300 UNION BOULEVARD, SUITE 600, LAKEWOOD, COLORADO 80228 U.S.A.

TECHLAW INC.

PHONE: (303) 763-7188 FAX: (303) 763-4896

November 21, 1997

NOV 1997
RECEIVED
HAZARDOUS WASTE
PROGRAM

Mr.Benito Garcia
Hazardous and Radioactive Materials Bureau
New Mexico Environment Department
P.O Box 26110
Santa Fe, New Mexico 87502-6110

Dear Mr. Garcia:

TechLaw, Inc. (TechLaw) is very pleased to submit this proposal for RCRA Permit Application and Technical Document Review support to the New Mexico Environment Department (NMED). On October 1, 1997, A.T.Kearney's EH&S practice was purchased by TechLaw, bringing with it over 100 professionals who have provided RCRA support to both the State of New Mexico and U.S.EPA for a number of years. A.T.Kearney, now TechLaw, would welcome the opportunity to continue serving the NMED on this important procurement.

We have included an original and five copies of our proposal, which is presented in two volumes (Volume I: Technical Proposal and Volume II: Cost Proposal and Supplemental Information). The original volume includes the original proposal text single-sided so that NMED may copy this section easily, while the five copies are double sided. If you have any questions, please feel free to contact me at 703-818-1000, or Ms.June Dreith at 303-763-7188. We look forward to your response regarding our proposal.

Sincerely,

Connie Walker for

J.William Jordan
Vice President

cc: B.Jackson, TLI
S.Forehand, TLI Contracts
J. Dreith
C.Olin (file)

GEOTECHNICAL TEST PITS

The proposed landfill site is located in a remote portion of eastern Chaves County, New Mexico. The land surface gently slopes to the west. This sloping plain is characterized by low-relief hummocky wind-blown deposits, sand ridges, and dunes.

A geotechnical field investigation involving the excavation of test pits was conducted by a TerraMatrix/Montgomery Watson field engineer on August 18, 1997. Five test pits were excavated to characterize the geotechnical conditions of the surficial sands and Upper Dockum claystone. Soil samples were also collected from the test pits to conduct soil characterization tests, recompacted permeability tests, and interface shear strength tests.

Four of the five test pits were excavated within the proposed footprint of the cell and one test pit was excavated in the area of the proposed evaporation ponds. Figure 1 displays the general location of the geotechnical field investigation. All test pits were located in the field by onsite personnel. The upper 6 to 10 feet of each pit was excavated by a D8 CAT dozer. A John Deere 310D backhoe with an extended boom was then used to excavate the test pits to their total depth. Total depth of the test pits ranged from 17 to 24 feet. Material types were noted, as was the presence or absence of moisture or water. Bag and bucket samples were collected from the backhoe cuttings at various depths as chosen by the field engineer. None of the test pits encountered a water table. The geotechnical field investigation test pit logs are attached.

Soil samples collected from each of the five test pits were submitted to the laboratory for material property analysis. The laboratory tests performed included:

- Moisture Content (ASTM D2216)
- Atterberg (ASTM D4318)
- Moisture/Density Relationship (ASTM D1557, D698)
- Sieve Analysis (ASTM D422)
- Recompacted Permeability (ASTM 5084)
- Interface Shear - Direct Shear

Table 1 summarizes the geotechnical field investigation and includes the test pit identification number, approximate location, sample type, and depth.

TABLE 1 GANDY GEOTECHNICAL TEST PITS				
Test Pit ID	Pit Location (approx.) Northing/Easting	Elevation (feet)	Sample Type	Sample Depth
TP-1	N859650/E645460		Bag	2 to 3
TP-1			Bag	15
TP-1			Bucket	17
TP-2	N861150/E646860		Bag	3 to 4
TP-2			Bag	16 to 18
TP-2			Bucket	17
TP-3	N859150/E646360		Bag	2
TP-3			Bag	3 to 4
TP-3			Bag	6.5
TP-3			Bucket	7.5
TP-4	N858850/E645060		Bag	5 to 7
TP-4			Bag	6 to 9
TP-4			Bucket	14
TP-5	N861750/E645660		Bag	6
TP-5			Bag	17
TP-5			Bucket	18

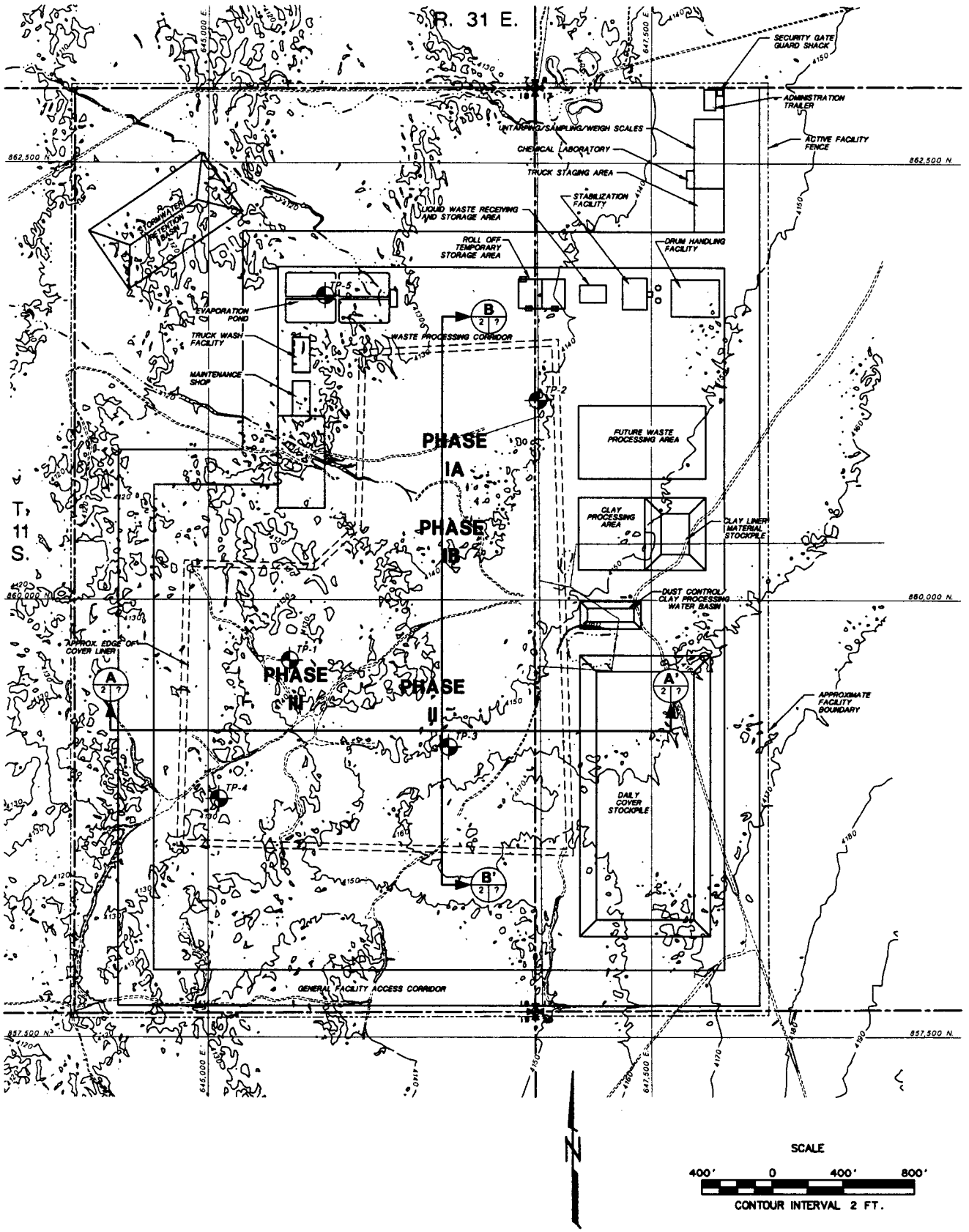
SUMMARY OF LABORATORY TEST RESULTS

A total of eight samples, one from each test pit and three from test pit number 4, and a composite sample from test pit 1-4 for the surficial silty sands were tested. All laboratory testing was conducted by TerraMatrix/Montgomery Watson Laboratories in Steamboat Springs, Colorado.

Natural moisture content ranged from 7.0% to 12.3%. Atterberg limits indicated a range of liqid limits of 37% to 46% and plasticity limits of 19% to 40% for the upper Dockum. The surficial silty sand was found to be non-plastic. The grain size analysis indicated the upper Dockum is predominantly fine grained with fines ranging from 65% to 99% and sands from 1% to 35%. The surficial sands had 17% fine material and no gravel sized material. The Caliche was found to have 5% gravel, 35% sand, and 60% fines which have a liquid limit of 34% and a plasticity index of 17%. These test results are summarized on the following page, Summary of Laboratory Test Results.

BEARING CAPACITY

The surficial silty sands were estimated to have a bearing capacity of 4000 psf using the table presented on page 4.



REV. No.	REVISIONS	REV. DATE	DESIGN BY	DRAWN BY	REVIEWED AND SIGNED BY

TerraMatrix
MONTGOMERY WATSON
Mining Group

PROJECT No.: 602-0200
AutoCAD FILE: testpitloc.dwg
SCALE: 1:1000
FIGURE No: 1

TRIASSIC PARK WASTE DISPOSAL FACILITY

TEST PIT LOCATION

SUMMARY OF LABORATORY TEST RESULTS

Sample Location		Natural Moisture Content (%)	Natural Dry Density (%)	Atterberg Limits		Gradation			Unconfined Compressive Strength (psf)	Soil/Bedrock Description	Unified Soil Classification (USCS)
Test Pit Hole No.	Depth (Feet)			Liquid Limit (%)	Plasitcity Index (%)	Gravel (%)	Sand (%)	Fines (%)			
1	17	9.9		37	19		5	95		Slightly weathered, dark reddish brown, CLAYSTONE, trace sand, trace calcareous, (sr), dry.	CL
2	17	12.1		54	40		27	73		Fresh to slightly weathered, reddish brown, weak, CLAY and CLAYSTONE, trace calcareous (sr), trace organics.	CH
3	7.5	9.7		36	20		2	98		Fresh to slightly weathered, reddish brown and grayish green, extremely weak, CLAYSTONE, trace calcareous (mr), damp.	CL
4	14	8.6		39	27		13	87		Slightly weathered, dark reddish brown, weak, stratified, CLAYSTONE, little calcareous (sr), damp.	CL
4	20	7.0		-	-		1	99		Fresh to slightly weathered, dark reddish brown, weak to medium strong, CLAYSTONE, little silt, damp to moist.	CL
5	18	12.3		46	32		35	65		Fresh to slightly weathered, reddish brown, extremely weak, SILTY CLAYSTONE, trace fine sand, trace calcareous (sr), trace organics, damp.	CL
1-4	comp			NP	NV		83	17		Orange Brown, non stratified homogeneous, fine SAND little to some silt, damp	SM
4	6-9			34	17	5	35	60		Whitish Pink, non-statified calcium carbonate, clayey silt, dry to damp	CL

Project Name: Triassic Park		
Project Location:		
Project No.: 790-12101	Technician: DCP	Date: 9/10/97

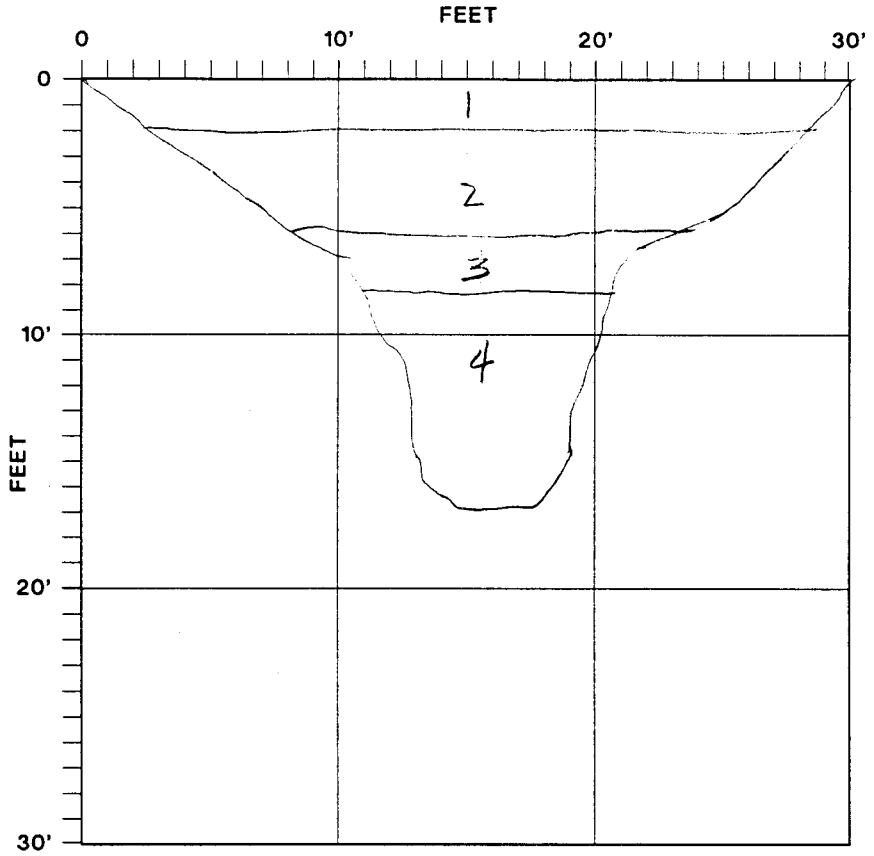
TerraMatrix
Engineering & Materials Testing Services
50360 Moffat Avenue
Steamboat Springs, Colorado 80487

SUMMARY OF LABORATORY TEST RESULTS

AutoCAD File: SUM-LTR.DWG

GENERAL LOCATION: TP-1 DATE: 8/18/97

PIT TREND: _____ ENGINEER: D. Gleason



LEGEND

SOIL HORIZON
SAMPLE LOCATION
HORIZON CONTACT

SAMPLE No.	DEPTH
Baggie	2 to 3'
Baggie	15'
Bucket	17'

SOIL UNIT	SOIL DESCRIPTION AND EXCAVATION NOTES
1	0-2' Loose tan, fine, SAND, some silt, with roots, moist
2	2'-6' Compact, reddish brown, SAND, some clay and silt, slightly calcareous, slightly moist, some gravelly lenses
3	6'-8' Hard, brownish red, weathered mudstone, slightly moist
4	8'-17' Hard to very hard, brownish red, mudstone/claystone, traces of olive claystone, slightly moist

SPECIAL NOTES:

No water encountered
Pocket penetrometer maxed out at 7'-8'

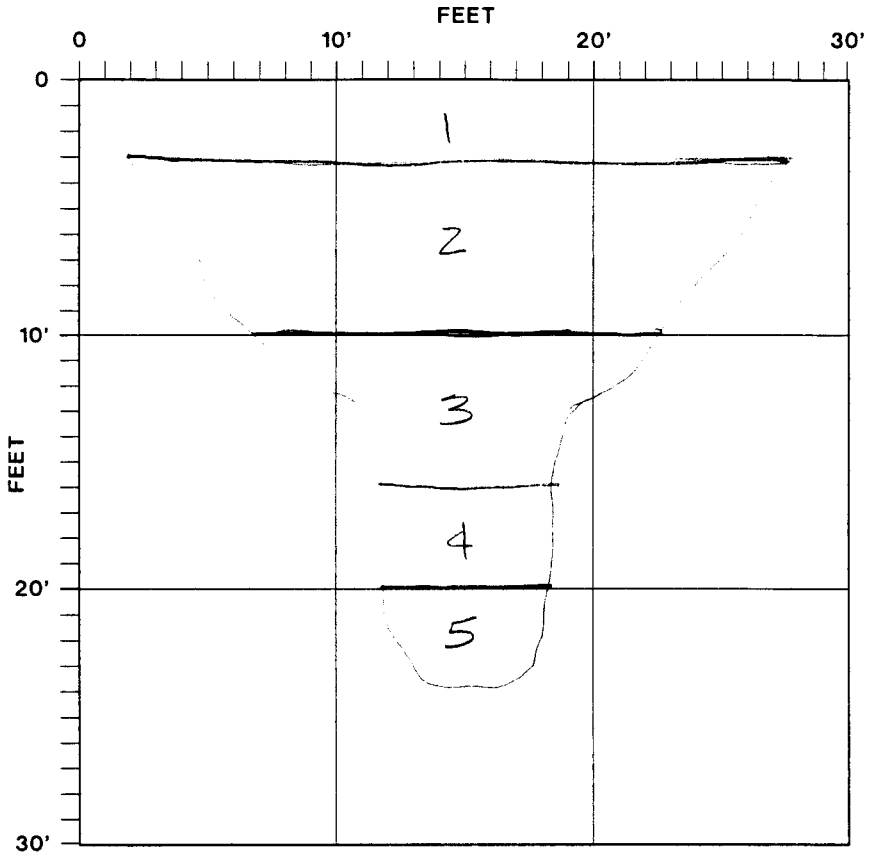
Project No.: 602	Design By:	Scale:	Triassic Park Landfill
File:	Drawn By:	Date:	
TerraMatrix Engineering & Environmental Services, 1475 Pine Grove Road, P.O. Box 774018, Steamboat Springs, Colorado 80477	Test Pit No: 1	Figure No.	TEST PIT #1

GENERAL LOCATION: TP-2

PIT TREND: _____

DATE: 8/18/97

ENGINEER: D Gleason



LEGEND

SOIL HORIZON
SAMPLE LOCATION
HORIZON CONTACT

SAMPLE No.	DEPTH
Baggie	3' to 4'
Baggie	16' to 18'
Bucket	17'

SOIL UNIT	SOIL DESCRIPTION AND EXCAVATION NOTES
1	0-3' Loose, tan, fine, SAND, some silt, with roots, moist
2	3'-10' stiff, tan, calcareous, CLAY, with silt and sand, slightly moist
3	10'-16' Dense, brown, medium to fine, SAND, some silt, trace coarse sand, slightly moist
4	16'-20' Slightly stiff to stiff, brown, silty CLAY, moist
5	20'-24' Hard, brown, clayey, sandy, SILT, moist

SPECIAL NOTES:

No water encountered

Project No: 602	Design By:	Scale:
File:	Drawn By:	Date:

TerraMatrix
Engineering & Environmental Services
1475 Pine Grove Road, P.O. Box 774018
Steamboat Springs, Colorado 80477

Test Pit No: 2

Figure No.

Triassic Park Landfill

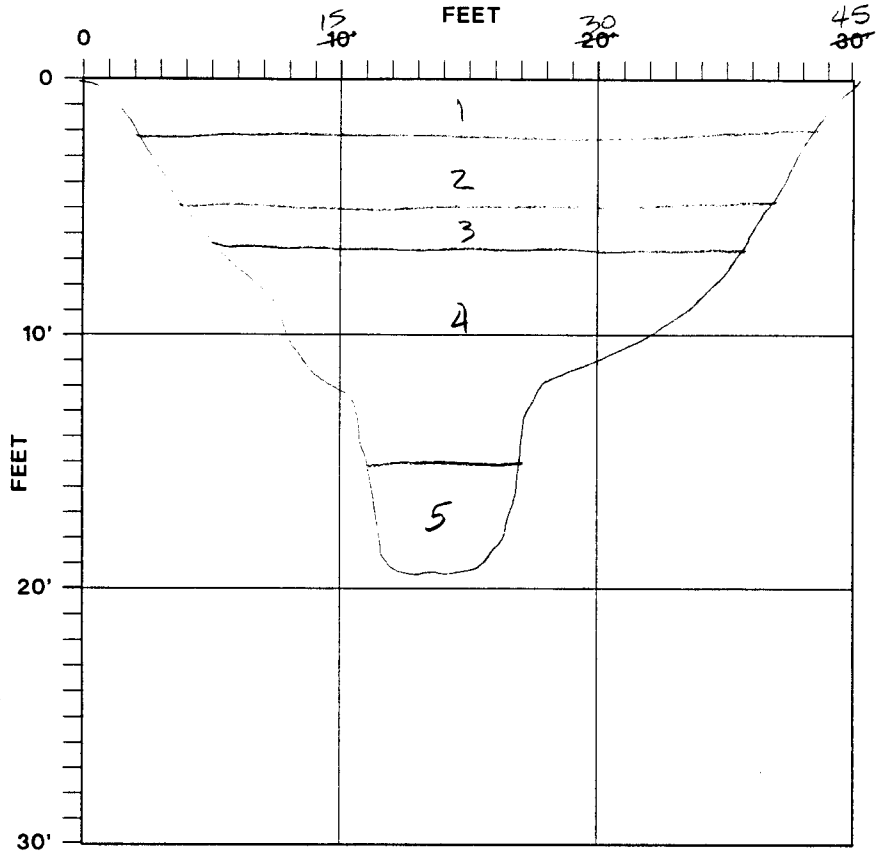
TEST PIT # 2

GENERAL LOCATION: TP-3

PIT TREND: _____

DATE: 8/18/97

ENGINEER: D Gleason



LEGEND

SOIL HORIZON
SAMPLE LOCATION
HORIZON CONTACT

SAMPLE No.	DEPTH
Baggie	2
Baggie	3' to 4'
Baggie	6.5'
Bucket	7.5
Baggie	5'

SOIL UNIT	SOIL DESCRIPTION AND EXCAVATION NOTES
1	0-2' Loose, tan, fine SAND, some silt, w/ roots, moist
2	2'-5' stiff, whitish tan, very calcareous CLAY, with silt and sand, some gravel and cobbles, slightly moist
3	5'-6.5' stiff, reddish brown, sandy CLAY, some silt
4	6.5'-15' slightly hard, reddish brown, slightly weathered, CLAYSTONE/SILTSTONE, slightly moist, blocky, greenish-grey siltstone lenses
5	15'-19' Very hard, brownish red, SILTSTONE, slightly moist

SPECIAL NOTES:

No water encountered
Pocket penetrometer maxed out at 10'-15'

Project No: 602	Design By:	Scale:
File:	Drawn By:	Date:

TerraMatrix
Engineering & Environmental Services
1475 Pine Grove Road, P.O. Box 774018
Steamboat Springs, Colorado 80477

Test Pit No: 3

Figure No.

Triassic Park Landfill

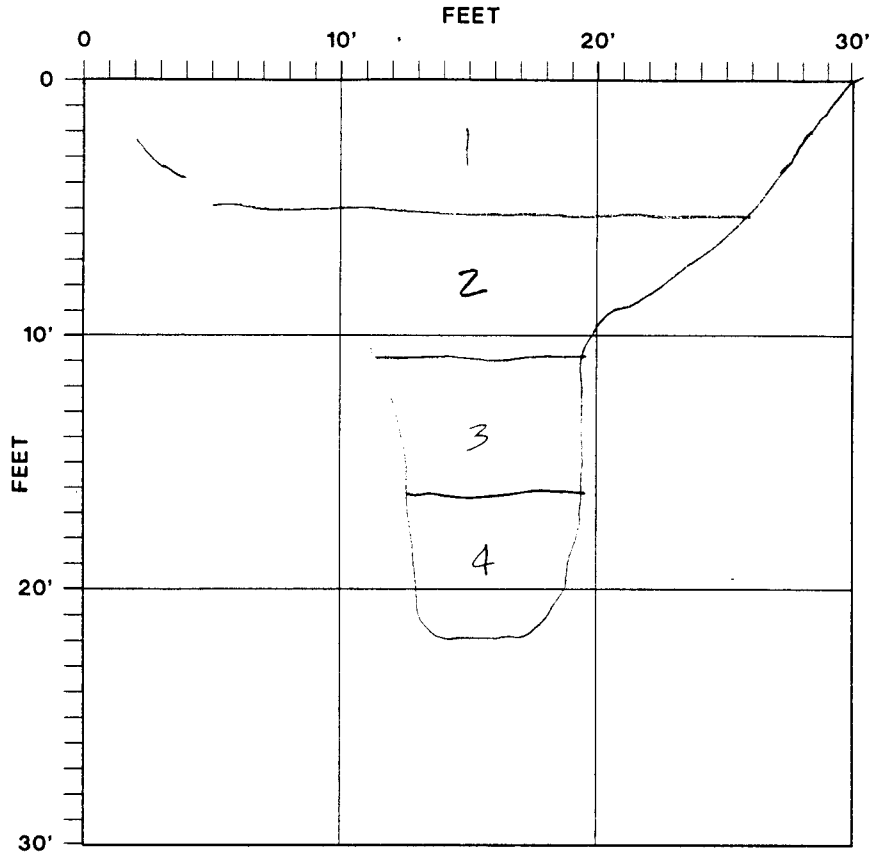
TEST PIT # 3

GENERAL LOCATION: TP-4

PIT TREND: _____

DATE: 8/18/97

ENGINEER: D Gleason



LEGEND

SOIL HORIZON
SAMPLE LOCATION
HORIZON CONTACT

SAMPLE No.	DEPTH
Baggie	5' to 7'
Baggie	6' to 9'
Bucket	14'
Baggie	20'

SOIL UNIT	SOIL DESCRIPTION AND EXCAVATION NOTES
1	0-6' Loose to dense, tan, fine, SAND, some silt, roots to 3', moist
2	6'-11' slightly stiff to stiff, whitish tan, calcareous, CLAY, with sand and gravel, some cobbles, slightly moist
3	11'-16' slightly hard, reddish brown, CLAYSTONE/MUDSTONE, slightly moist
4	16'-22' Hard to very hard, reddish brown, SILTSTONE, trace clay, greenish-grey SILTSTONE lenses

SPECIAL NOTES:

No Water encountered
Pocket penetrometer maxed out at 5'-6.5'

Project No. 602	Design By:	Scale:
File:	Drawn By:	Date:
TerraMatrix Engineering & Environmental Services, 1475 Pine Grove Road, P.O. Box 774018, Steamboat Springs, Colorado 80477	Test Pit No: 4	Figure No.

Triassic Park Landfill

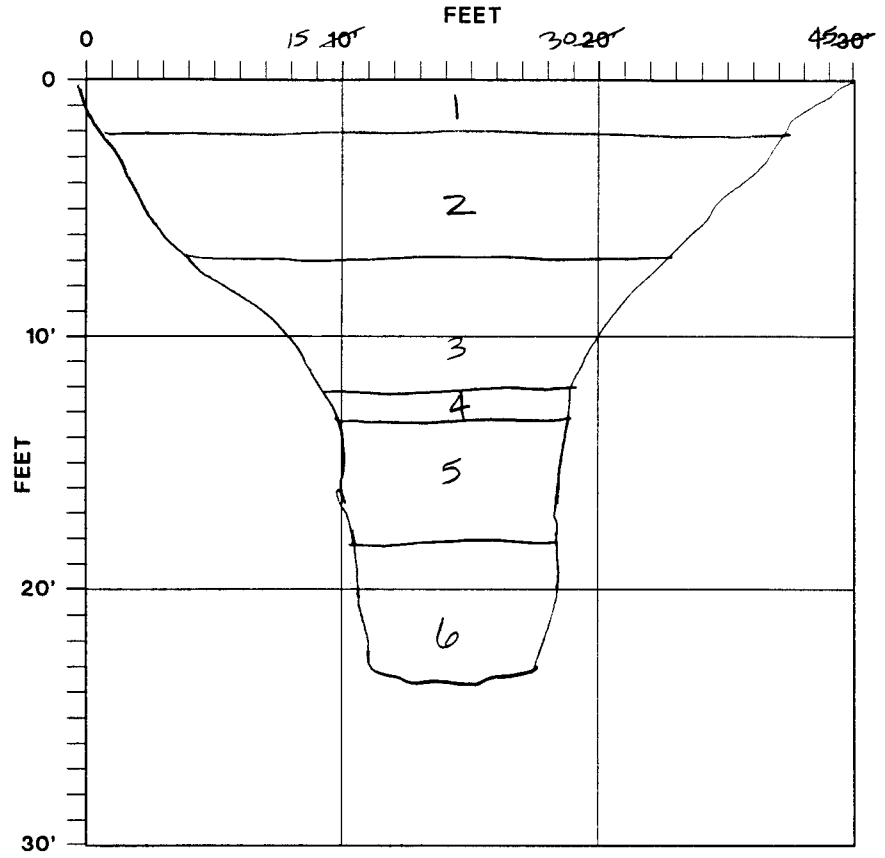
TEST PIT #4

GENERAL LOCATION: TP-5

PIT TREND: _____

DATE: 8/18/97

ENGINEER: D. Gleason



LEGEND

SOIL HORIZON
SAMPLE LOCATION
HORIZON CONTACT

SAMPLE No.	DEPTH
Bucket	6'
Baggie	17'
Bucket	18'

SOIL UNIT	SOIL DESCRIPTION AND EXCAVATION NOTES
1	0-2' Loose, tan, fine SAND, some silt, moist, w/ roots
2	2'-7' Dense, brownish red, fine, Silty SAND, slightly moist
3	7'-12' stiff, brown, calcareous CLAY, with SAND, slightly moist.
4	12'-13' Gravely, clay lense
5	13'-18' Hard, dark brown, mudstone/CLAYstone, slightly moist
6	18'-23' slightly hard, reddish brown, sandy SILTSTONE

SPECIAL NOTES:

No water encountered
Pocket penetrometer maxed out at 13'-17'

Project No.: 602	Design By:	Scale:
File:	Drawn By:	Date:

TerraMatrix
Engineering & Environmental Services
1475 Pine Grove Road, P.O. Box 774018
Steamboat Springs, Colorado 80477

Test Pit No: 5

Figure No.

Triassic Park Landfill

TEST PIT # 5

INTERFACE TESTING

An interface shear testing program was conducted as outlined below:

The testing program consisted of the following:

- Three direct shear tests of the entire liner section run at three different normal loads of 2000 psf, 8,000 psf, and 14,000 psf.
- The liner section consists of the following (from top to bottom, see attached figure):
    - Protective soil
    - Geocomposite
    - Textured HDPE Geomembrane
    - GCL (non woven side up, in contact with textured HDPE)
    - Recompacted clay subgrade

- The GCL was be saturated for a minimum of 72 hours under a normal load of 200 psf prior to testing.
- The protective soil was be compacted at a moisture content of approximately 7% and to a dry density of approximately 95 pcf.
- The recompacted clay subgrade was compacted at a moisture content of 12.2% and to a dry density of 114.3 pcf.
- The liner section was assembled and allowed to sit for 1 to 2 hours under the normal loads specified prior to shearing.
- The shear rate was 0.04 cm/sec.

The results of the testing program are presented on pages 2 and 3.

GEOSYNTEC CONSULTANTS

Soil-Geosynthetic Interaction
Testing Laboratory
5775 Peachtree Dunwoody Road, Suite 11D
Atlanta, Georgia 30342 • USA
Tel. (404) 705-9500 • Fax (404) 705-9300

11 December 1997

Mr. Paul Pellicer
TerraMatrix Montgomery Watson
1475 Pine Grove Road, Suite 109
P.O. Box 774018
Steamboat Springs, Colorado 80477

Subject: Final Report
Interface Direct Shear Testing
TerraMatrix Project No. 602

Dear Mr. Pellicer:

GeoSyntec Consultants (GeoSyntec) is pleased to present the enclosed final report on the interface direct shear testing performed for TerraMatrix Montgomery Watson (TerraMatrix) for the TerraMatrix Project No. 602. The testing program was conducted in accordance with the test procedures defined in the 3 October 1997 letter prepared by Mr. Paul Pellicer of TerraMatrix and transmitted to Mr. Robert H. Swan, Jr. of GeoSyntec. All of the interface direct shear testing was conducted at GeoSyntec's Soil-Geosynthetic Interaction Testing Laboratory located in Atlanta, Georgia.

GeoSyntec appreciates the opportunity to provide laboratory testing services to TerraMatrix for the TerraMatrix Project No. 602. Should you have any questions regarding the enclosed report, please do not hesitate to contact any of the undersigned.

Sincerely,

Zehong Yuan, Ph.D., P.E. (Georgia)
Assistant Program Manager

Robert H. Swan, Jr.
Laboratory Manager

Gary R. Schmertmann, P.E. (Georgia)
Senior Project Engineer

Enclosure

GLI0406/SGI97133

Prepared for

TerraMatrix Montgomery Watson
1475 Pine Grove Road, Suite 109
P.O. Box 774018
Steamboat Springs, Colorado 80477

FINAL REPORT
INTERFACE DIRECT SHEAR TESTING
TERRAMATRIX PROJECT NO. 602

Prepared by

GEOSYNTEC CONSULTANTS
Soil-Geosynthetic Interaction Testing Laboratory
5775 Peachtree Dunwoody Road, Suite 11D
Atlanta, Georgia 30342

Project Number GLI0406

11 December 1997

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1. INTRODUCTION

This report was prepared by Mr. Robert H. Swan, Jr. and Dr. Zehong Yuan, P.E. (Georgia), both of GeoSyntec Consultants (GeoSyntec), Atlanta, Georgia. The report was reviewed by Dr. Gary R. Schmertmann, P.E. (Georgia), also of GeoSyntec, in accordance with the internal peer review policy of the firm. The laboratory testing program described in this report was performed at the request and authorization of Mr. Paul Pellicer of TerraMatrix Montgomery Watson (TerraMatrix), Steamboat Springs, Colorado.

TerraMatrix authorized GeoSyntec to undertake a laboratory testing program to evaluate the interface shearing resistance between two site soils (i.e., protective soil and clay subgrade soil) and three geosynthetic materials (i.e., geomembrane, geocomposite, and geosynthetic clay liner (GCL)) for the TerraMatrix Project No. 602. GeoSyntec understands that the sample preparation procedures and testing conditions used in the testing program were selected by Mr. Pellicer of TerraMatrix to model anticipated field conditions. All of the interface direct shear testing was conducted at GeoSyntec's Soil-Geosynthetic Interaction Testing Laboratory located in Atlanta, Georgia.

2. TESTING PROGRAM

2.1 Scope

The testing program consisted of two interface direct shear test series. Each interface direct shear test series consisted of three tests.

2.2 Testing Methods

The interface direct shear tests were performed in accordance with the American Society for Testing and Materials (ASTM) Standard Test Method D 5321, "*Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method*". The tests were conducted in a large direct shear device containing an upper and lower shear box. The upper shear box measured 12 in. by 12 in. (300 mm by 300 mm) in plan and 3 in. (75 mm) in depth. The lower shear box measured 12 in. by 14 in. (300 mm by 350 mm) in plan and 3 in. (75 mm) in depth.

2.3 Geosynthetic and Soil Materials

The geosynthetic and soil materials used in the testing program are presented in Appendix A. The soil materials were provided to GeoSyntec by TerraMatrix. TerraMatrix arranged to have each geosynthetic manufacturer ship their geosynthetic materials directly to GeoSyntec for testing.

2.4 Test Configuration and Procedures

The configuration of the test specimens and the specific test procedures used to conduct the interface direct shear tests are presented in Appendix B. GeoSyntec understands that the test procedures and test conditions were selected by TerraMatrix to model anticipated field conditions.

3. TEST RESULTS

3.1 Failure Modes

For Test Series 1, sliding (i.e., shear failure) was observed to occur at the interface between the nonwoven geotextile of the GCL and the geomembrane for the test conducted at the normal stress of 14 psi (98 kPa), and within the GCL for the tests conducted at normal stresses of 56 and 100 psi (392 and 700 kPa). For Test Series 2, shear failure was observed to occur at the interface between the protective soil and the geocomposite for the test conducted at the normal stress of 100 psf (5 kPa), and at the interface between the woven geotextile of the GCL and the clay subgrade soil for the tests conducted at normal stresses of 300 and 500 psf (15 and 24 kPa).

3.2 Data Presentation

For each of the interface direct shear tests, the total-stress shearing resistance was evaluated for each applied normal stress. The test data were plotted on a graph of shear force versus horizontal displacement. The resulting plots are presented in Appendix C. The peak value of shear force was used to calculate the peak shear strength. For this report, the large displacement shear strength (τ_{LD}) was calculated using the shear force measured at the end of each test. No area correction was used when computing normal and shear stresses because each test was performed using a constant effective sample area (i.e., the area of the geosynthetic specimen and/or lower shear box was larger than that of the upper shear box).

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The calculated shear strengths were plotted on a graph of shear stress versus normal stress and the results were used to evaluate total-stress peak and large displacement shear strength envelopes. A best-fit straight line was drawn through the data points from each test series to obtain the corresponding total-stress peak and large displacement shear strength friction angles and adhesions. The coefficient of correlation (R^2), a standard statistical indicator of how well the best-fit line matches the test data, was obtained for each best-fit line. The summary plots of shear stress versus normal stress for each test series are also presented in Appendix C. The friction angles, adhesions, and R^2 values derived from the plotted test results are presented in Table 1.

For each test series, it is noted that the reported total-stress shear strength parameters of friction angle and adhesion were determined based on the best-fit straight line drawn through the test data on a plot of shear stress versus normal stress. Caution should be exercised in using these shear strength parameters for applications involving normal stresses outside the range of stresses covered by each test series.

4. CLOSURE

The reported results apply only to the materials and test conditions used in the laboratory testing program. The results do not necessarily apply to other materials or test conditions. The test results should not be used in engineering analyses unless the test conditions model the anticipated field conditions. The testing was performed in accordance with general engineering testing standards and requirements. This testing report is submitted for the exclusive use of TerraMatrix.

TABLE 1

INTERFACE DIRECT SHEAR TEST RESULTS
MEASURED TOTAL STRESS SHEAR STRENGTH PARAMETERS
TERRAMATRIX MONTGOMERY WATSON
TERRAMATRIX PROJECT NO. 602

Test Series Number	Interfaces Tested[1]	Normal Stress	Peak Strength[2]			Large Displacement Strength[2,3]			Reference Appendix Figure Numbers
			Friction Angle	Adhesion (psf)	R^2	Friction Angle	Adhesion (psf)	R^2	
1	Protective Soil/NSC TN3002-1125 Geocomposite/60-mil NSC Textured HDPE Geomembrane/Hydrated Bentofix NS GCL with Nonwoven Geotextile Against Geomembrane/Clay Subgrade Soil Under Consolidated Conditions	14 to 100 psi	9°	650	0.951	2°	440	0.977	C-1 and C-2
2	Protective Soil/NSC TN3002-1125 Geocomposite/60-mil NSC Textured HDPE Geomembrane/Hydrated Bentofix NS GCL with Nonwoven Geotextile Against Geomembrane/Clay Subgrade Soil Under Consolidated Conditions	100 to 500 psf	33°	18	0.999	31°	15	1.000	C-3 and C-4

Notes: (1) See Appendix B for detailed test conditions and procedures. For each test, sliding (i.e., shear failure) was observed to occur at a specific interface or within the GCL as described in Section 3 of the report.

(2) The reported total-stress shear strength parameters for each test series were determined from a best-fit line drawn through the test data. Caution should be exercised in using these shear strength parameters for applications involving normal stresses outside the range of stresses covered by each test series. The value of R^2, the coefficient of correlation, provides an indication of how well the best-fit shear strength parameters match the test data.

(3) The large displacement shear strength (τ_{LD}) was calculated using the shear force measured at the end of each test.

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APPENDIX A

GEOSYNTHETIC AND SOIL MATERIALS

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Geosynthetic Materials

Three geosynthetic materials were used in the testing program. These materials are referenced by name in this report, and include:

- 60-mil (1.5-mm) thick National Seal Company (NSC) textured high density polyethylene (HDPE) geomembrane, referred to as 60-mil NSC textured HDPE geomembrane;

- NSC TN3002-1125 geocomposite consisting of a Trevira 1125 nonwoven geotextile heat-bonded to each side of a NSC PN3000 geonet component, referred to as NSC TN3002-1125 geocomposite; and

- NSC Bentofix NS GCL consisting of a woven geotextile on one side of the bentonite component and a nonwoven geotextile on the other side of the bentonite component, needle-punched and thermally-locked together forming the finished product, referred to as Bentofix NS GCL.

TerraMatrix arranged to have NSC ship the bulk samples of the three geosynthetic materials directly to GeoSyntec for testing.

Soil Materials

Two site soil materials (i.e., protective soil and clay subgrade soil) were used in the testing program. Bulk samples of the two soil materials were obtained from the project by TerraMatrix and provided to GeoSyntec for testing.

APPENDIX B

TEST PROCEDURES AND TEST CONDITIONS

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 1

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: protective soil initially placed at a dry unit weight of 94.9 to 95.0 pcf and a moisture content of 6.7 to 6.8%. Final moisture content ranged from 6.2 to 6.5% for the test series;
- NSC TN3002-1125 geocomposite;
- 60-mil NSC textured HDPE geomembrane;
- Bentofix NS GCL with nonwoven geotextile against geomembrane. GCL's initial moisture content was 13.0%. GCL's final moisture content ranged from 73% to 90% for the test series; and
- lower shear box: clay subgrade soil initially placed at a dry unit weight of 114.1 to 114.8 pcf and a moisture content of 12.3 to 12.6%. Final moisture content ranged from 12.6 to 13.8% for the test series.

Test Interface: upper soil against geocomposite against geomembrane against GCL against lower soil.

Test Procedures for Each Normal Stress Condition:

- GCL Hydration: a fresh specimen of GCL was trimmed from the bulk sample and hydrated in tap water for 72 hours under a normal stress of 200 psf.
- A fresh specimen of the lower soil was compacted into the lower shear box. The initial target dry unit weight and moisture content were 114.3 pcf and 12.2%, respectively, as specified by TerraMatrix.
- The hydrated GCL specimen, and fresh specimens of geomembrane and geocomposite trimmed from each bulk sample were placed on top of the lower soil, but not attached to either of the lower or upper shear boxes. The GCL was oriented so that the nonwoven geotextile component of the GCL was in contact with the geomembrane. With this method of specimen preparation, shear failure would likely occur at the weakest interface within the test cross section.
- A fresh specimen of the upper soil was compacted directly on top of the geocomposite. The initial target dry unit weight and moisture content were 95.0 pcf and 7.0%, respectively, as specified by TerraMatrix.
- Consolidation conditions: the entire test specimen was consolidated for 1 hour under each test normal stress prior to being sheared.
- Test normal stresses: 14, 56, and 100 psi.
- Constant shear displacement rate: 0.04 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 2

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: protective soil initially placed at a dry unit weight of 95.1 to 95.5 pcf and a moisture content of 6.5 to 6.9%. Final moisture content ranged from 6.2 to 6.3% for the test series;
- NSC TN3002-1125 geocomposite;
- 60-mil NSC textured HDPE geomembrane;
- Bentofix NS GCL with nonwoven geotextile against geomembrane. GCL's initial moisture content was 12.8%. GCL's final moisture content ranged from 86% to 98% for the test series; and
- lower shear box: clay subgrade soil initially placed at a dry unit weight of 113.9 to 114.3 pcf and a moisture content of 12.0 to 12.5%. Final moisture content ranged from 12.8 to 13.5% for the test series.

Test Interface: upper soil against geocomposite against geomembrane against GCL against lower soil.

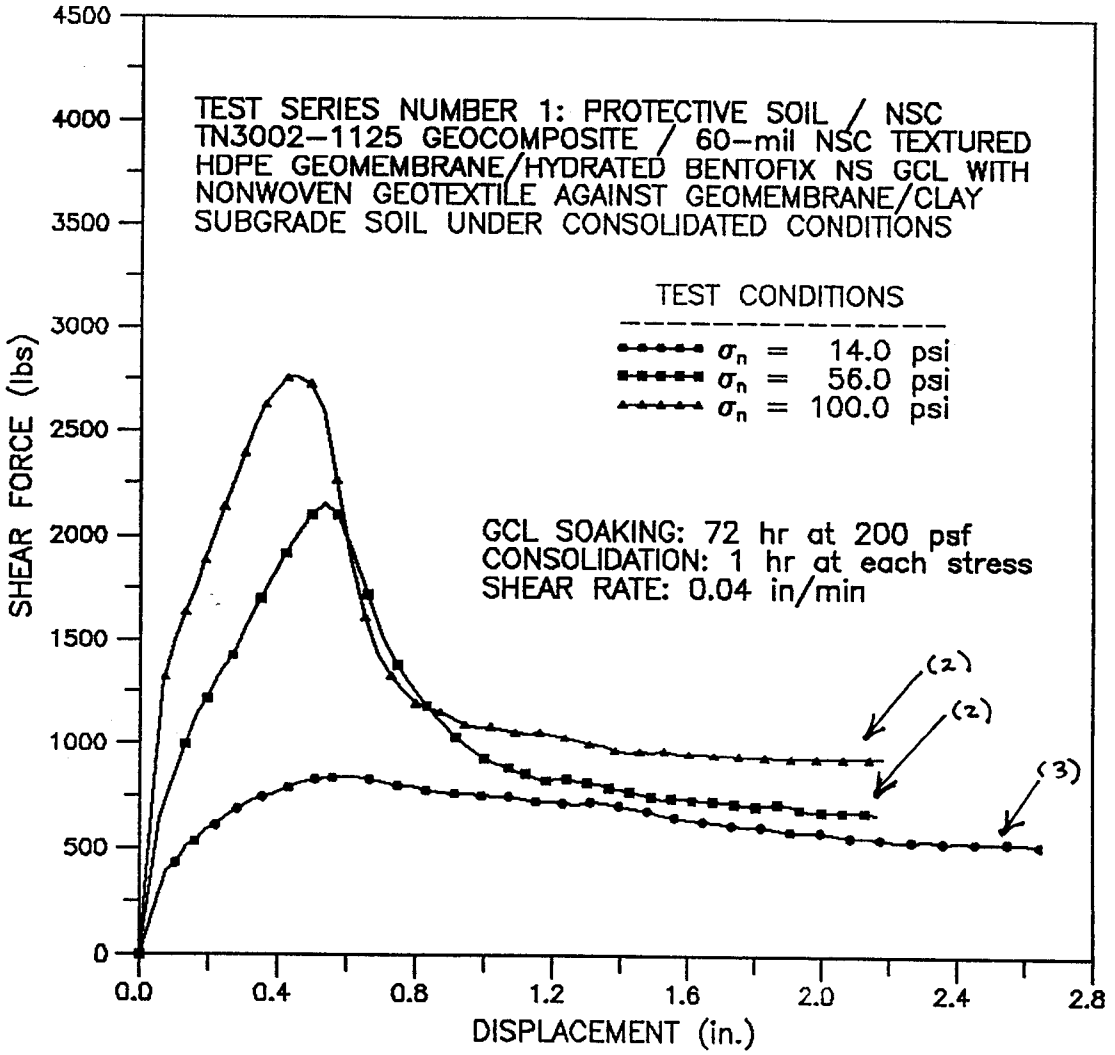
Test Procedures for Each Normal Stress Condition:

- GCL Hydration: a fresh specimen of GCL was trimmed from the bulk sample and hydrated in tap water for 45 hours under a normal stress of 200 psf.
- A fresh specimen of the lower soil was compacted into the lower shear box. The initial target dry unit weight and moisture content were 114.3 pcf and 12.2%, respectively, as specified by TerraMatrix.
- The hydrated GCL specimen, and fresh specimens of geomembrane and geocomposite trimmed from each bulk sample were placed on top of the lower soil, but not attached to either of the lower or upper shear boxes. The GCL was oriented so that the nonwoven geotextile component of the GCL was in contact with the geomembrane. With this method of specimen preparation, shear failure would likely occur at the weakest interface within the test cross section.
- A fresh specimen of the upper soil was compacted directly on top of the geocomposite. The initial target dry unit weight and moisture content were 95.0 pcf and 7.0%, respectively, as specified by TerraMatrix.
- Consolidation conditions: the entire test specimen was consolidated for 1 hour under each test normal stress prior to being sheared.
- Test normal stresses: 100, 300, and 500 psf.
- Constant shear displacement rate: 0.04 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

APPENDIX C

TEST RESULTS

TERRAMATRIX MONTGOMERY WATSON
INTERFACE DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

(2) Shear failure was observed to occur within the GCL.

(3) Shear failure was observed to occur at the interface between the GCL and the geomembrane.

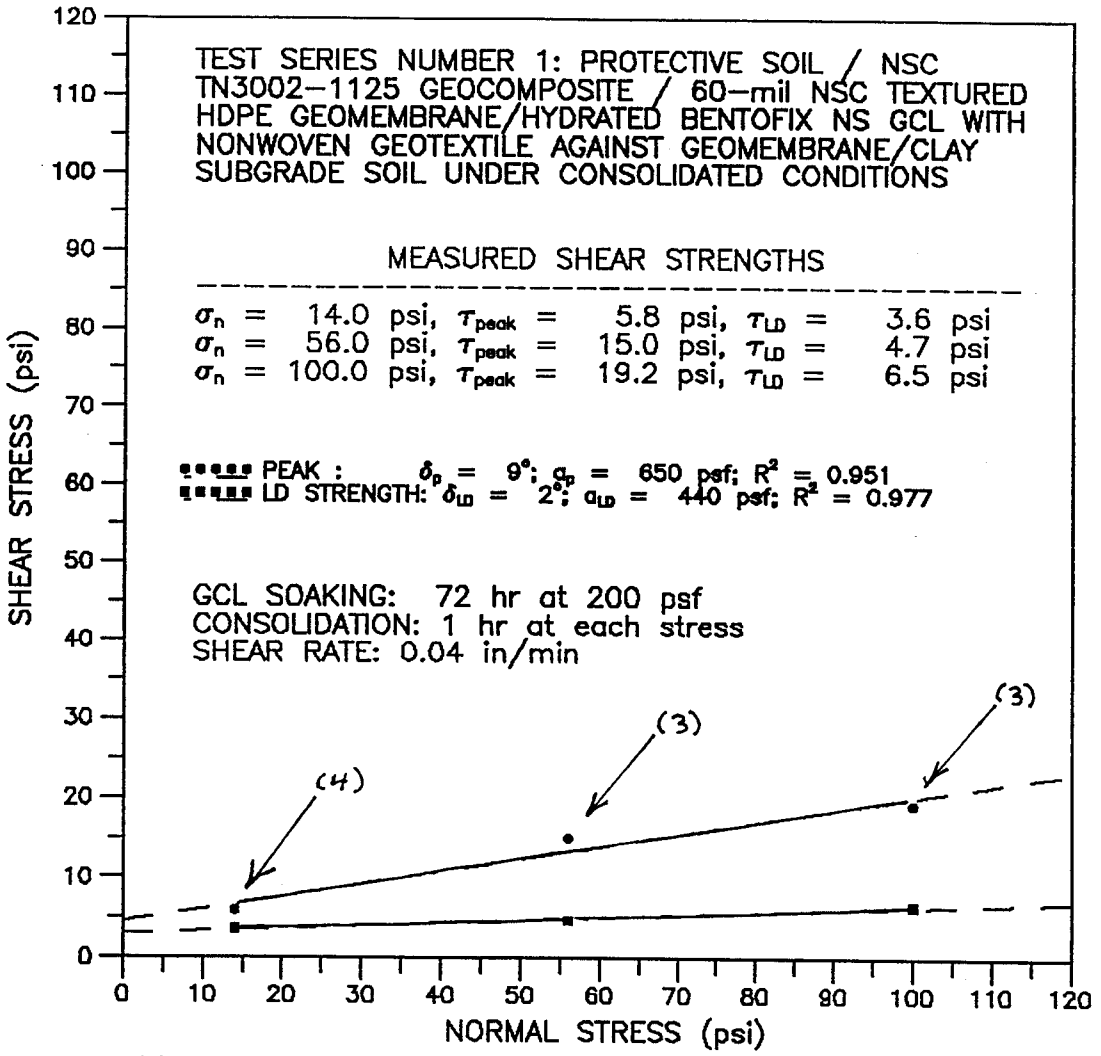
DATE TESTED: 4 TO 7 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	C-1
PROJECT NO.	GLI0406
DOCUMENT NO.	SGI97133
FILE NO.	

TERRAMATRIX MONTGOMERY WATSON
INTERFACE DIRECT SHEAR TESTING



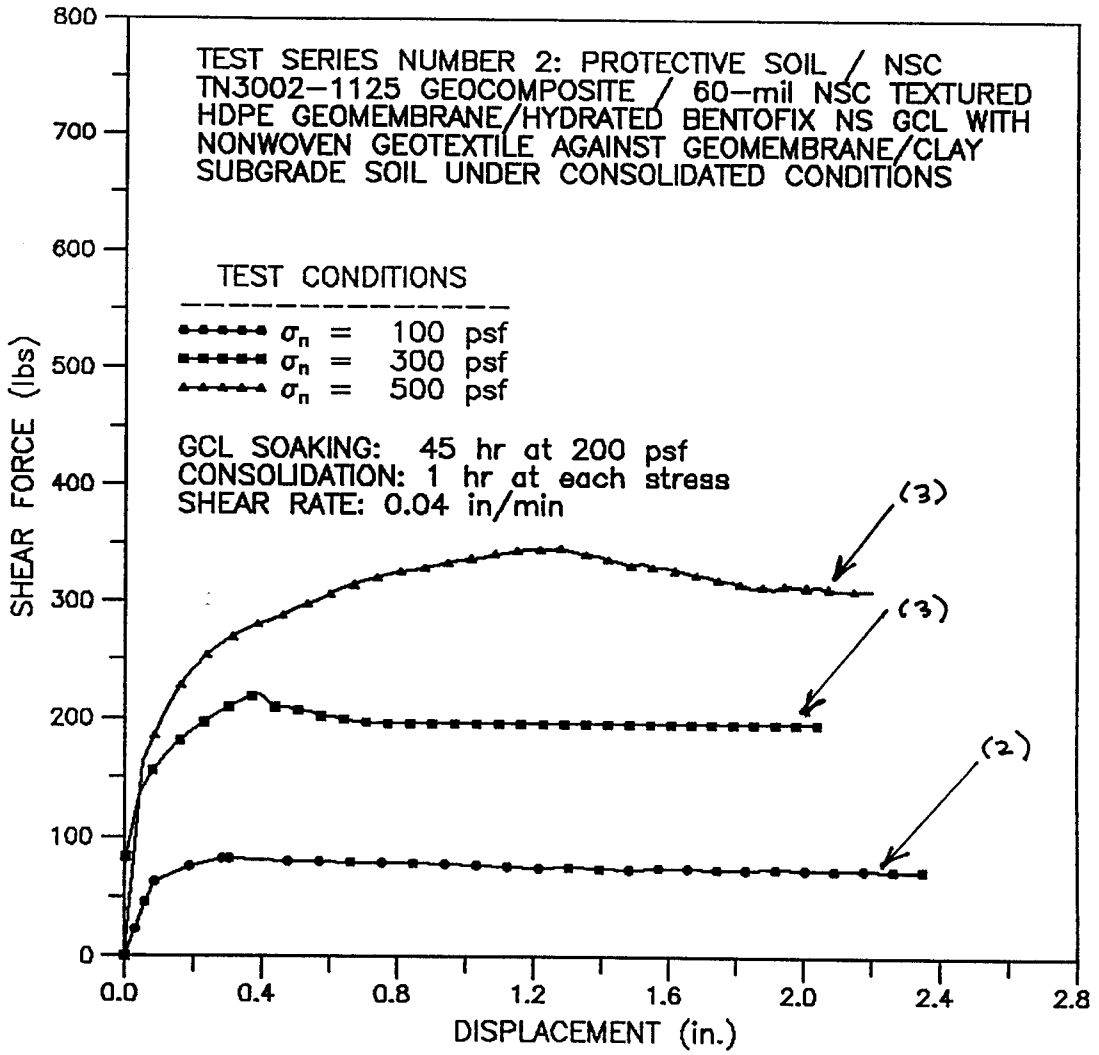
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at the end of each test.
(3) Shear failure was observed to occur within the GCL.
(4) Shear failure was observed to occur at the interface between the GCL and the geomembrane.

DATE TESTED: 4 TO 7 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	C-2
PROJECT NO.	GLI0406
DOCUMENT NO.	SGI97133
FILE NO.	

TERRAMATRIX MONTGOMERY WATSON
INTERFACE DIRECT SHEAR TESTING



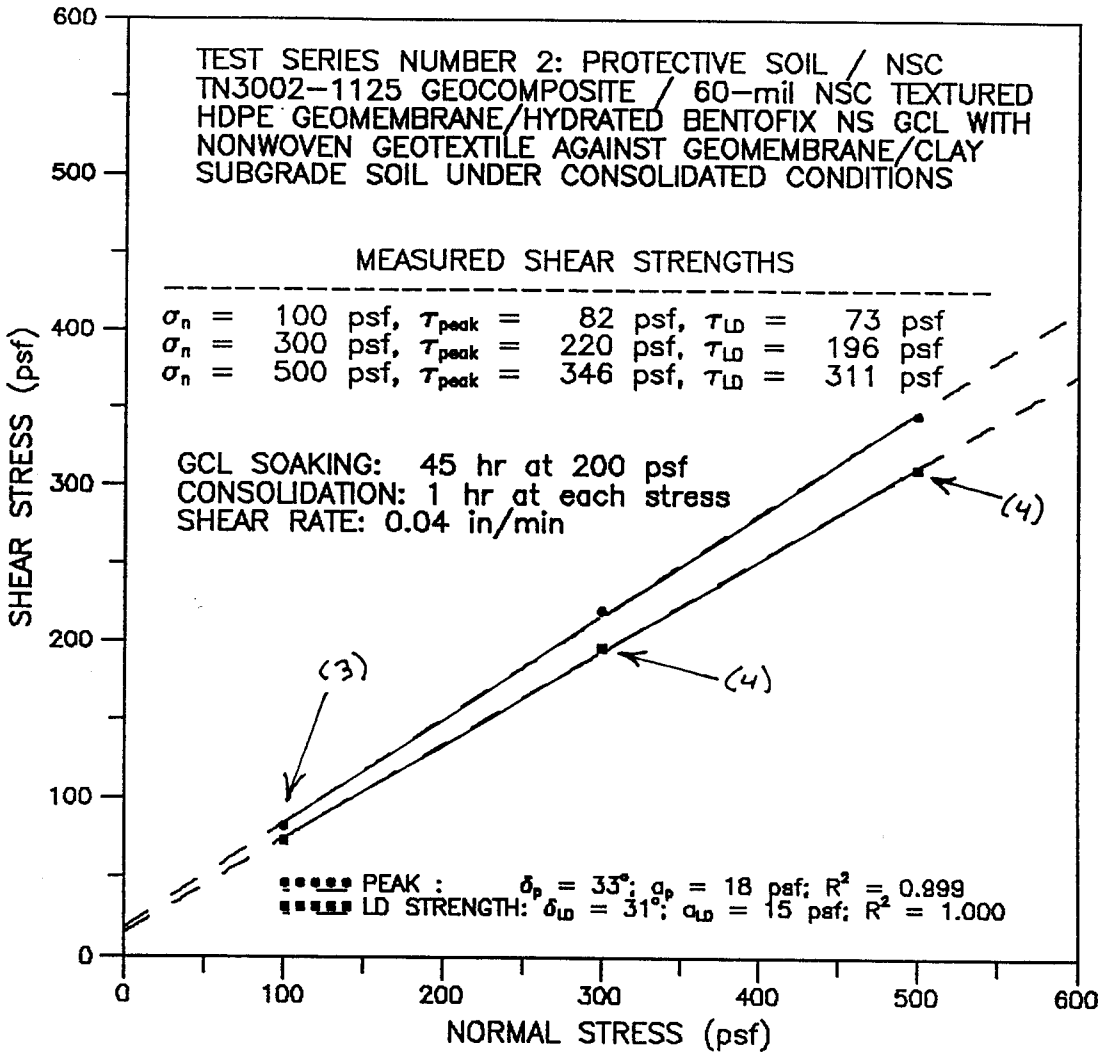
NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.
(2) Shear failure was observed to occur at the interface between the protective soil and the geocomposite.
(3) Shear failure was observed to occur at the interface between the GCL and the clay subgrade soil.

DATE TESTED: 7 TO 9 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	C-3
PROJECT NO.	GLI0406
DOCUMENT NO.	SGI97133
FILE NO.	

TERRAMATRIX MONTGOMERY WATSON
INTERFACE DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at the end of each test.
(3) Shear failure occurred at the protective soil-geocomposite interface.
(4) Shear failure occurred at the GCL-clay subgrade soil interface.

DATE TESTED: 7 TO 9 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	C-4
PROJECT NO.	GL10406
DOCUMENT NO.	SGI97133
FILE NO.	