		550 lbf DD	750 lbf DD	550 lbf DD	750 lbf DD	550 lbf DD	750 lbf DD
1" Tensile Elongation Peak % (Scrim Break)	ASTM D 7003	20 lbf MD 20 lbf DD	33 lbf MD 33 lbf DD	20 lbf MD 20 lbf DD	30 lbf MD 31 lbf DD	20 lbf MD 20 lbf DD	36 lbf MD 36 lbf DD
Tongue Tear Strength	ASTM D 5884	75 lbf MD 75 lbf DD	97 lbf MD 90 lbf DD	75 lbf MD 75 lbf DD	104 lbf MD 92 lbf DD	100 lbf MD 100 lbf DD	117 lbf MD 118 lbf DD
Grab Tensile	ASTM D 7004	180 lbf MD 180 lbf DD	218 lbf MD 210 lbf DD	180 lbf MD 180 lbf DD	222 lbf MD 223 lbf DD	220 lbf MD 220 lbf DD	257 lbf MD 258 lbf DD
Trapezoid Tear	ASTM D 4533	120 lbf MD 120 lbf DD	146 lbf MD 141 lbf DD	130 lbf MD 130 lbf DD	189 lbf MD 172 lbf DD	160 lbf MD 160 lbf DD	193 lbf MD 191 lbf DD
* Dimensional Stability	ASTM D 1204	<1	<0.5	<1	<0.5	<1	<0.5
Puncture Resistance	ASTM D 4833	50 lbf	64 lbf	65 lbf	83 lbf	80 lbf	99 lbf
Maximum Use Temperature		180 °F	180 °F	180 °F	180 °F	180 °F	180 °F
Minimum Use Temperature		-70 °F	-70 °F	-70 °F	-70 °F	-70 °F	-70 °F

NOTES:

Minimum Roll Averages are set to take into account product variability in addition to testing variability between laboratories.
MD stands for machine Direction and DD for Diagonal Direction.
*Dimensional stability maximum value
**30 mil, 36 mil, & 45 mil are a four layer reinforced laminate containing no adhesives. The outer layers consist of a high strength polyethylene film manufactured using virgin grade resins and stabilizers for UV resistance in exposed applications. 30 mil, 36 mil, & 45 mil are reinforced with a 1300 denier (minimum) tri-directional scrim reinforcement.

Table 3: Required Secondary Geomembrane Properties

Properties	Test Method	24 mil	
Grab Tensile	ASTM D 751/NSF	Warp 258 lb, 1160 N	Weft 250 lb, 1114 N
Tongue Tear – Large Scale	ASTM D 5884-01	Warp 140 lb, 621 N	Weft 149 lb, 663 N
Trapezoidal Tear	ASTM D 4533-04	Warp 200 lb, 890 N	Weft 130 lb, 578 N
Mullen Burst	ASTM D 3786-01	370 psi, 2553 kPa	370 psi, 2553 kPa
Hydrostatic Resistance	ASTM D 751-00	208 psi, 1438 kPa	208 psi, 1438 kPa
Puncture Resistance	ASTM D 4833-00	76 lb, 339 N	76 lb, 339 N
Carbon Black Content	ASTM D 4218-96	3.71%	3.71%
Volatile Loss	ASTM D 1203-94	0.07%	0.07%
Dimensional Stability	ASTM D 1204-02	Warp -1.40 %	Weft -1.34 %
Low Temperature Flex	ASTM D 2136-94	Warp Pass @ -40°	Weft Pass @ -40°
Accelerated UV Weathering	ASTM G151-00 ASTM G154-04	>95% strength retention after 2000 hrs exposure @ 0.77 W/m^2/nm, or 1200 hours exposure @ 1.35 W/m^2/nm.	

NOTES:

Q.U.V. (A-340 Lamps): 8 hrs UV @ 60° C; 4 hrs condensation @ 50 C°; Construction: Reinforcing polyester scrim between LLDPE barrier layers; Colour: Black and other colors available after consultation; Weight: 16 oz/yd^2 (542 g/m^2) ±5%; Thickness: Nominal 24 mils 0.024" (0.61mm)

These values are typical data and are not intended as limiting specifications. All cut edges where scrim is exposed must be sealed using PE welding rod. Warp = machine direction; Weft = cross machine direction

C. Leak Detection System Geotextile and Gravel

1. A minimum 4-ft long by 4-ft wide by 16-inch deep pit fill with gravel and wrapped with an 8-oz non-woven geotextile fabric shall be placed at the low point of the pond and at the bottom end of the leak detection well. The geotextile shall serve as separation and filtration. The geotextile shall conform to the following standards or approved equivalent:

Table 4: Required Geotextile Properties

Property	Test method	Units	Value
Mechanical			
Grab Tensile Strength (MARV)	ASTM D 4632	lb	205
Grab Elongation (MARV)	ASTM D 4632	%	50
Puncture Strength (MARV)	ASTM D 4833	lb	110
Mullen Burst (MARV)	ASTM D 3786	psi	350
Trapezoidal Tear (MARV)	ASTM D 4533	lb	85
Hydraulic			
Apparent Opening Size (AOS) (MaxMARV)	ASTM D 4751	US Sieve	80
Permittivity (MARV)	ASTM D 4491	sec^{-1}	1.5
Permeability	ASTM D 4491	cm/sec	0.30
Water Flow Rate	ASTM D 4491	gpm/ft^2	110
Physical			
Mass per Unit Area	ASTM D 5261	oz/yd^2	6.5
Thickness	ASTM D 5199	mils	70
Endurance			
UV Resistance	ASTM D 4355	% Retained @ 50 0hours	70
Standard Packaging			
Roll Width	Measured	feet	15
Roll Length	Measured	feet	360
Roll Area	Calculated	yd^2	600

NOTES:

The property values listed are effective 2/01/2004 and are subject to change without notice.
Values reported in weaker principle direction.
All values listed are minimum average roll values (MARV) unless otherwise noted, calculated as the typical minus two standard deviations. Statistically it yields a 97.7% degree of confidence that any sample taken during quality assurance testing will exceed the value reported. MaxMARV represents typical plus two standard deviations.
Underlined styles meet and/or exceed the American Associate of State Highway Transportation Officials (AASHTO) M288 specifications.

7.0 INSTALLATION

A. Geocomposite

1. Prior to deployment of the geocomposite, the geosynthetics contractor shall inspect, certify, and accept, the subgrade on which the liner is to be placed to ensure

conformance with the specifications. Surfaces not in compliance with the specifications shall be rectified by the earthwork Contractor.

2. The geocomposite layer shall be handled in such a manner as to ensure that it is not damaged in any way. On slopes, the material shall be anchored in the anchor trench and then rolled down the slope in such a manner as to continually keep the material under tension.

3. In the presence of wind, the leading edge of the material shall be weighted with sandbags or ballasts until the final cover is placed.

4. Care shall be taken to assure that any underlying layers are not damaged during placement. Low ground pressure machines such as ATVs are recommended to facilitate deployment over the geosynthetic layers. Low ground pressure machines shall be used when carrying a driver weighing approximately 150 lbs.

5. The bottom geocomposite layer is to act as cushion and gas vent and the top one as a leak detection layer. The bottom layer is to be placed along the slope of the bottom of the pit so it conforms to the shape of the pit bottom or as directed by the field engineer.

B. Geomembrane (Primary and Secondary RPE)

1. Prior to deployment of geomembrane, the geosynthetics contractor shall inspect, certify and accept, all surfaces on which the liner is to be placed to ensure conformance with the specifications. Surfaces not in compliance with the specifications shall be rectified by the geosynthetics contractor.

2. The amount of geomembrane liner deployed without final quality control and final repairs being completed shall not exceed 100,000 square feet. In addition, no seams shall be left unwelded and no openings in the liner shall be left at the end of a shift unless approved by the field engineer. The liner shall be placed over the prepared surface using methods and procedures that ensure a minimum of handling. The geosynthetics contractor shall provide adequate temporary anchoring devices to prevent damage due to wind.

3. Handling and storage of liner material shall be in accordance with the manufacturer's printed instructions. All persons walking or working on the geomembrane shall wear soft-sole shoes.

4. The liner shall be installed in a relaxed condition and shall be free of tension or stress upon completion of the installation. All necessary precautions, including provisions for installing extra material, shall be taken to avoid trampolining of liner which will remain exposed (i.e., pad, pond corners and solution channels).

5. Horizontal field seams on slopes should be kept to a minimum. Seams shall be made by lapping the uphill material over the downhill material with sufficient

overlap. A minimum of five feet is to be allowed from the toe of the slope to any horizontal seam on flat areas.

6. Installation shall be performed under the direction of a superintendent who has installed a minimum of 10,000,000 square feet of HDPE or LLDPE flexible lining material. The superintendent shall be provided by the geosynthetics contractor and shall be in charge of the installation.

7. Extreme care shall be taken by the geosynthetics contractor in the preparation of the areas to be welded. The area to be welded shall be cleaned and prepared according to approved procedures, and all sheeting shall be welded together by thermal methods.

C. Geotextile

1. Geotextile panels shall be continuously overlapped a minimum of 12 inches at all longitudinal and transverse joints. Where seams must be oriented across the slope, the upper panel shall be lapped over the lower panel. If approved, sewn seams may be used instead of overlapped seams.

2. The geotextile shall be protected during installation from clogging, tears, and other damage. Damaged geotextile shall be repaired or replaced as directed. Adequate ballast (e.g. sand bags) shall be used to prevent uplift by wind. The geotextile shall not be left uncovered for more than 14 days after installation.

3. Torn or damaged geotextile shall be repaired. Clogged areas of geotextile shall be removed. Repairs shall be performed by placing a patch of the same type of geotextile over the damaged area. The patch shall extend a minimum of 12 inches beyond the edge of the damaged area. The machine direction of the patch shall be aligned with the machine direction of the geotextile being repaired. Geotextile rolls which cannot be repaired shall be removed and replaced. Repairs shall be performed at no additional cost to the Owner

4. Geotextile shall not be covered prior to inspection and approval by the Engineering Inspector. Cover soil shall be placed in a manner that prevents soil from entering the geotextile overlap zone, prevents tensile stress from being mobilized in the geotextile, and prevents wrinkles from folding over onto themselves. On side slopes, soil backfill shall be placed from the bottom of the slope upward. Cover soil shall not be dropped onto the geotextile from a height greater than 3 feet. No equipment shall be operated directly on top of the geotextile without approval of the Engineering Inspector. Equipment with ground pressures less than 7 psi shall be used to place the first lift over the geotextile. A minimum of 12 inches of soil shall be maintained between full-scale construction equipment and the geotextile. Cover soil material type, compaction, and testing requirements are described in Section 8.0. Equipment

placing cover soil shall not stop abruptly, make sharp turns, spin their wheels, or travel at speeds exceeding 5 mph.

8.0 FIELD INSPECTION AND TESTING

A. Geocomposite

1. Each component of the geocomposite (geotextile(s) and geonet) shall be secured or seamed to the like component at overlaps.

2. Adjacent edges of geonet along the length of the geocomposite, shall be overlapped 2-3 inches or as approved by the Engineer based on the site specific conditions, placed with the edges of each geonet butted against each other. These overlaps shall be joined by tying the geonet cores together with white or yellow cable ties or plastic fasteners. These ties shall be spaced at a maximum of every 10 feet along the roll length.

B. Geomembrane (Primary and Secondary RPE)

1. A maximum effort shall be made to install a perfect liner. This means that all seams completed in the field patches, and extrusions shall be inspected, tested, and recorded.

2. The welding equipment used shall be capable of continuously monitoring and controlling the temperatures in the zone of contact where the machine is actually fusing the lining material in order to ensure that the integrity of the weld is not affected by changes in weather conditions.

3. No "fish mouth" shall be allowed within the seam area. Where "fish mouths" occur, the material shall be cut, overlapped, and extrusion welded. Welds on completion of the work shall be tightly bonded. Any membrane area showing distress due to excessive scuffing or puncture from any cause shall be replaced or repaired.

4. The geosynthetics contractor shall take into account that rapid weather changes are very possible, resulting in delays in construction of field seams. Joining of panels and repairs will only be permitted under weather conditions allowing such work within the warranty limits imposed by the manufacturer.

5. A quality-control technician shall inspect each seam, marking his initials and the date inspected at the end of each panel. Any area showing a defect shall be marked and repaired in accordance with approved repair procedures.

6. The field installation testing program shall consist of periodic visual observations, continuity, and strength tests. These inspections and tests are to be made routinely and are automatic regardless of other types of testing

required. The program shall include:

a. Visual Observations

- To perform visual check field seams for squeeze out, footprint, melt and overlap.
- Machines to be checked for cleanliness.
- Any area of the seam or panel showing a defect shall be marked and repaired in accordance with the applicable repair procedures.

b. Non Destructive Testing

A 48 inch (1.2 m) sample should be taken from each factory seam welding unit used in this work at the beginning of every work shift an every four hours of production thereafter. Samples shall be nondestructive, not requiring patching of fabricated panels. Test specimens shall be cut at quarter points from each 48 inch seam sample (a total of three places) and tested for seam strength and peel adhesion. The shear seam strength shall be tested in accordance with ASTM D751 modified method and peel adhesion will be tested in accordance with ASTM D413, Machine Method, Type A. A log shall be maintained showing the date, time, panel number and test results. Failure of the material and/or seams to meet all the requirements of these specifications may be cause for rejection of the RPE material and/or seams as appropriate. The fabricator shall provide the test results to the owner or engineer upon request. The results of the leak test shall be marked at the location and shall be recorded by the geosynthetics contractor. If the test fails, the location of the leak shall be found and repaired or the entire seam shall be repaired and retested.

c. Strength Testing

1. For trial welds, the following procedure is to be used:

   - Trial welds shall be completed under the same conditions and using the same materials, pre-seaming, and seaming techniques as used to fabricate field seams. The trial weld samples shall be a minimum of 3 feet long by 1 foot wide, marked with the date, technician's name, ambient temperature, and welding machine number and temperature. Coupons from the test weld shall be tested for peel and bonded seam strength using a calibrated tensiometer, as well as thickness, in accordance either the applicable ASTM or

NSF 54 standards as appropriate. If failing results occur, the welding machine shall be repaired or replaced and retested.

- The minimum frequency for obtaining trial weld samples from each of the welding machines in operation is the following:
  - Prior to the beginning of seaming operations.
  - After every four hours of seaming operations.
  - After repairs have been made to seaming equipment.
  - By each technician using the seaming equipment.
  - As required by the Owner.

d. Destructive Testing

1. For destructive testing of field seams the following procedure is to be used:

- Destructive samples may be obtained from field seams or repaired areas by cutting perpendicular to the seams. The sample should be approximately 2 feet long by 1 foot wide. This sample shall be cut into two samples of 1 foot by 1 foot and labeled with the welder's identification, date, and location. One of the samples will be retained by the Owner and one of the samples will be tested by the Geosynthetics Contractor, using a calibrated tensiometer, in accordance with the applicable ASTM or NSF 54 standards as appropriate.

- The frequency for obtaining destructive test samples shall not be less than one sample per 750 feet of field seam. Coupons from the destructive sample shall be tested for peel and bonded strength as well as thickness, in accordance with the applicable ASTM standards. If one or more of the coupons fails, the sample will be considered a failure. As far a practicable, samples should be taken from above the water level in the pond or from the anchor trench to minimize repair within the water bearing surface.

- In the event of a failing test result, additional samples, on either side of the failure, shall be tested to isolate the portion of the seam which needs to be repaired, and the failed portion of the weld shall be "capped". Alternatively, the entire seam can be rewelded and retested.

C. Hydrotesting of Completed Pit (All Liquid)

1. After installation of the uppermost liner and prior to operating the pit, the synthetic liner system shall be tested by filing the pit with at least four (4) feet of fresh water, measured from the base of the pit (not to exceed the two (2) foot freeboard requirement). The engineer's representative shall monitor the pit for a period of seventy-two (72) hours prior to draining the pit and commencing operations.

2. Any leakage through the liner shall be noted over the test period as measured at least twice daily using a gauge mounted within the pit or by measuring the distance from the water to a fixed point down the slope of the pit. A visual inspection of the Leak Detection System pipe shall be taken at each measurement. Measurements shall be taken and recorded by the engineer's representative. See attached form for recording the hydrotesting data. Method of measuring level of water in pit shall be recorded on the hydrotest form.

3. Evaporation losses or precipitation gains will be accounted for from an evaporation pan (12 square foot surface area and 8 to 12 inches deep) or similar device installed in close proximity to the pit.

4. If leakage occurs, the pit shall be drained, inspected and repaired; and the pit shall be refilled and retested as described above. Operations shall not commence until a successful hydrotest is performed and no leaks observed.

5. Hydrotest monitoring results must be maintained by the operator for the life of the pit and provided to COGCC upon request.

6. Operations must be suspended within twenty-four (24) hours if leaks in the liner are observed. The leaks are to be repaired and hydrotests repeated as described above.

D. Hydrotesting of Completed Pit (Part Ice/Part Liquid)

Although more difficult, hydrotesting of a pit may be done if the surface of the water in the pit is frozen. Hydrotesting will be performed in accordance with Section C above with the additional requirements as follows:

1. For sufficient hydrostatic head, the amount of liquid water in the pit must be at least two-thirds of the total volume of hydrotest water and shall not be frozen solid. For example, for a minimum 4-ft test level, liquid water should be at least 2.67-ft of the total depth. If ice is expected to be more than one-third level, more water could be added for the test so that there is sufficient liquid in the pit for the hydrotest.

2. The ice cap on the pit shall be free-floating and not adhered to the side slopes of the pits. The geomembrane material should naturally allow for the ice cap to float on the surface of the water beneath the ice, still providing a head on the bottom of the liner system. If the ice is not free-floating on the surface of the water, then this method can not be used and the liner system should be inspected and hydrotested upon thawing of ice.

3. The pit must have a leak detection system in order for this method of hydrotesting to be implemented. If visual inspection of the leak detection system is not permissible then a mechanical means for measuring must be provided.

4. Proper egress (such as a tire escape ramp) from the pit must be installed prior to performing a hydrotest with ice on the pit. Entrance into the pit will be required to complete a hydrotest for a containing part ice/part liquid. Protective flaps must also be installed prior to performing a hydrotest with ice on the pit to prevent damage of the primary liner system by testing equipment.

5. Measure from the top of the pit to the ice surface. Using a proper egress ramp, enter the pit and break through the ice with either an auger or other mechanical means (spud bar, etc.).

6. Visually inspect the liner at and above the water/ice surface and ensure that ice is free-floating on the surface of the water. Once the liquid level is exposed, measure the water level in the pit from top of the pit down to the surface. Measure the water depth in pit at the sample location and measure from the bottom of the ice surface to the top of the water surface. If ice is free-floating, there should not be a significant gap between the bottom of the ice surface and top of the liquid water surface.

7. Utilizing a strap sheet, determine the starting volume of ice and starting volume of water in the pit.

8. Observe and log air temperature throughout the duration of the hydrotest. If ambient air temperatures stay relatively stable and ice in the pit does not show signs of significant expansion or contraction, then subsequent measurements to complete the test can be taken from the top of the pit down to the ice surface in combination with observations of the leak detection system through the monitoring conduit.

9. If ambient air temperatures vary to the point where significant expansion and contraction of the ice surface is observed, measurements of ice thickness and water levels must continue to be made throughout the hydrotest as described above. Perform continuous comparisons of the volumes of ice and water present to those expected on the strap sheet and record the data on the attached

form.

10. Field representatives performing this test should describe in the field notes the exact method used to perform the test and record all observations.

END OF SECTION 02530

ATTACHMENT

HYDROTEST FORM

SAMUEL ENGINEERING, INC
ConocoPhillips
G-21 Produced Water Pit
Pit Liner Hydrostatic Test

Reading	Date And Actual Time	Weather Conditions	Precipitation Since Last Reading	Gauge Reading	Evaporation Pan Reading	Water In Leak Detection System	Pass/Fail
Initial							
Comments							
12 Hour							
Comments							
24 Hour							
Comments							
36 Hour							
Comments							
48 Hour							
Comments							
60 Hour							
Comments							
72 Hour (End)							
Comments							

Test Performed by ____________________ Signature ____________________ Print Name

Contractor ____________________ Signature ____________________ Print Name

Samuel Engineering, Inc.
We Provide Solutions

8450 E. Crescent Parkway, Suite 200
Greenwood Village, Colorado 80111-2855

Tel: 303-714-4840
Fax: 303-714-4800

01630587

PERFORMANCE SPECIFICATION

SPECIFICATION 02517

EARTHWORK AND LEAK DETECTION WELL

FOR

ConocoPhillips

G-21 Produced Water Pit Geosynthetic Lining System
SE Project 8053-14

Orig./Lead Eng.: Melissa C Lambat Date 1/6/09

Project Engineer Approval: Melissa C Lambat Date 1/6/09

Project Manager Approval: [signature] Date 1/6/09

Client Approval: ______ Date ______

Rev. No.	By	Revisions	Approval	Date
0	JM	ISSUED FOR CONSTRUCTIONS		

1.0 GENERAL

A. Related specifications: 02530 GEOSYNTHETICS INSTALLATION AND TESTING.

B. These technical specifications establish the quality of materials and workmanship and define how quality is measured for earthwork, hard material subgrade, and leak detection wells. They apply to lined containment pond areas. It also establishes the quality of materials and workmanship for furnishing, delivering, installing and constructing hard material subgrade and standard leak detection wells for double-lined systems.

C. The word "Owner," as used here shall mean ConocoPhillips.

2.0 ABBREVIATIONS

A. The abbreviation below shall mean:

AASHTO............... American Association of State Highway and Transportation Officials

ASTM.................... American Society for Testing Materials

3.0 CODES AND STANDARDS

A. Unless otherwise specified or shown on drawings, the following codes and standards shall apply to the extent indicated herein:

ASTM D422...... Standard Method of Test for Particle-Size/Analysis of Soils

ASTM D2487.... Standard Test Methods for Classification of Soils for Engineering Purposes

ASTM D2488.... Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

ASTM D3740.... Evaluation of Agencies engaged in Testing and/or Inspection of Soil and Rock as used in Engineering Designing Construction

4.0 MATERIALS

A. Hard materials will be encountered in 100 percent of the excavation from the existing surface.

B. Material for subgrade will consist of the naturally occurring shale rock, shaped to the lines and grades on the Design Drawings. The naturally occurring shale rock shall be broken into pieces with excavation equipment. The side slopes and bottom of the excavation shall be shaped with aggregate less than 2 inches in diameter in a manner that is smooth and does not allow for protrusion of rocks from the planar surface of the side slopes and the bottom of the pit.

C. Drill cuttings mixed with fly ash and wood chips or drill cuttings alone may be used to provide a smooth finish to the subgrade for placement of the geosynthetic liner materials including geocomposites. Such cuttings must have passed the testing required by COGCC in Table 910-1.

D. Materials will consist of the geocomposites and geomembranes used in the pond liner system. The leak detection well shall consist of 8-in diameter HDPE pipe perforated at the bottom end as shown on the design drawings. The 8-in HDPE shall be sealed from the primary liner with a pipe boot. An 8-in cap will be provided above grade as shown on the design drawings. Refer to 02530 GEOSYNTHETICS INSTALLATION for more information on geocomposites and geomembranes.

E. A minimum 4-ft x 4-ft x 16-in deep sump pit filled with gravel and wrapped with 8-oz non-woven geotextile fabric shall be placed at the low point of the pond and at the bottom end of the leak detection well. Refer to 02530 GEOSYNTHETICS INSTALLATION for more information on geotextile.

F. Class 2 Backfill is defined as all soils and rock excavated at the site with a diameter of less than 2 inch maximum dimension. Suitable equipment or approved procedures shall be provided to ensure the maximum dimension is not exceeded.

5.0 QUALITY ASSURANCE

A. Quality assurance during preparation of hard material subgrade shall be performed by an agent of the sealing engineer. Inspections during filed construction shall be visual and the subgrade shall be approved by the certifying engineer prior to placement of the liner system.

B. The owner shall engage a third party independent Engineering firm for quality control.

C. Inspections during filed construction shall be visual and the subgrade shall be approved by the certifying engineer prior to placement of the leak detection well and related liners. The leak detection well shall be approved by the certifying engineer prior to backfill of the well.

6.0 PROJECT SITE CONDITIONS

A. Data on indicated subsurface conditions are made available for the convenience of the earthwork contractor and are not intended as representations or warranties of continuity of such conditions.

B. Protect existing benchmarks and monuments and other reference points; if disturbed or destroyed, replace as directed by Owner.

C. Erect and maintain such safeguards as required by construction operations, codes or existing conditions, for the safety of persons or property and to protect the same from damage, injury or loss.

D. Provide for diversion of surface drainage during the period of earthwork, keeping excavations free of water during entire process of work, regardless of cause, source or nature of the water.

7.0 SURVEY

A. The Owner will establish the control point(s) to be utilized by the Contractor. The Contractor shall be responsible for all construction surveying to control the work.

B. Cross-sections of the original surface and the as-built condition will be taken as directed.

C. Prior to installation of any geosynthetic liners, Contractor shall verify with grading level that the pit side slopes are 2:1 maximum, the bottom of the pit slopes as designed for the leak detection system, and the pit depth and general layout is per the design drawings.

D. All survey work will be subject to checking by the Owner or Owner's representative.

8.0 CLEARING AND GRUBBING

A. Existing pit will be drained and the existing liner system removed prior to construction.

B. Existing fencing will be removed prior to the start of work to allow for proper re-shaping of the existing pit.

C. Fluids, solids, and existing liners removed from the existing pit shall be disposed of at the waste locations identified and approved by Owner.

D. Clearing and grubbing shall be performed as required.

E. Clearing will consist of the removal and disposal of all brush, grass, rubbish, and other obstructions resting on the surface of the original ground. Unless otherwise indicated, clearing shall be performed within the limits of and ten feet outside of the pits.

9.0 DUST PALLIATIVE

A. Apply water or chemical for the control of airborne dust originating as a result of earthwork operations in accordance with applicable ordinances and regulations. Chemicals if utilized are to be approved in advance of use by field.

10.0 EXCAVATION

A. Classification of all excavated materials shall be included in the following:

1. Common and Rippable Excavation shall consist of all materials that can be excavated without blasting. Rippable excavation shall consist of all materials that can be effectively loosened or broken down by ripping in a single pass with a late model tractor-mounted hydraulic ripper equipped with one digging point of standard manufacturer's design adequately sized for use with and propelled by a crawler-type tractor rated equal to or better than a D-9 Caterpillar flywheel horsepower, operating in low gear. Additionally, all boulders or detached pieces of solid rock less than 2 cubic yards in volume will be classified as Common and Rippable Excavation.

2. Rock Excavation - For the purpose of classification of excavation, rock is defined as sound and solid masses, layers, or ledges of mineral matter in place and of such hardness and texture that it cannot be effectively loosened or broken down by a hydraulic ripper specified above. Testing to determine compliance with this classification shall be made when requested. All boulders or detached masses of solid rock larger than 2 cubic yards in volume will be classified as rock.

B. Suitable excavated materials conforming to the requirements of Section 4.0 shall be utilized in backfills. Unsuitable material within the limits of excavation shall be removed and disposed of as waste. Unsuitable material is defined as material that is greater than 2 inches in diameter, organic materials and debris of any kind, or any material that is protruding from the planar surface of the bottom of the pit, side slopes of the pit, and within the anchor trench. Unsuitable or excess excavated material shall be disposed of at Owner's designated waste locations.

C. The method of excavation shall not weaken surrounding areas or damage structures or parts thereof that are completed or under construction. Existing structures and utilities adjacent to excavations shall be protected and supported to prevent displacement.

D. Excavations shall conform within the tolerances specified to the lines, grades, sections and elevations shown on Design Drawings.

E. Except as otherwise shown, grading tolerances shall be zero to minus 4 inches for horizontal and sloped planes of excavation in earth and zero to minus 6 inches for horizontal and sloped planes excavation in rock.

F. Over-excavated areas within the pit area shall be restored with properly compacted drill cuttings to the elevations shown on Design Drawings. Compaction equipment shall be suitable for the size and depth of the holes being filled.

G. If any areas outside of the pit area are over-excavated in rock, the over-excavation shall be restored by backfilling spaces under and adjacent to footings, foundations or other bearing portions of structures with concrete having a 28-day compressive strength of 2000 psi. Restoration of over-excavated areas in rock and soil shall provide uniform bearing values at least equivalent to that previously given by the excavation prior to the over-excavation.

H. Areas being excavated and areas to be backfilled shall be maintained in a clean condition free from debris.

I. Compaction shall be "Ordinary compaction" without field testing but shall require close observation to ensure that the materials are being densified and that no soft or loose spots remain. Loose lifts shall be no more than six inches in thickness prior to compaction. Care must be taken to ensure that tracks compact evenly and do not 'bridge' between hard points leaving uncompacted material between. Tracked equipment exerts fairly low ground pressures but may be suitable for this project if closely observed. For reference the following equipment exerts pressure on the soil.

i. D8 Tractor with standard track and dozer Ground pressure is 1884 pounds per square foot (13.1 psi).

ii. 345 D Hydraulic excavator with 36" track Ground pressure is 1163 pounds per square foot (8.1 psi).

11.0 PIPE TRENCH EXCAVATION

A. The pipeline route for the leak detection system shall be over excavated and backfilled with Class 2 backfill or approved drill cuttings so that the pipe rests in bedding material, as indicated on the Design Drawings. The bottom and sides of the trench shall be finished as smooth as the pit subgrade with similar surface treatment. The pipe will be onsite and used to test the slope of the trench to ensure a uniform slope to the top. No bends will be allowed in the pipe.

B. The 8 oz non-woven textile liner shall wrap around the outside of the gravel sump. The bottom geocomposite cushion and 24 mil RPE liners shall deform into the trench beneath the 8 oz non-woven textile liner. The geocomposite conduction liner shall continue over the top of the pit until the reaching the pipe and shall also be positioned underneath the pipe, as indicated on the Design Drawings. Ensure that the primary geomembrane liner is not significantly deformed over the pipe. Backfill around the pipe with clean drill cuttings.

C. The leak detection sump shall be excavated so as to provide the cover, bedding depth and minimum width of 4 feet as shown on the drawings.

D. The bottom of the pit shall be graded to drain to the leak detection system sump as indicated on the Design Drawings.

E. The method of excavation shall not weaken surrounding areas or damage structures or parts thereof that are completed or under construction.

F. All excavation shall conform within the tolerances specified to the lines, grades, sections and elevations shown on drawings and shall be shaped on the bottom to the bedding details shown to provide uniform bearing and support of each pipe section for the entire length.

G. In all excavation requiring blasting, care shall be taken to minimize overbreak. Material outside the authorized cross section, which has been shattered or loosened by blasting, shall be removed.

H. Precautions shall be taken so as not to excavate below the depths indicated on the drawings. Where excessive or unauthorized excavation occurs, backfill the depth to the proper grade with compacted sand and or pea gravel or other suitable material.

I. Except as otherwise shown, grading tolerances shall be plus zero to minus 4 inches for rippable rock excavation.

J. Remove excavated material not required or suitable for backfill from the excavation area and dispose of it at an onsite, designated location.

12.0 PIT SURFACE TREATMENT

A. Benching of Sloped Surfaces

Pit side slopes will be no steeper than 2 to 1 (horizontal to vertical) as indicated on Design Drawings. Tolerance for side slopes will be 2 inches in a 4 foot length of straight edge provided the transitions are smooth curves.

B. Surface Preparation:

Existing rippable hard material on the exposed surface of the pit bottom and side slopes shall be reduced in size to a maximum of 2 inches in diameter. Ensure that there are no rock protrusions above the planar surface of the pit bottom, side walls, and anchor trench. Reduction of this rock shall be done with the most appropriate means and methods available, such as tracking over the rock with the dozer, the use of ripper attachments on excavators, and/or the use of compaction equipment. Large or very hard materials which are resistant to crushing with available equipment may require removal or reduction with special equipment.

C. Filling Holes, Depressions and Cavities

Depressions and other cavities shall be filled in with clean drill cutting to the elevations of the pit bottom and side slopes indicated on the Design Drawings. Crushed rock less than 2 inches in diameter may also be used to fill in holes, depressions, and cavities. Compaction equipment shall be suitable for the size and depth of the holes being filled.

13.0 ANCHOR TRENCHES

A. Geosynthetic runout and anchor trench shall be constructed to the dimensions as indicted on Design Drawings. The subgrade surface of the anchor trench runout shall be of the same material as the side slope of the pit and will be smooth for placement of the liner system. Subgrade will be approved by the onsite engineer prior to placement of geosynthetics.

B. Class 2 Backfill as defined in Section 4.0 shall be used to backfill over the geosynthetic runout and in the anchor trench. Class 2 Backfill shall be used on top of the geosynthetic runout to a minimum depth of 12 inches and will match existing depth and grade as indicated on Design Drawings.

C. Backfill within anchor trench and over geosynthetic runout shall be placed in 6-inch lifts and wheel or bucket compacted with onsite equipment. Tolerance for final grade over runout and anchor trench shall be minus zero to plus 2 inches. Compaction efforts will be observed and approved by the onsite engineer to ensure sufficient compaction in required lifts.

14.0 STOCKPILING

A. As part of earthwork operations, stockpiling of excavated or borrowed material may be required.

B. Different classes of material shall be stockpiled separately if required by Owner.

C. Stockpiles and waste material shall be placed in such a manner to provide natural drainage and a stable embankment as approved by Owner.

D. Stockpiles shall be constructed with maximum height not exceeding 40 feet.

E. Location of stockpiles to be determined by Owner.

15.0 RESHAPING AND GRADING EXISTING IMPROVEMENTS

A. Prior to commencing finish grading, existing improvements shall be checked for their compliance with rough grading requirements shown on design drawings and restored to original lines, grade and cross section if required.

B. Clean and reshape previously constructed ditches of sedimentation and debris to original lines, grade and cross section.

C. Clean all previously constructed culverts of sedimentation and debris.

16.0 FINISH GRADING TOLERANCES

A. The finish grade tolerance for the rippable rock shall be plus zero and minus 4 inches to the lines and grades as indicated on the Design Drawings.

B. Areas not within the allowable tolerances shall be corrected by breaking, scarifying, placing additional material, remixing, and reshaping to the specifications herein.

17.0 CLEANUP

A. Leave area in a clean and neat condition. Grade all disturbed surfaces to prevent standing surface water.

END OF SECTION 02515

ATTACHMENT 1

GEOSYTHETIC COMPRESSION LOADING TEST RESULTS

August 4, 2008

Mr. John Heap
Colorado Lining Intl.
1062 Singing Hills Rd.
Parker, CO 80138-4653
(303) 841-2022
jheap@coloradolining.com

Re: Results of Compression Loading Testing (TRI Log 2308-47-03)

Dear Mr. Heap,

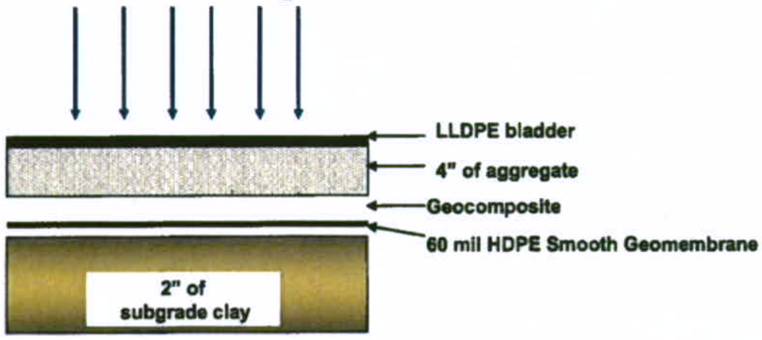
TRI/Environmental, Inc. (TRI) is pleased to present this final report for the requested compression testing in support of the Roan Plateau shale project. The testing was performed to determine the out-of-plane deformation resistance of a 60 mil HDPE smooth geomembrane and a 36 mil RPE geomembrane to compressive loading within a liner system. All sample materials and testing activities were managed under TRI log number E2308-47-03.

Technical Approach

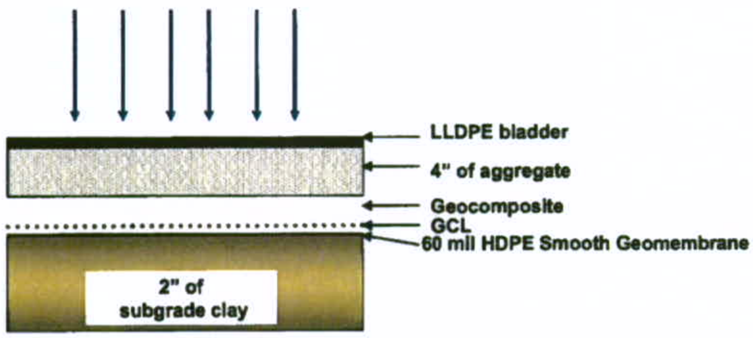
The compression testing was performed in general accordance with ASTM D 5514, *Test Method for Large Scale Hydrostatic Puncture Testing of Geosynthetics*. The test vessel measured 30" in diameter facilitating a 24" diameter test area. The test vessel is composed of a top and bottom half with an intermediate center section measuring 4" in height. The bottom of the test vessel was filled with a compacted clay liner substrate, which the geomembranes were placed over. Four different liner configurations were evaluated. Test configurations are depicted in the test configuration section. Each liner configuration was separated from the loading system via a 40 mil LLDPE geomembrane bladder.

After securing the top test chamber, air was introduced above the bladder to provide normal compressive stress through the bladder and onto the liner system. A normal compressive stress was applied at 1 psi per minute until a static load of 20.8 psi was achieved. This load was allowed to remain static for 1 hour.

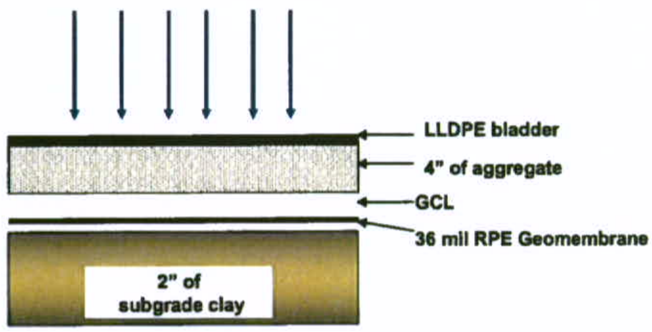
Test Configurations:



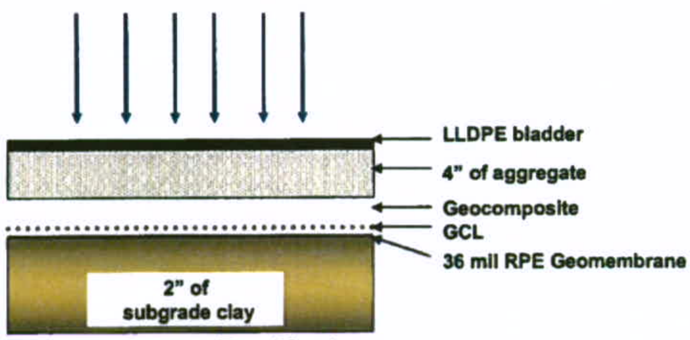
Test No. 1



Test No. 2



Test No. 3



Test No. 4

Post Test Inspection: After dismantling, the 60 mil smooth and 36 mil RPE geomembranes were inspected for out-of-plane deformations, punctures, and abrasions. Pictures showing equipment, system layers and post test exposure are also included. No visible punctures of the geomembrane were found.

Test No.	Observations
1	No measurable deformations, no punctures or notable marks
2	No measurable deformations, no punctures or notable marks
3	Three barely visible deformations noted, no punctures or notable marks
4	No measurable deformations, no punctures or notable marks

Conclusion

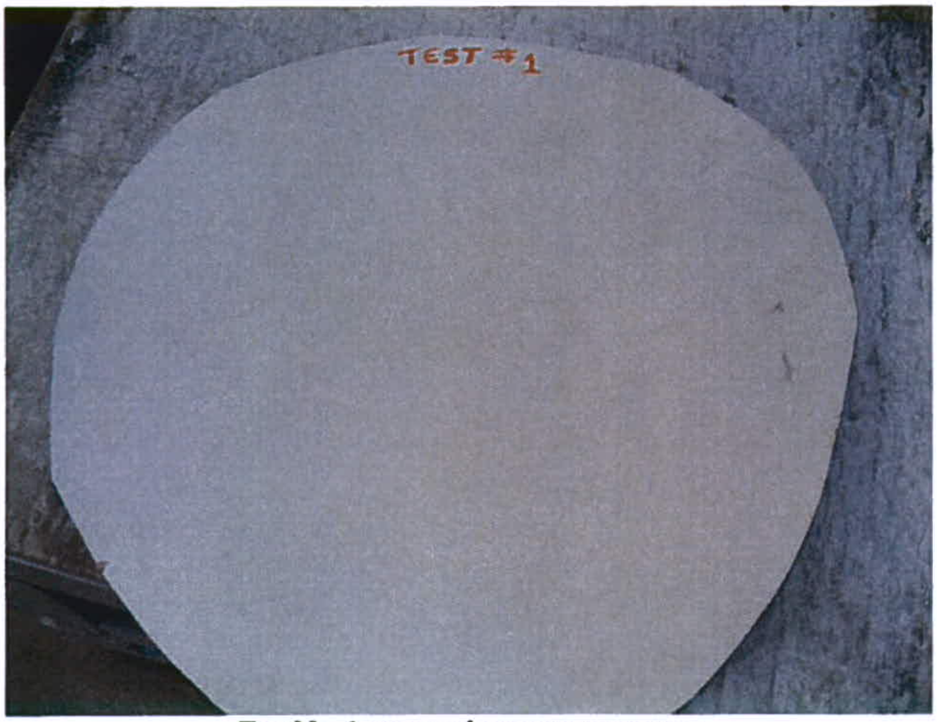
TRI trusts that this report sufficiently documents the testing described herein. TRI is pleased to be of service to Colorado Lining. Please contact me if you have any questions or require any additional information.

Sincerely,

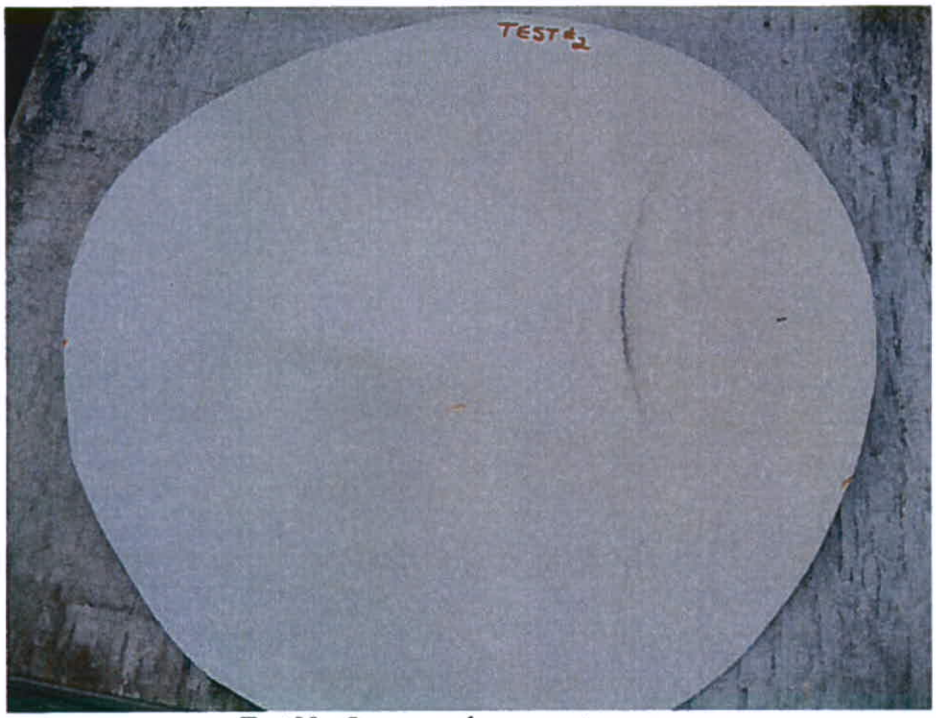
John M. Allen
Director
Geosynthetics Services
www.GeosyntheticTesting.com

Test Cell

Example of the Roan Plateau shale placed over geosynthetic liner system

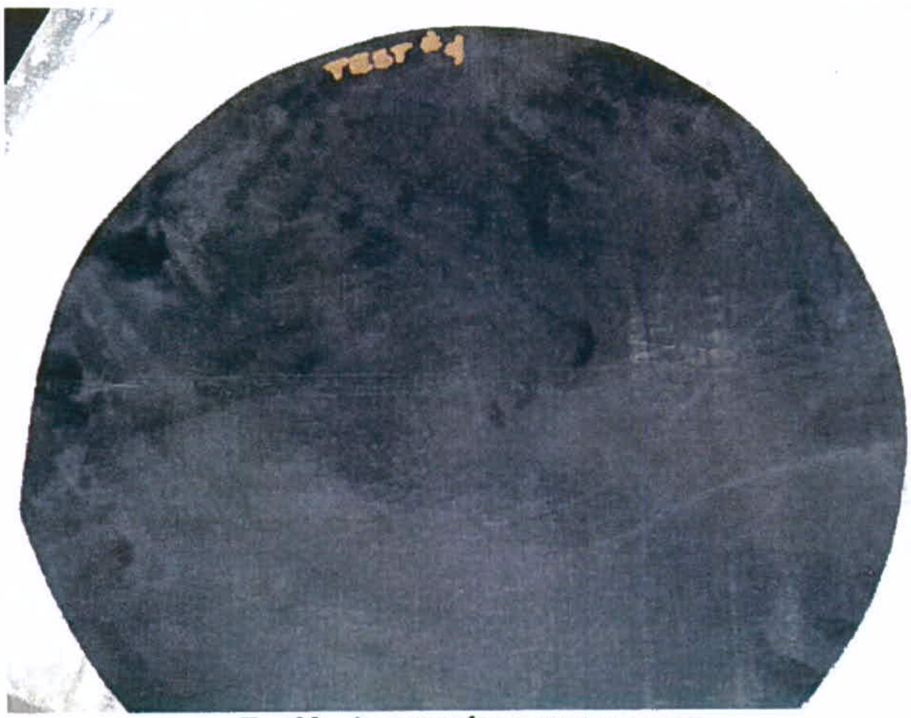


Test No. 1 geomembrane post exposure



Test No. 2 geomembrane post exposure

Test No. 3 geomembrane post exposure



Test No. 4 geomembrane post exposure

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CALCULATION COVER SHEET

Date: 1/7/09

Calculation No.: G21-001

Calculation Title: Anchor Trench Calculations

Project No. and Name: 8053-14: G-21 Produced Water Pit

Design Verification Required: ☒ Yes ☐ No

Calculation Type: ☐ Scoping ☐ Preliminary ☒ Final

☐ Superseded by Calculation No.: ____________ ☐ Voided

ORIGINAL AND REVISED CALCULATIONS / ANALYSIS APPROVAL

	REV. 0 Printed Name / Signature / Initials / Date	REV. ____ Printed Name / Signature / Initials / Date	REV. ____ Printed Name / Signature / Initials / Date
Originator:	NBD NBD 1/6/09		
Checked By:	MCL MCL 1/6/09		
Approved By:	JM [signature] 1/5/09		
Other:			

AFFECTED DOCUMENTS

Document Number	Document Title	Rev. No.	Responsible Project Manager Initials
Varies	Design Drawings	0	JM

RECORD OF REVISION

Rev. No.	Reason for Revision
0	Issued for Permit and Construction

ATTACHMENTS

Attachment No.	Title	Total Pages
1	Tables 1 and 2 – Manufacturer's Test Data for Primary and Secondary Geomembrane	2
2	Martin, J.P., Koerner R.M., and Whitey, J.E., "Experimental Friction Evaluation of Slippage between Geomembranes, Geotextiles and Soils, "Proceedings of the International Conference on Geomembranes	6

TOTAL CALCULATION PAGE COUNT 12

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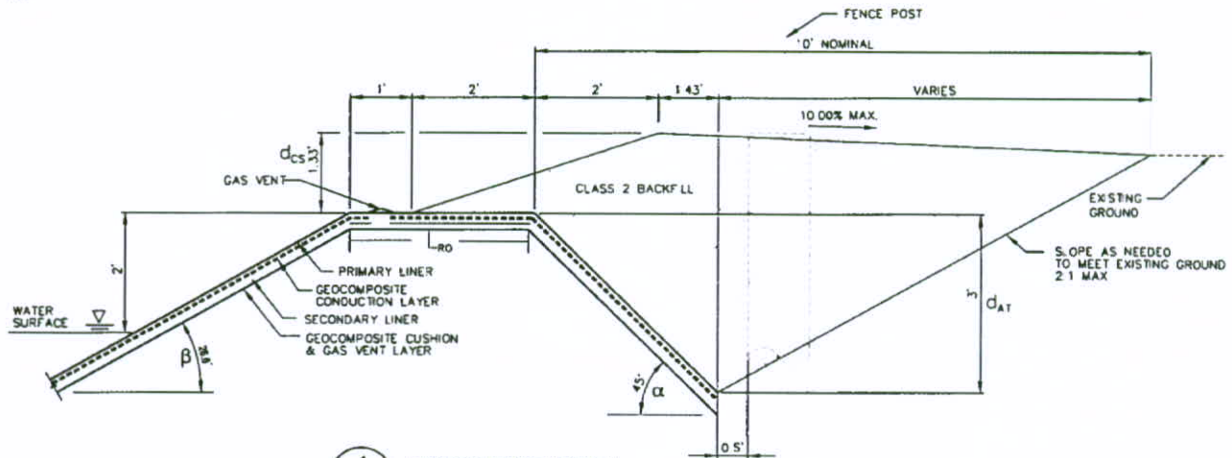
DESIGN CALCULATION No.: G21-0001

Client:	ConocoPhillips	Project:	G-21 Produced Water Pit Design
Area:	G-21	Subject:	Anchor Trench Calculation Details
Proj. No.:	8053-14	Page:	1 Of: 4
Sub No.:	N/A	Prep:	NBD Date: 10/29/2009
Ref. Dwg No.:	N/A	Check:	MCL Date: 1/7/2009

Typical Liner Detail:



1 ANCHOR TRENCH DETAIL
N.T.S.

Interior slopes of ponds are 2V:1H and slope of anchor trench v-shap is 1V:1H.

b = tan-1 (1/2) = 26.6° = side slope angle
a = 45° as indicated in typical detail

Primary Liner - 36 Mil Reinforced Polyethylene (RPE):

Purpose:

To calculate resistance capacity of a V-shaped anchor trench of given dimensions using a 36 mil RPE as a primary liner.

References:

1. The text books referenced for these calculations are "Geotechnical Aspects of Landfill Design and Construction" by Qian, Koerner and Gray and "Designing with Geosynthetics" Fifth Edition by Rober M. Koerner.
2. The specific design example that has been used as reference has been taken from Chapter 4, "Geomembranes", Section 4.7.3 of Qian, Koerner and Gray.
3. The value dc for the friction angle between geomembrane and geotextile has been considered as 13 degrees and the friction angle between geomembrane and soil has been considered as 21 degrees based on a study done by Martin et. al. [Martin, J.P., Koerner R.M., and Whitey, J.E., "Experimental Friction Evaluation of Slippage between Geomembranes, Geotextiles and Soils, "*Proceedings of the International Conference on Geomembranes*, IFAI, 1984, pp. 191-196]. Since no data was available for Reinforced Polyethylene (RPE), the value for Reinforced Chlorosulphonated Polyethylene (CSPE-R) was used in lieu of RPE and concrete sand was used as the soil type.
4. The unit weight of Shale has been considered 135 psf based on the Geotechnical Investigation conducted for the "Crawford Truck Loadout Facility and Evaporation Pond" at Garfield County, Colorado by CTL/Thompson Incorporated of Glenwood Springs, CO.
5. The Ultimate Tensile Strength for 24 mil and 36 mil RPE has been taken from values provided by the manufacturer, which are attached herewith as Tables 1 and 2.

Formula:

$$T_{AT} = \frac{\gamma_s \cdot d_{CS} \cdot L_{RO} \cdot \tan\delta_C \cdot \gamma s \cdot (d_{CS} + 0.5 \cdot d_{AT}) \cdot d_{AT} \cdot (\tan\delta_C + \tan\delta_F) \cdot (\cot\alpha_L + \cot\alpha_R)}{\cos\beta - \sin\beta \cdot \tan\delta_C}$$

Definitions:

L_{RO} runout length

d_{AT} anchor trench depth

d_{CS} depth of cover soil

γ_s unit weight of cover soil and the backfill soil

δ_C friction angle between the geomembrane and the underlying material or underlying soil

δ_F friction angle between the geomembrane and the overlying material or overlying soil

α_L left bottom angle of V-shaped anchor trench, measured from horizontal

α_R right bottom angle of V-shaped anchor trench, measured from horizontal

β sideslope angle, measured from horizontal

T_{AT} resistance capacity of the geomembrane in a V-shaped anchor

T_{ULT} ultimate tensile strength as determined by manufacturer

Calculatios for Input Values:

L_{RO} variable - adjusted as needed to obtain desired results - only the amount of runout under the cover soil is considered in the equation.

d_{AT} variable - adjusted as needed to obtain desired results

d_{CS} variable - adjusted as needed to obtain desired results

γ_s = 135 psf; based on Reference No. 4

δ_C = 13° from Reference No. 3

δ_F = 13° or 21° depending upon the calculation being performed per Reference No. 3.

α_L = 45°; selected to obtain maximum length of material runout in the shortest horizontal distance

α_R = 0°; assumed to be zero since material may not be placed on the right side of the V-shaped trench

$\beta = \tan^{-1}(1/2)$; based on a client-preferred deign slope of 2V:1H
= 26.6°

T_{ULT} Obtained from Manufacturer's data from the Ultimate Tensile Strength of each type of material
Test results for 36mil are reported in lbs per each 1-inch test strip.

$T_{ULT-36mil}$	=	90 lbs for a 1-in strip
	=	(90 lbs/in * 12in/1ft)
	=	1080 lbs/ft (psf)
$T_{ULT-24mil}$	=	258 lbs for a 4-inch strip
	=	258 lbs/4 in = 64.5 lbs per in
	=	(64.5 lbs/in * 12 in/1ft)
	=	774 psf

T_{AT} Calculated based on the formula listed above. See pages 3 and 4 for calculation results.

Summary of Values:

L_{RO} variable
d_{AT} variable
d_{CS} variable
γ_s 135 psf
δ_C 13°
δ_F 13° or 21°
α_L 45°
α_R 0°
β 26.6°
$T_{ULT-36mil}$ 1080 psf
$T_{ULT-24mil}$ 774 psf
T_{AT} calculated per sheets following

Refer to Pages 2 and 3 for calculation results

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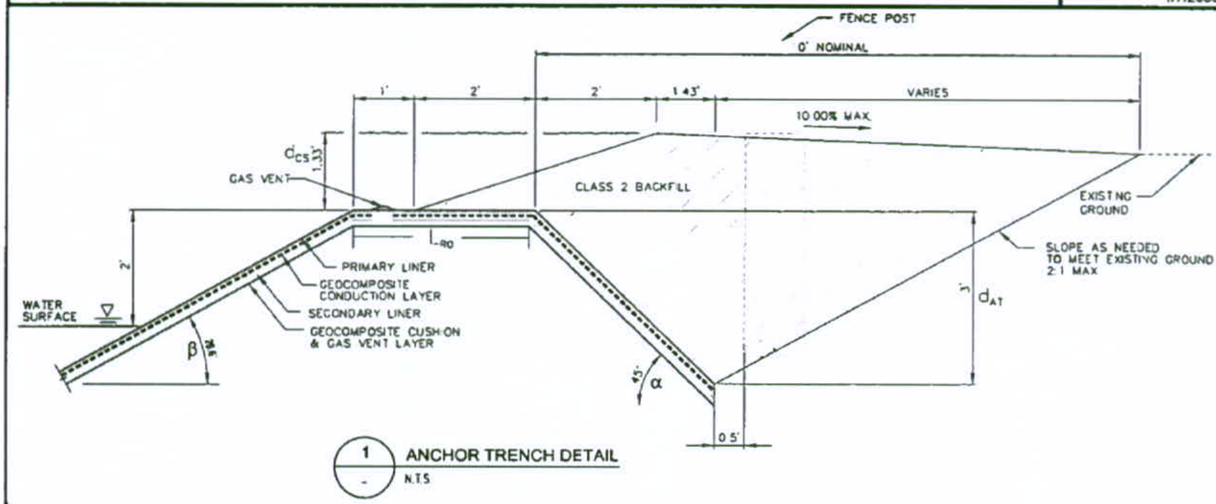
DESIGN CALCULATION No.: G21-0001

Client:	ConocoPhillips	Project:	G-21 Produced Water Pit Design
Area:	G-21	Subject:	Anchor Trench Calculation Details
Proj. No.:	8053-14	Page:	3 Of: 4
Sub No.:	N/A	Prep:	NBD Date: 10/29/2009
Ref. Dwg No.:	N/A	Check:	MCL Date: 1/7/2009

Runout Length and Anchor Trench Design

POND G-21
1/7/2009



36 mil RPE

Runout distance (L_{RO} Covered by Cover Soil)	L_{RO}	2	ft
Depth of the anchor trench	d_{AT}	3.0	ft
Unit weight of cover soil (Shale)	γ_s	135	pcf
Thickness of soil cover (assumed min)	d_{cs}	1.33	ft
Friction Angle between Geomembrane and underlying material	δ_c	13	degrees
Friction Angle between Geomembrane and the backfill	δ_F	21	degrees
Bottom Angle of the right side V Shaped Anchor Trench	α_R	45	degrees
Bottom Angle of the left side V Shaped Anchor Trench	α_L	45	degrees
Side Slope Angle	β	26.6	degrees
Ultimate Tensile Strength of 36 mil RPE	T_{ult}	1080	plf
	$\sin\beta$	0.448	
	$\cos\beta$	0.894	
	$\tan\delta_c$	0.231	
	$\tan\delta_F$	0.384	
	$\cot\alpha_R$	0.617	
	$\cot\alpha_L$	0.617	
Resistant Capacity of 36 mil RPE	T_{AT}	1183	plf
	Strength Ratio	1.10	

Analysis Notes:

If $T_{ult} < T_{AT}$ (Strength Ratio>>1), The Geomembrane will fail if sufficient tensile stresses are mobilized.

If $T_{ult} > T_{AT}$ (Strength Ratio<<1), The Geomembrane will pull out if sufficient tensile stresses are mobilized.

If $T_{ult} \approx T_{AT}$, (Strength Ratio approximately equal to 1) indicates a balanced design

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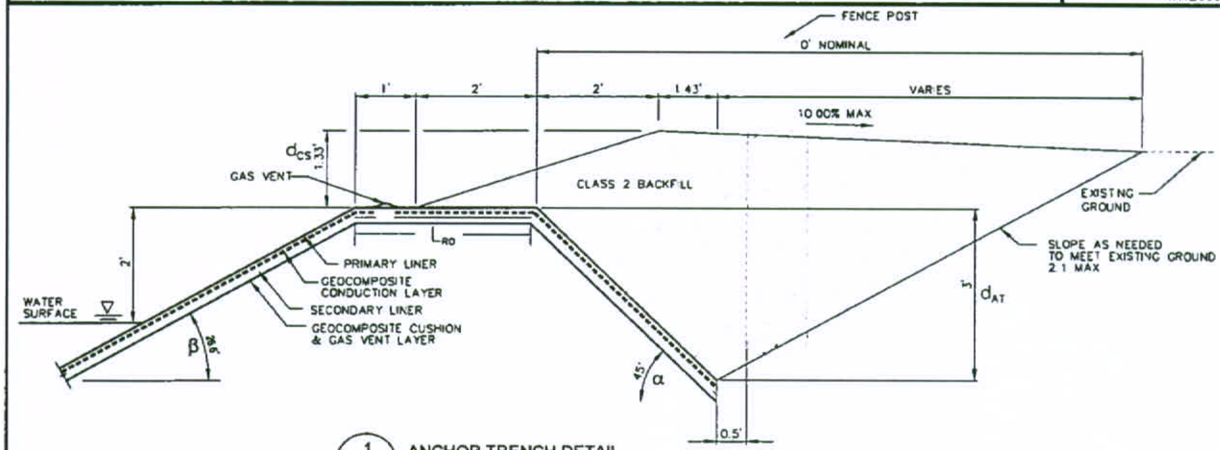
Runout Length and Anchor Trench Design — POND G-21 — 1/7/2009



ANCHOR TRENCH DETAIL
N.T.S.

24 mil RPE

Runout distance (L_{RO} Covered by Cover Soil)	L_{RO}	2	ft
Depth of the anchor trench	d_{AT}	3.0	ft
Unit weight of cover soil	γ_s	135	pcf
Thickness of soil cover (assumed min)	d_{cs}	1.33	ft
Friction Angle between Geomembrane and underlying material	δ_c	13	degrees
Friction Angle between Geomembrane and the overlying material	δ_F	13	degrees
Bottom Angle of the right side V Shaped Anchor Trench	α_R	45	degrees
Bottom Angle of the left side V Shaped Anchor Trench	α_L	45	degrees
Side Slope Angle	β	26.5	degrees
Ultimate Tensile Strength of 24 mil RPE	T_{ult}	774	plf
	$\sin\beta$	0.446	
	$\cos\beta$	0.895	
	$\tan\delta_c$	0.231	
	$\tan\delta_F$	0.231	
	$\cot\alpha_R$	0.617	
	$\cot\alpha_L$	0.617	
Resistant Capacity of 24 mil RPE	T_{AT}	908	plf
	Strength Ratio	1.17	

Analysis Notes:

If $T_{ult} < T_{AT}$ (Strength Ratio>>1), The Geomembrane will fail if sufficient tensile stresses are mobilized.

If $T_{ult} > T_{AT}$ (Strength Ratio<<1), The Geomembrane will pull out if sufficient tensile stresses are mobilized.

If $T_{ult} \approx T_{AT}$, (Strength Ratio approximately equal to 1) indicates a balanced design

Attachment 1: Tables 1 and 2 - Manufacturer's Test Data for Primary and Secondary Geomembranes

Table 1: Required Primary Geomembrane Properties

Properties	Test Method	30 mil		36 mil		45 mil	
		Min. Roll Avg.	Typical Roll Avg.	Min. Roll Avg.	Typical Roll Avg.	Min. Roll Avg.	Typical Roll Avg.
Appearance		Black/Black		Black/Black		Black/Black	
Thickness	ASTM D 5199	27 mil	30 mil	32 mil	36 mil	40 mil	45 mil
Weight Lbs Per MSF (oz/yd^2)	ASTM D 5261	126 lbs (18.14)	140 lbs (20.16)	151 lbs (21.74)	168 lbs (24.19)	189 lbs (27.21)	210 lbs (30.24)
Construction		**Extrusion laminated with encapsulated tri-directional scrim reinforcement					
Ply Adhesions	ASTM D 413	16 lbs	20 lbs	19 lbs	24 lbs	25 lbs	31 lbs
1" Tensile Strength	ASTM D 7003	88 lbf MD 63 lbf DD	110 lbf MD 79 lbf DD	90 lbf MD 70 lbf DD	113 lbf MD 87 lbf DD	110 lbf MD 84 lbf DD	138 lbf MD 105 lbf DD
1" Tensile Elongation @ Break % (Film Break)	ASTM D 7003	550 lbf MD 550 lbf DD	750 lbf MD 750 lbf DD	550 lbf MD 550 lbf DD	750 lbf MD 750 lbf DD	550 lbf MD 550 lbf DD	750 lbf MD 750 lbf DD
1" Tensile Elongation Peak % (Scrim Break)	ASTM D 7003	20 lbf MD 20 lbf DD	33 lbf MD 33 lbf DD	20 lbf MD 20 lbf DD	30 lbf MD 31 lbf DD	20 lbf MD 20 lbf DD	36 lbf MD 36 lbf DD
Tongue Tear Strength	ASTM D 5884	75 lbf MD 75 lbf DD	97 lbf MD 90 lbf DD	75 lbf MD 75 lbf DD	104 lbf MD 92 lbf DD	100 lbf MD 100 lbf DD	117 lbf MD 118 lbf DD
Grab Tensile	ASTM D 7004	180 lbf MD 180 lbf DD	218 lbf MD 210 lbf DD	180 lbf MD 180 lbf DD	222 lbf MD 223 lbf DD	220 lbf MD 220 lbf DD	257 lbf MD 258 lbf DD
Trapezoid Tear	ASTM D 4533	120 lbf MD 120 lbf DD	146 lbf MD 141 lbf DD	130 lbf MD 130 lbf DD	189 lbf MD 172 lbf DD	160 lbf MD 160 lbf DD	193 lbf MD 191 lbf DD
* Dimensional Stability	ASTM D 1204	<1	<0.5	<1	<0.5	<1	<0.5
Puncture Resistance	ASTM D 4833	50 lbf	64 lbf	65 lbf	83 lbf	80 lbf	99 lbf
Maximum Use Temperature		180 °F	180 °F	180 °F	180 °F	180 °F	180 °F
Minimum Use Temperature		-70 °F	-70 °F	-70 °F	-70 °F	-70 °F	-70 °F

NOTES:

Minimum Roll Averages are set to take into account p testing variability between laboratories.

MD stands for machine Direction and DD for Diagonal Direction.

*Dimensional stability maximum value

**30 mil, 36 mil, & 45 mil are a four layer reinforced laminate containing no adhesives. The outer layers consist of a high strength polyethylene film manufactured using virgin grade resins and stabilizers for UV resistance in exposed applications. 30 mil, 36 mil, & 45 mil are reinforced with a 1300 denier (minimum) tri-directional scrim reinforcement.

Attachment 1: Tables 1 and 2 - Manufacturer's Test Data for Primary and Secondary Geomembranes

Table 2: Required Secondary Geomembrane Properties

Properties	Test Method	24 mil	
Grab Tensile	ASTM D 751/NSF	Warp 258 lb, 1160 N	Weft 250 lb, 1114 N
Tongue Tear – Large Scale	ASTM D 5884-01	Warp 140 lb, 621 N	Weft 149 lb, 663 N
Trapezoidal Tear	ASTM D 4533-04	Warp 200 lb, 890 N	Weft 130 lb, 578 N
Mullen Burst	ASTM D 3786-01	370 psi, 2553 kPa	370 psi, 2553 kPa
Hydrostatic Resistance	ASTM D 751-00	208 psi, 1438 kPa	208 psi, 1438 kPa
Puncture Resistance	ASTM D 4833-00	76 lb, 339 N	76 lb, 339 N
Carbon Black Content	ASTM D 4218-96	3.71%	3.71%
Volatile Loss	ASTM D 1203-94	0.07%	0.07%
Dimensional Stability	ASTM D 1204-02	Warp -1.40 %	Weft -1.34 %
Low Temperature Flex	ASTM D 2136-94	Warp Pass @ -40°	Weft Pass @ -40°
Accelerated UV Weathering	ASTM G151-00 ASTM G154-04	>95% strength retention after 2000 hrs exposure @ 0.77 W/m^2/nm, or 1200 hours exposure @ 1.35 W/m^2/nm.	

NOTES:

Q.U.V. (A-340 Lamps): 8 hrs UV @ 60° C; 4 hrs condensation @ 50 C°; Construction: Reinforcing polyester scrim between LLDPE barrier layers; Colour: Black and other colors available after consultation; Weight: 16 oz/yd^2 (542 g/m^2) ±5%; Thickness: Nominal 24 mils 0.024" (0.61mm)

These values are typical data and are not intended as limiting specifications. All cut edges where scrim is exposed must be sealed using PE welding rod. Warp = machine direction; Weft = cross machine direction Test strips are 4-inches wide

MARTIN, J. P., KOERNER, R. M., and WHITTY, J. E.
Drexel University, Philadelphia, Pennsylvania, USA

Experimental Friction Evaluation of Slippage Between Geomembranes, Geotextiles and Soils

A common failure mechanism of geomembrane lined side slopes of impoundments and reservoirs is by slipping of components within the liner system or of the cover soil. While safe design is indeed possible, the friction values between individual components are required and are essentially not available to date. This study focuses on presenting a test methodology and data base for friction values between three soil tyes, four geomembranes and four geotextiles. Seen is that the values vary widely in accordance with the materials being used. Mobilized friction values from 60% to 100% of the intrinsic values of the material by itself were determined. Details of the tests and individual values are reported.

INTRODUCTION

The usual design goal of excavated or built-up impoundments is to build the side slopes as steeply as possible. This is particularly true at sites of high water table or in containing large volumes with respect to the available land area. To eliminate, or minimize, the loss of the contained liquids or generated leachates it is usually necessary to line both the bottom and sides of such impoundments. For the purpose of this study, the primary liner will be assumed to be a flexible membrane liner (FML), i.e., a geomembrane, made from polymeric materials into relatively thin sheets, 20 mils to 100 mils thick, and adequately seamed together wherever joints are necessary. In some circumstances it is necessary to sandwich this geomembrane between one or two geotextiles, which are porous woven or nonwoven fabrics that serve the following functions:

The geotextile underliner:

- prevents underlying stones and sharp objects from puncturing the geomembrane
- provides a clean working surface for placement of the geomembrane and the making of field seams
- provides some support (reinforcement) over weak areas in the subgrade
- acts as a lateral transmitter of water and gas which may come up from the subsurface soil beneath the geomembrane -- in this case, one must select a bulky, needled nonwoven geotextile which possesses adequate transmissivity.[1,2]

The geotextile overliner:

- protects the geomembrane from puncture of stones in the cover soil or in the landfilled material itself
- provides some load spreading capability for heavy objects in the landfill, i.e. reinforcement
- protects the geomembrane from ozone and ultraviolet attack for cases where the liner system is not soil covered

Usually, but certainly not always, the sandwiched geomembrane liner is covered with a layer of soil. This cover soil should be select material with good gradation and strength characteristics so that it can be easily placed and compacted in as thin a layer as possible. Usually its thickness is from 30.48 to 91.44 centimeters. In many cases it serves a dual role as protection to the liner system and as a leachate collection system containment media, i.e., pipe underdrains are placed within it.

With the above thoughts in mind, the general cross section of the side slopes of lined impoundments containing liquids and/or solids is presented in Figure 1. Note that the following alternates for the liner system can be used:

- geomembrane alone (GM)
- geomembrane plus cover soil (GM/CS)
- geotextile underliner plus geomembrane (GTU/GM)
- geotextile underliner plus geomembrane plus cover soil (GTU/GM/CS)
- geotextile underliner plus geomembrane plus geotextile overliner (GTU/GM/GTO)
- geotextile underliner plus geomembrane plus geotextile overliner plus cover soil (GTU/GM/GTO/CS)

Upon the decision as to the choice of above liner system and a knowledge of the depth of the impoundment, the critical variable becomes the slope angle and the general stability of the lined side slopes.

The analysis of slope stability for both homogeneous and heterogeneous soil masses is well developed in geotechnical engineering practice. However, the analysis of stability when flexible synthetic sheets (geomembranes and geotextiles) under tension are placed on the slope face is still in its infancy. This situation falls into the general classification of soil-structure interaction problems. The three major elements necessary to extend organized slope stability analysis into membrane-lined impoundments are:

(a) Data on limiting shear strength along interfaces between soils, geomembranes and geotextiles.
(b) Effect of tension in the liner system (provided for by the anchor trench) on the overall slope stability.

(c) Effect of slippage between soils, geomembranes and geotextiles and its relationship to the general stress-strain behavior of the materials.

This paper is a report of experimental work that concentrates primarily on item (a). It extends published data on friction between geotextiles and soils, and presents new data on frictional behavior between soils and geomembranes and also between geotextiles and geomembranes. Item (b) is more analytical than experimental, and is only considered briefly herein. However, a review of analytical methods is included since it provides a basis for further work in this area with the experimental data obtained and presented. A brief discussion of item (c) is included, but it is actually a summary of a more extended report soon to be available.(3,4)

ANALYSIS OF STABILITY OF LINED SIDE SLOPES

There are two major areas of concern with respect to stability of the side slopes of a lined enclosure: slope stability of the soil subgrade, natural formations and compacted embankment under the liner and slippage within the liner system consisting of geomembrane, geotextiles and cover soil.

Analysis of general slope stability involves determination of the factor of safety against shear failure along an undefined critical surface, usually assumed to be circular. Design centers around the selection of the appropriate geometry, materials and other measures to obtain the desired factor of safety. The driving force for most slope failures is the applied stress along a continuous surface that results from body and surcharge forces. The resistance is provided by the cohesive and frictional strength of the soil and other materials along a slip surface. Schematically, this type of a failure is shown in Figure 2(a). Proper design to prevent this situation from occurring is well within the state-of-the-art of geotechnical engineering. It is, indeed, an important consideration but it is beyond the scope of this paper.

Slippage between the various components of the liner system, however, is of very real concern and is the general thrust of this study. It is shown schematically in Figure 2(b) for both the geomembrane liner system and the cover soil over the liner. The design procedure in this case of a liner failure along a known surface is straighforward once the values of friction are known between the various interfaces involved. Assuming these values are known a force polygon can be drawn consisting of the following items which are shown and illustrated in Figure 3.

- The weight of the liner system and cover soil (if present); which act vertically downward (W_A and W_{NB})
- The tensile strength of the liner system (geomembrane plus geotextiles, if present); which acts along the slope and is eventually mobilized in the anchor trench (T)
- The possible resistance to failure of a small wedge of cover soil at the toe of the slope; which also acts along the slope (E_A and E_{NB})
- The unknown frictional forces (F_A and F_{NB}) which act at different friction angles (δ_A and δ_{NB}), where the friction angle δ_A is the minimum value between any interface in the liner system and must be determined experimentally (this item is the specific focus of this paper) and the friction angle δ_{NB} which is completely within the cover soil and is generally equal to the friction angle of the soil.

This type of problem is best solved by assuming a factor of safety and applying it to δ_A and δ_{NB}. A force polygon for the neutral block is drawn to obtain a trial value for E_{NB}. This value is then made equal to E_A and is used in construction of a force polygon for the active zone. If closure of the active zone polygon is obtained, the initially assumed factor of safety is correct. If not, successive trials using different values will be required until a graph can be drawn to accurately assess the actual factor of safety. Usually three or four trials are necessary.

Critical in this design process, and not available in the required form as far as the authors are aware, is the value for interface friction between components of the liner system, i.e., δ_A values. The design value will be the minimum value between any component of the liner system; soil, geomembrane or geotextile. It is, of course, material dependent so that each specific material will have to be experimentally evaluated. This paper describes such experiments and presents data on a wide range of soil types, geomembranes and geotextiles.

TEST DETAILS AND PROCEDURES

A modified direct shear apparatus was used to evaluate friction values between soils, geomembranes and geotextiles in various combinations. In this type of test, the two materials being evaluated were placed in a split shear box, as shown in Figure 4. The shear box used had dimensions of 10.16 X 10.16 centimeters. For soil testing the depth in each part of the shear box was 2.54 centimeters of soil. For composite soil and geomembrane or soil and geotextile testing, the soil was placed in the upper half of the shearbox and the fabric was in the lower half. Rather than laying loose in the lower half of the shear box, the geomembrane or geotextile was firmly attached to a plexiglass block so that wrinkling could not occur. For geomembrane on geotextile testing, each material was attached to a separate plexiglass block and placed opposing one another in the two parts of the test device. All materials were tested in saturated condition, with the soils being placed at about 90% of their maximum density (ASRM D-698). This apparatus and techniques appears to be easier to perform than other shear box tests and be more representative of field boundary conditions than pullout tests, see Collios, et a.(5)

The normal stress range used in these tests was varied from 2.0 psi to 15 psi. These values are somewhat lower than in normal geotechnical testing but probably better reflect the low normal stresses that shallow cover soils impose on typical liner systems. The shear phase of the test was deformation controlled at a displacement rate of .127 millimeters/min. This low deformation rate assured complete dissipation of pore water pressures during the test. Typical data that resulted from these tests are shown in Figure 5. Here a set of different types of geomembranes were each tested with a concrete sand (sieved through a #10 sieve) at 6.0 psi of normal stress. Typical elastic-plastic response curves are observed, each having a well defined maximum value of shear stress.

Upon testing these same sets of materials at different normal stresses one can plot the peak shear stress versus applied normal stress on Mohr's stress space, as shown in Figure 6. Note that all failure envelopes pass through the origin attesting to the fact that there is no (or non-measurable) cohesion in the soils tested nor adhesion between these soils and the fabrics evaluated. (This would not have been the case if fine grained soils such as clays or cohesive silts had been used). The slope of these curves, often presented as an angle, is the desired value for design purposes. In all cases in this study, the response was linear and the data spread in a given locus of points was nominal.

After each shear failure, the direction of deformation was reversed, and the test repeated. The purpose of this exercise was to indicate residual friction angles where membrane tension is alternately increased and reduced as the level of a storage lagoon changes. Such reversals of strain direction may tend to align particles along the shear plane, and reduce slip resistance. However, the difference between initial and repeated shear strengths was negligible in all cases.(3)

MATERIALS TESTED AND RESULTS

Three granular soil types were used in these tests:

(1) Ottawa sand (SP) with d_{10} = 0.42 mm; CU = 1.9 and rounded particle shapes.
(2) Concrete sand (SP) with d_{10} = 0.20 mm; CU = 2.6 and angular particle shapes.
(3) Mica schist silty sand (SM) with d_{10} = 0.057 mm; CU = 5.1 and angular particle shapes.

Thus the three soil types selected give a contrast in particle shape, size and uniformity. They are limited however, to granular soils with essentially no plasticity.

Four types of geomembranes (using five separate surfaces) were used in these tests. They were all tested in their manufactured directions.

(1) High density polyethylene (HDPE) which was 20 mils thick and can be characterized as being stiff, hard and smooth as far as physical or frictional characteristics are concerned.
(2) Ethylene propylene diene monomer (EPDM) which was 30 mils thick and can be characterized as being flexible, soft and smooth.
(3) Polyvinyl chloride (PVC) which was 30 mils thick and characterized as being of medium stiffness and hardness and rough on one side while smooth on the other side. Both sides were used during these tests.
(4) Chlorosulfonated polyethylene (CSPE) which was reinforced with a fabric scrim and was 36 mils thick. It is characterized as being of medium stiffness and hardness, but was of wavy roughness due to the laminated 10 x 10 scrim reinforcement contained within it.

Four types of geotextiles were used in these tests which represented each of the general manufacturing classifications of these materials.(6) They were all tested in their manufactured directions.

(1) Woven monofilament polypropylene fabric (Carthage Mills Polyfilter X) which is characterized as being a thin, stiff fabric with a relatively high percent open area as far as physical or frictional characteristics are concerned.
(2) Woven silt film (tape) polypropylene fabric (Mirafi 500 X) which is characterized as being a thin, flexible fabric with a low percent open area.
(3) Nonwoven heat set polypropylene fabric (duPont 3401) which is characterized as being a thin, flexible fabric with a relatively low open area.
(4) Nonwoven needled polypropylene fabric (Crown Zellerbach 600) which is characterized as being a compressible, thick, bulky, very flexible fabric with a relatively high open area.

These three soil types, four geomembranes types and four geotextile types were tested within their own categories and against one another in the manner described in the previous section. The results are given in Table 1 in two ways. The principal information (for design purposes) is given as angular values of friction angle; "ϕ" values for the soil by itself and "δ" values for the composite behavior. In parenthesis is given the relative amount (for comparison purposes) of mobilized soil strength that the geomembrane or geotextile gives, i.e.,

$$E = \frac{\tan \delta}{\tan \phi}$$

where

E = efficiency ratio
$\tan \delta$ = tangent of soil to material friction angle
$\tan \phi$ = tangent of soil friction angle, where
$\tau = c + \bar{\sigma}_n \tan \phi$
c = cohesion (zero for these granular soils)
$\bar{\sigma}_n$ = effective normal stress

Table 1 – Summary of Friction Angle and Efficiencies (in Parentheses) For Soils, Geomembranes and Geotextiles Testing in this Study

(a) Soil to Geomembrane Friction Angles

Geomembrane \ Soil		Concrete Sand (ϕ = 30°)	Ottawa Sand (ϕ = 28°)	Mica Schist (ϕ = 26°)
EPDM		24° (.80)	20° (.71)	24° (.92)
PVC	(Rough)	27° (.90)	-	25° (.96)
	(Smooth)	25° (.83)	-	21° (.81)
CSPE		25° (.83)	21° (.75)	23° (.88)
HDPE		18° (.60)	18° (.64)	17° (.65)

(a) Soil to Geotextile Friction Angles

Geomembrane \ Soil	Concrete Sand (ϕ = 30°)	Ottawa Sand (ϕ = 28°)	Mica Schist (ϕ = 26°)
CZ 600	30° (1.00)	26° (.93)	25° (.96)
Typar 3401	26° (.87)	-	-
Polyfilter X	26° (.87)	-	-
500 X	24° (.80)	24° (.86)	23° (.88)

(c) Geomembrane to Geotextile Friction Angles

Geotextile \ Geomembrane	EPDM	PVC (R)	PVC (S)	CSPE	HDPE
CZ 600	23°	23°	21°	15°	8°
Typar 3401	18°	20°	18°	21°	11°
Polyfilter X	17°	11°	10°	9°	6°
500 S	21°	28°	24°	13°	10°

INTERPRETATION OF RESULTS

Table 1, parts "a" and "b" show the results of the direct shear tests for friction between various soils and synthetic materials in terms of friction angle (ϕ or δ)

and relative efficiency (E). It can be seen that the friction between all soils and the geotextiles or geomembranes is less than that of the soil itself. Consequently, soil to fabric friction governs the design of a slope, recall Figure 3. Soil to geotextile friction generally exceeds soil to geomembrane friction. Therefore, placement of a geotextile over or under a liner (as discussed in the introduction) will tend to allow a steeper slope, provided that both fabrics are securely anchored. If the anchor fails, then the safe slope angle will obviously be decreased. Part "c" of this table shows that geotextile to geomembrane friction is relatively low and depends greatly on the particular type of geomembrane being used.

Certain additional trends can be inferred from the data of Table 1 that allow prediction of the behavior of other materials not represented in the testing program. The three soils were selected to indicate the influence of particle angularity and gradation. For instance, EPDM is a smooth, flexible and surficially soft material. The friction angle with angular soil is higher than that with rounded soil. Here, the higher friction resulted from surface penetration, and surface scratches in the geomembrane were noted with the concrete sand tests. A high relative efficiency (92%) was obtained with the well graded silty sand probably due to the high contact area between the soil and the geomembrane and the surface roughness induced by distorting, but not piercing, the soft surface. Thus, it is worthwhile to use angular and well graded cover soils on soft membranes.

In contrast, the stiff, hard and smooth HDPE was fairly insensitive to soil type. Surface roughness is not induced by normal stress on the HDPE to soil interface, and low friction angles and relative efficiency indexes result. It would appear that it is necessary to place and anchor a geotextile over the material in order to build a steep slope with HDPE.

As expected, the angular soil readily penetrated into most of the geotextiles, and the relative efficiencies of all geotextiles and particularly, the needled-punched fabric, are particularly high. One generalization that can be made is that is it easier to estimate soil to geotextile friction for nonwoven than woven fabrics. There are a wide range of fabric openings in the non-wovens, whereas the woven geotextiles have a more regular pattern and limited opening size range. Hence, while the specific gradation of one soil type may allow considerable fabric penetration, a slightly coarser soil will not interlock as well. However, this analysis does not take into account the tensile strength or puncture resistance of woven materials; parameters which may be of equal importance in a particular situation.

Certain additional trends are evident in part "c" of Table 1. The pliable EPDM readily takes on the imprint of the opposing geotextile during conducting of the test, producing a surface roughness resulting in improved behavior. Hence, special care must be taken to assure that an overlying or underlying geotextile is securely anchored. The relatively stiff woven monofilament geotextile, substantially interacts (mechanically) with only the EPDM. The effect of geotextile stiffness is particularly evident with the scrim-reinforcement CSPE, such that the relatively stiff monofilament geotextile imprints the CSPE material around the reinforcement grid, but does not deform sufficiently to contact much of the soft material below and between the grid.

It must be noted, however, that the selection of a liner system (geomembrane, geotextile and soil cover) is dependent not only on the above friction behavior but also on the basis of chemical resistance to the impounded materials, availability and cost. As noted in the introduction, geotextiles are employed with liners for purposes other than friction. Finally, the subgrade soil is usually that which is native to the site. Consequently, the cover soil is often the only material of concern which can be selected largely on the basis of its mechanical properties.

SUMMARY AND CONCLUSIONS

Proper design of geomembrane lined side slopes is necessary whenever slopes greater than approximately 4 (horizontal) on 1 (vertical) are contemplated. Since this usually is the case (except in areas where large land areas are available), one must consider at least two different failure mechanisms. One is a general slope stability failure of a large mass consisting of the liner system and subsoils which is an area beyond the scope of this paper but well within the state-of-the-art. The other is linear slippage between individual components of the liner system or of the cover soil. This latter aspect was the concentration in this study. Elements of the general design were presented illustrating the need for experimental data on friction between soils, geomembranes and geotextiles. Toward supplying this needed data base, a modified direct shear test was used on a variety of materials of different interfaces.

Three soil types, four geomembranes and four geotextiles were evaluated, where the geomembranes mobilized from 60% to 86% of the soil friction and the geotextiles mobilized from 80% to 100% of the soil friction of those soils tested. Friction values for geomembranes on geotextiles were relatively low, suggesting the need for careful choice between materials when used in a composite manner and high assurance of anchor integrity. The need for additional data in this regard seems justified.

Concerning additional investigations on this subject, the lack of data using soils with cohesion is obvious. Indeed, such soils are encountered as subgrade materials, and their shear strength values (cohesion and friction) should be evaluated. Regarding design much remains. Included here was a limit equilibrium method of analysis. Needed is a method which is based on the entire stress vs. strain behavior of the materials involved. Work is currently ongoing in this regard.

ACKNOWLEDGEMENTS

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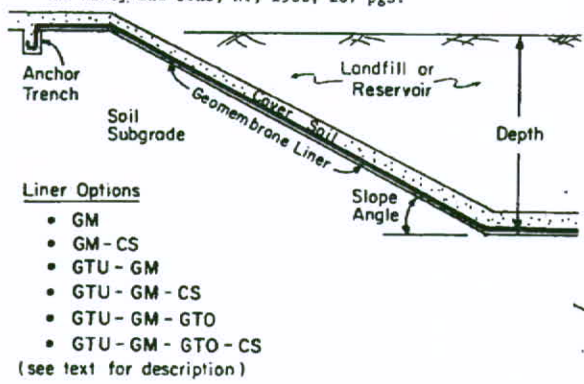


Fig. 1. - Typical Cross Section of Impoundment or Reservoir Slope with Geomembrane Liner System and Cover Soil

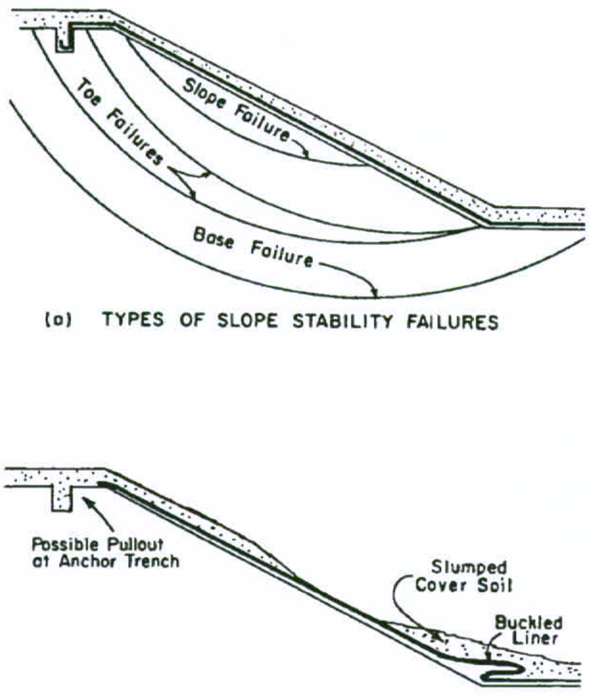


Fig. 2. - General Types of Failures of Lined Impoundments or Reservoir Slopes

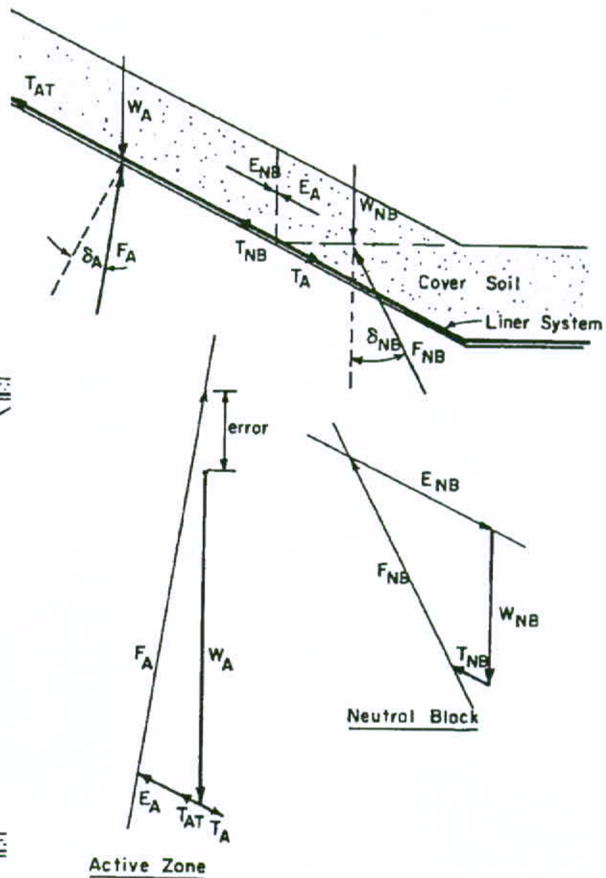


Fig. 3 - Design Details of Geomembrane Liner and Cover Soil Under Incipient Slippage Failure with Corresponding Force Polygons

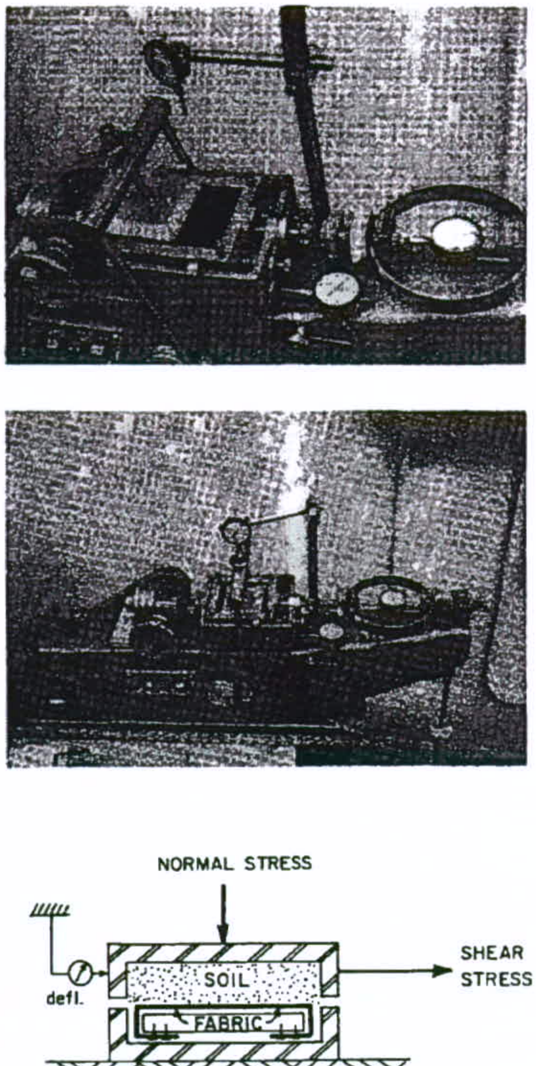


Fig. 4 - Photograph and Schematic Drawing of Direct Shear Device Used to Determine Friction Values in this Study

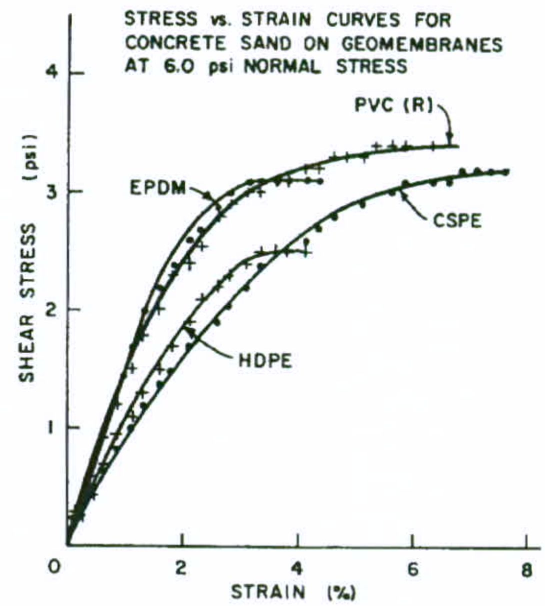


Fig. 5. - Typical Shear Stress vs. Strain Curves Generated in this Study. Illustrated is Concrete Sand on Four Geomembranes at 6.0 psi Normal Stress (Values Include 0.50 psi Machine Tare)

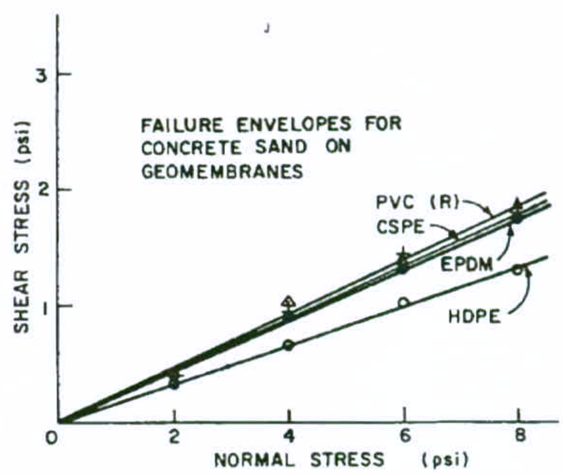


Fig. 6. - Failure Envelopes for Concrete Sand on Four Geomembranes Where Resulting Friction Angles Range from 18° to 27° (Figure 5 Values are Included here at 6.0 psi Normal Stress)

ConocoPhillips Company
Sensitive Area Determination*
G21 Pit

ConocoPhillips

Sensitive Area Factors	Comments	Sensitive Area Determination
Quality of Produced or Stored Water	Exceeds Total Dissolved Solids of 1.25 x Background	Yes
Presence of unconfined aquifers or recharge areas	Unconfined Aquifer Not Present	No
		NO

* Per Colorado Oil and Gas Conservation Commission Rule 901.f – Sensitive Area Operations and Figure 901-1 Sensitive Area Determination Decision Tree.

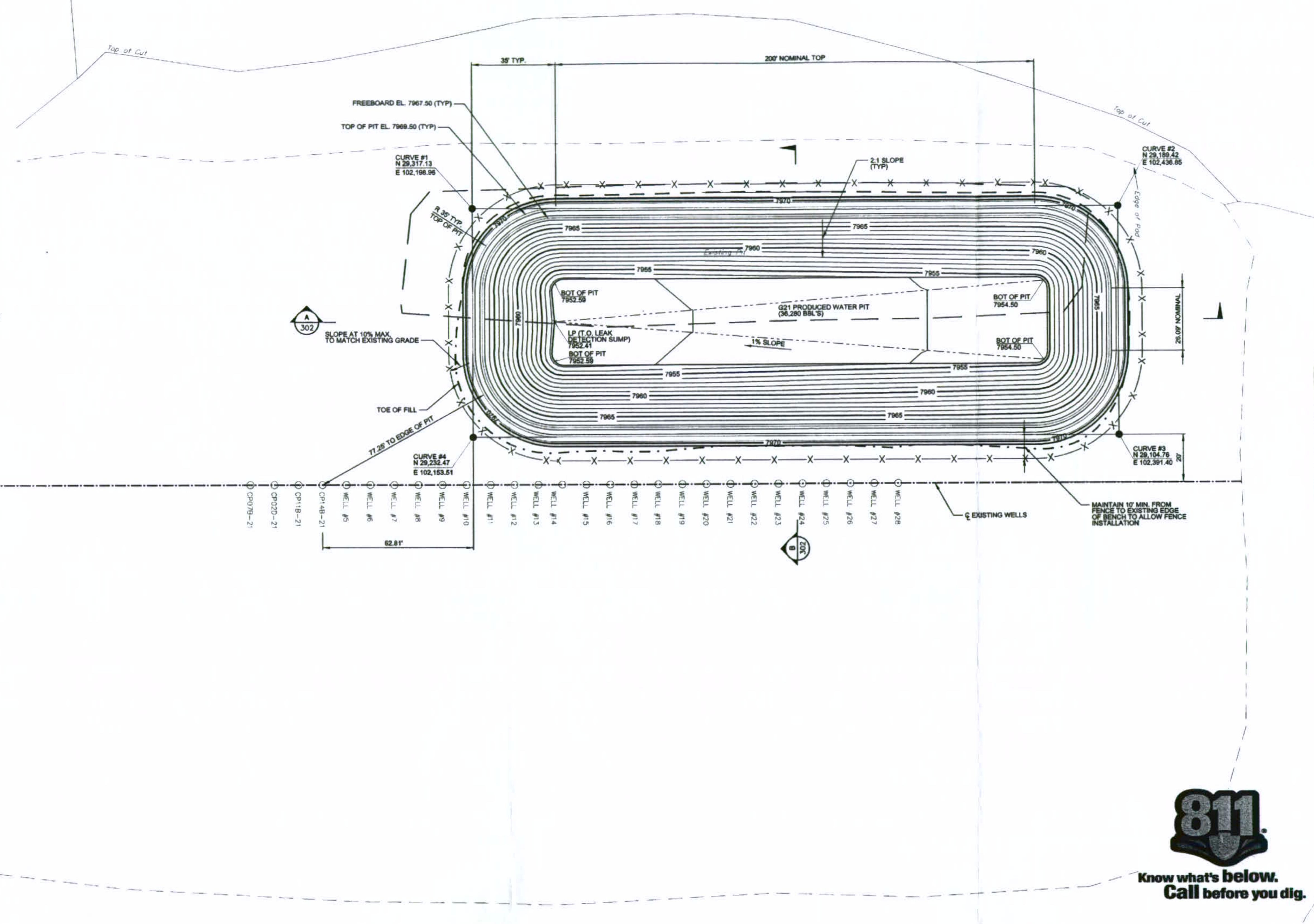
Prepared by HRL Compliance Solutions, Inc
Date: 01-05-09

CONTROL NORTH

SCALE: 1" = 20'

NOTES:

1. SITE FEATURES AND TOPOGRAPHY WAS PROVIDED BY UINTAH ENGINEERING AND LAND SURVEYING, 85 S. 200 EAST, VERNAL, UTAH, 84078 (435)789-1017.
2. SURVEY BENCHMARK AND SURVEY CONTROL SHOULD BE ESTABLISHED FOR PIT LOCATION, DEPTH AND SLOPE LIMITS, PRIOR TO COMMENCING EXCAVATION ACTIVITIES.
3. WHERE WATERLINE RISER INTERFERES WITH PROPOSED PRODUCED WATER PIT, RISER SHALL BE RELOCATED BY OTHERS, PRIOR TO COMMENCING EXCAVATION ACTIVITIES.
4. PRIOR TO ANY EXCAVATION WORK ON A PAD THAT HAS PIPELINES, THE PIPELINE SHALL BE PREPPED FOR CONSTRUCTION. PIPELINES SHALL BE LOCKED-OUT/TAGGED-OUT, PURGED, WATER TESTED AND OPEN TO ATMOSPHERE.
5. ONE-CALL SHALL BE MADE IN ACCORDANCE WITH CO STATE LAW. AFTER ALL PIPES HAVE BEEN HORIZONTALLY LOCATED, DEPTH OF PIPES MUST BE DETERMINED WHEN PIPELINES ARE WITHIN TWO FEET OF EXCAVATION. THIS SHALL BE DONE BY DIGGING 6' DOWN ON EITHER SIDE OF THE PIPE AND SLOUGHING OFF THE MATERIAL BY HAND TO LOCATE THE PIPE. WHERE SPACE IS CONFINED, POT-HOLING SHALL BE USED TO LOCATE THE PIPE.
6. FENCING, SWING GATE, EMERGENCY EGRESS PERSONNEL GATES AND BIRD NETTING TO BE DESIGNED AND LOCATED BY OTHERS. FENCING SHOWN ON PLAN IS FOR INFORMATION ONLY. THE SWING GATE SHOULD BE LOCATED ADJACENT TO THE PIT WATERLINE RISER. ALL FENCE POST PLACEMENT SHOULD AVOID EXIST. GAS AND WATER LINE INTERFERENCE.
7. WARNING SIGNS & ENTRY REGULATORY SIGNAGE TO BE PROVIDED & INSTALLED BY OWNER.
8. PIT VOLUME SHOWN ON PLANS IS MEASURED FROM WATER SURFACE ELEVATION TO BOTTOM OF PIT.
9. REMOVE EXISTING LINERS AND FILL IN EXISTING PIT WITH SPOILS FROM NEW PIT EXCAVATION. SPOILS SHOULD BE PLACED AND COMPACTED WITH EQUIPMENT TRACKS AND WHEELS IN 8" TO 12" LIFTS SUCH THAT THE FILL MATERIAL WILL SUPPORT THE SIDEWALLS OF THE NEW PIT.



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REFERENCE DRAWINGS

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DESIGNED: M. LAMBERT 12/19/08
DRAWN: E. TRUJILLO 12/23/08
CHECKED: M. LAMBERT 1/5/08
APPROVED: J. MAIDA 1/5/08

CLIENT: ConocoPhillips
LOCATION: Parachute, CO

Samuel Engineering, Inc.
We Provide Solutions
8450 E. CRESCENT PARKWAY
GREENWOOD VILLAGE, CO 80111
Phone: 303.714.4840
Fax: 303.714.4800

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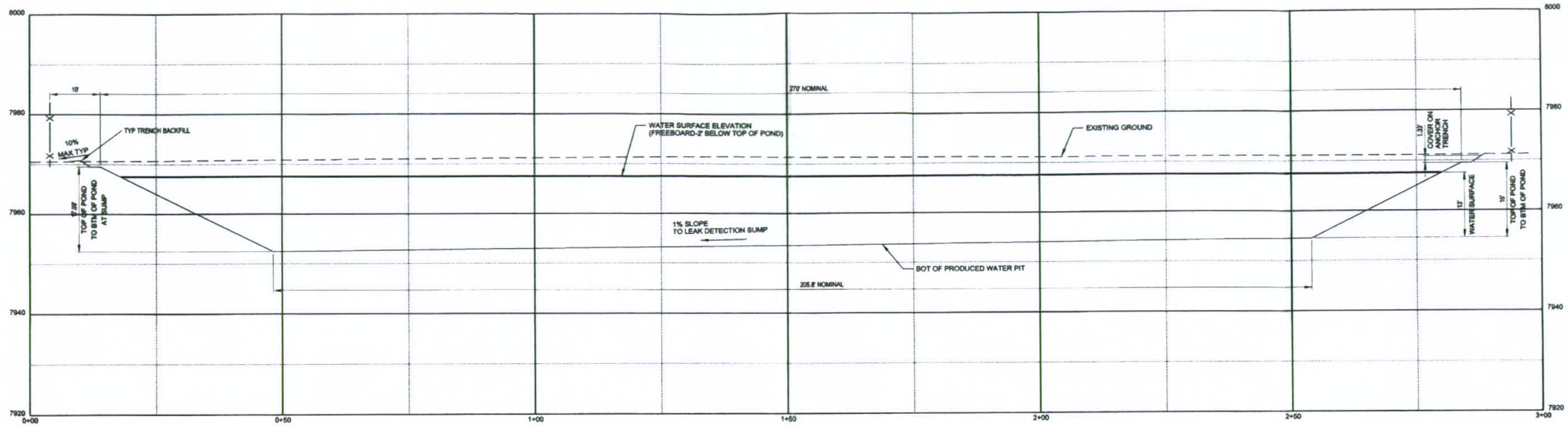
PROJECT NO. 8053-14

DRAWING NUMBER G21-CE-103 REV 0



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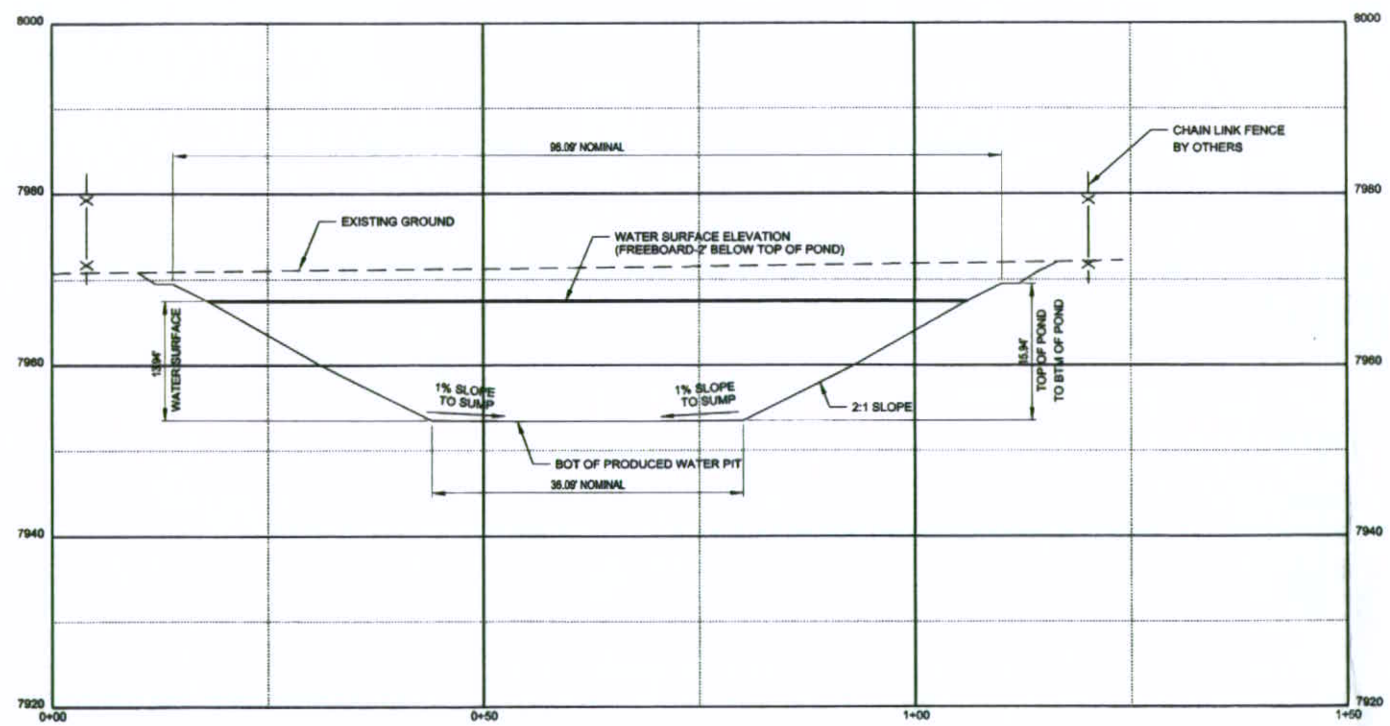

SECTION "B-B"

NOTES:

1. PRIOR TO ANY EXCAVATION WORK ON A PAD THAT HAS PIPELINES, THE PIPELINE SHALL BE PREPPED FOR CONSTRUCTION. PIPELINES SHALL BE LOCKED-OUT/TAGGED-OUT, PURGED, WATER TESTED AND OPEN TO ATMOSPHERE.
2. ONE-CALL SHALL BE MADE IN ACCORDANCE WITH CO STATE LAW. AFTER ALL PIPES HAVE BEEN HORIZONTALLY LOCATED, DEPTH OF PIPES MUST BE DETERMINED WHEN PIPELINES ARE WITHIN TWO FEET OF EXCAVATION. THIS SHALL BE DONE BY DIGGING 6' DOWN ON EITHER SIDE OF THE PIPE AND SLOUGHING OFF THE MATERIAL BY HAND TO LOCATE THE PIPE. WHERE SPACE IS CONFINED, POT-HOLING SHALL BE USED TO LOCATE THE PIPE.
3. FENCING, GATES AND BIRD NETTING TO BE DESIGNED AND LOCATED BY OTHERS. FENCING SHOWN ON PLAN IS FOR INFORMATION ONLY.
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APPROVED:		1/6/09
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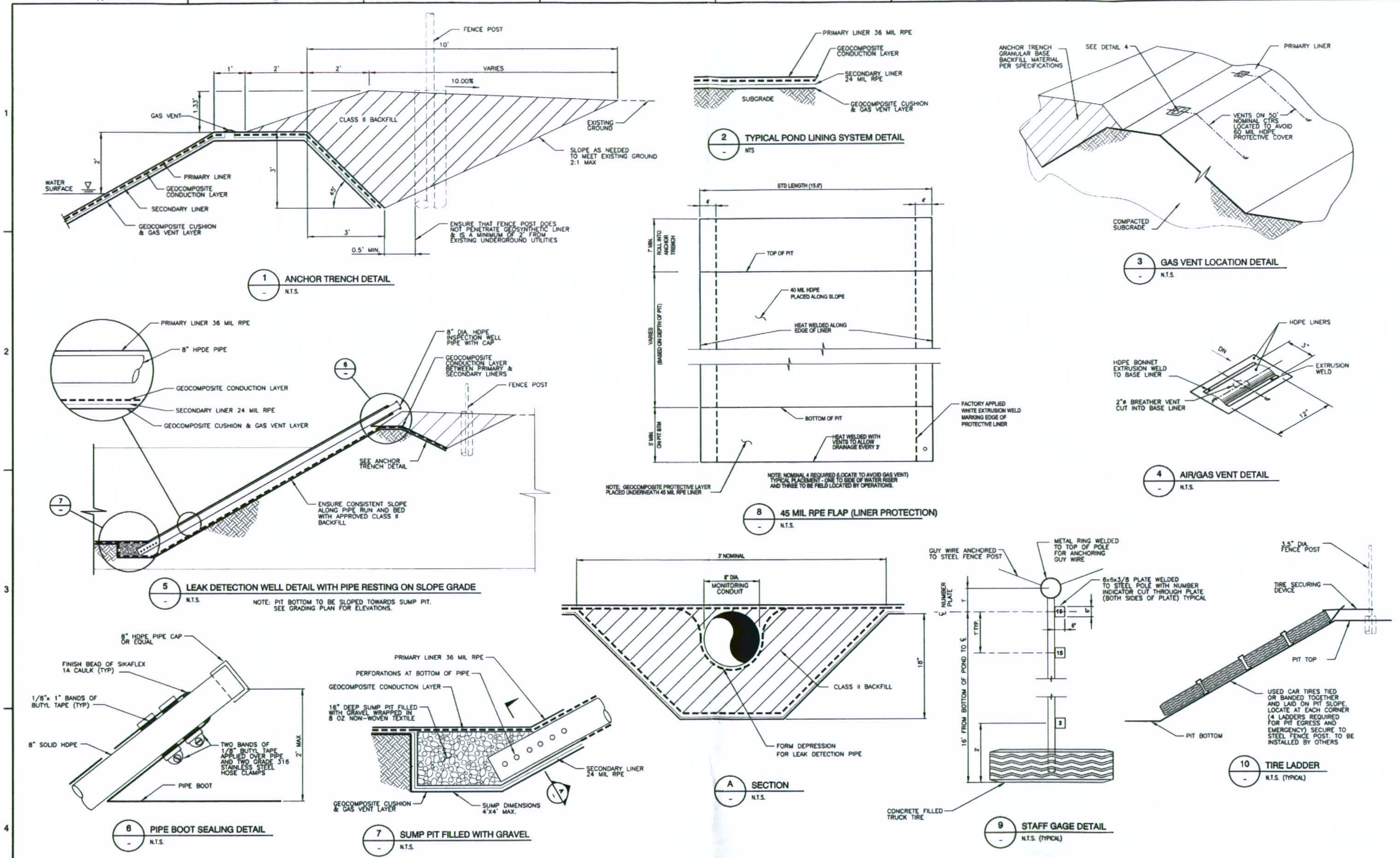
PROJECT NO. 8053-14

DRAWING NUMBER G21-CE-302

REV. 0



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DRAWN	E. TRUJILLO 12/23/08
CHECKED	(signature) 1/4/09
APPROVED	(signature) 1/4/09
CLIENT	ConocoPhillips
LOCATION	Parachute, CO
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TITLE	G-21 PRODUCED WATER PIT DESIGN SECTIONS AND DETAILS, SHEET 2 OF 2
PROJECT NO.	8053-14
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